

Respawning Originality Into Gamified Keyboard Practice: How Video Games Can Be Used To Practice Technical Skills For Adult Beginner Keyboardists



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I would like to dedicate this thesis to those who have supported my journey over the past four years. To my mother, Josephine: without your support and love, I would have never found myself rising to such accomplishments; although the last four years have been long and listening to my constant ramblings must have become tedious, you were always patient with me. To the rest of my family; James, Fred, Kate and Stephen: your belief in me as well as offering a place of safety which was free of judgement has given me the strength to never give up and ensure that my work reflects my own beliefs. To all of those I have had the honour of spending time with at ROLI, I thank you; the incredible mix of people and their interesting perspectives allowed both the research and me to flourish. Finally, to Chantelle: although you joined my life during the final year of the doctorate, your patience, kindness, support and love ensured I never gave up; you offered words of wisdom and insights I could never see and were the light that guided me through to the end. To all of whom that have been mentioned and to those that have not, I thank you for everything from the bottom of my heart.

Declaration

I hereby declare that except where specific reference is made to the work of others, the contents of this dissertation are original and have not been submitted in whole or in part for consideration for any other degree or qualification in this, or any other university. This dissertation is my own work and contains nothing which is the outcome of work done in collaboration with others, except as specified in the text and Acknowledgements. This dissertation contains fewer than 100,000 words including bibliography, footnotes, tables and equations and has fewer than 150 figures.

Jack Brett
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Abstract

Learning to play a physical instrument (specifically, key-based instruments) and understanding music theory presents significant challenges, particularly for adults pursuing independent learning. Research demonstrates that a large majority of adult beginner keyboard learners abandon their musical pursuits early in their journey, often before achieving proficiency in fundamental skills. Through systematic literature review and primary research across multiple studies, this work identified that a key factor in early abandonment was the disconnect between effort invested and perceived progress, particularly in foundational skills like rhythm, audiation, and notation reading. While existing solutions attempt to gamify either the entire learning process or add surface-level game elements to traditional methods, there remains a critical gap in research regarding game-based learning specifically designed to develop these core competencies.

This research presents three primary contributions: novel artifacts in the form of learning-based games, a comprehensive framework for their design and development, and a robust methodology for assessing such solutions. Through iterative development and multiple empirical studies, including a week-long longitudinal study with 30 participants, we demonstrate that properly designed game-based learning tools can significantly improve both engagement and skill acquisition compared to traditional practice methods. Results showed that those who engaged with our game-based solution demonstrated 30% greater improvement in notation reading skills while maintaining consistently higher practice engagement throughout the study period. Beyond addressing immediate learning challenges, this work provides a foundation for future development in game-based music education and potentially extends to other domains requiring sustained practice and engagement. The framework and assessment methodologies developed through this research offer valuable tools for researchers and developers seeking to create effective educational games that balance engagement with meaningful skill development.

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List of Abbreviations

VR - virtual reality
AR – augmented reality

GBL – game-based learning
EBI – equivalence-based learning
DAW – digital audio workstation
CD – compact disc
PC – personal computer
AI - artificial intelligence
MIDI - musical instrument digital interface
HCI – human-computer interaction
PSVR – PlayStation virtual reality
UI – user interface
IP – intellectual property
UX – user experience
SFX – sound effects
VFX – visual effects
BPM – beat per minute
RPG – role-playing game
FPS – first-person shooter
XP – experience points
DLC – downloadable content

List of Publications

Publications by the authors that contribute to this thesis include:

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- Brett, J., Gatzidis, C., Davis, T., Amelidis, P., Xu, N. and Gladwell, T. (2021), Learning Through Play; a Study Investigating How Effective Video Games Can Be Regarding Keyboard Education at a Beginner Level, in ‘The 16th International Conference on the Foundations of Digital Games (FDG) 2021’, ACM, Montreal QC Canada, pp. 1–12. URL: <https://dl.acm.org/doi/10.1145/3472538.3472555>

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Chapter 1

Introduction

1.1 Overview

This research is an exploration into how video games can be utilised most effectively within the context of music learning, with a focus on keyboard instruments. Current music related digital entertainment products and software either takes the form of video games which offer no educational attributes or are mostly outdated. The ‘Guitar Hero’ style of interactions, which involve pressing buttons on a plastic guitar-shaped controller in time with on-screen prompts, still dominate the music education games market. However, these games are solely focused on simulated guitar play and offer little in terms of learning transferable musical skills. There is an overwhelming body of evidence that engaging with music learning offers a multitude of benefits to students and players of all ages. However these positive effects are only realised if students find playing enjoyable, rewarding and readily available. There is evidence that suggests music training has long term positive effects on verbal memory (the ability to recall and reproduce verbal information) (Chan et al. 1998), can help reduce stress and maintain mental health (Jutras 2006) as well as increase psychological and physiological quality of life in older adults (Seinfeld et al. 2013a). However, learning to play a physical instrument (in this case, key-based) and understand the intricacies of music theory can be seen as a daunting; this is especially true for adults who have never attempted to learn. There is a significant number of adults who want to learn to play the keyboard (or other key-based instruments) (ABRSM 2018a), but never reach a point of skill in which they can express themselves in the manner they desire. There are a multitude of reasons for adults to want to learn to play any instrument: it is an outlet for creativity, they are inspired by other competent musicians, they want to play with other likeminded musicians. However, one of the main goals beginners stress, founded through primary research (direct data collection from participants) and secondary research (analysis of existing data) (ABRSM 2018a), is the

desire to play existing pieces; to be able to replicate the songs they listen to with their own skills which could later lead to explorations of their own creative pursuits. These goals are substantial and as such require considerable amounts of dedication, both in time and effort of the learner.

The combination of a such an immensely high goal with the lack of understanding of the depth of learning to play an instrument, can often lead to adult learners dropping out of learning swiftly after beginning their journey (Evans 2009). In fact, statistics show that a large majority of adult beginner keyboard learners will give up quickly after starting and never truly reach a level of skill in which they can actually express themselves freely with their instrument (i.e., play music spontaneously and creatively without being limited by technical constraints) – and this not only applies to keyboard, but other instruments (ABRSM 2018a, North et al. 2000). Researchers agree that there is “an alarmingly high proportion” of students who began to learn an instrument and subsequently abandoned this effort (North et al. 2000). Whilst there are many reasons for this quick drop off to the learning journey, a key factor that was established in context to this research was the lack of effect to the required amount of effort for learning. In addition, adult beginners lack crucial technical skills to apply what they learn from lessons or to play what they may have perceived is possible; skills such as rhythm, audiation (the ability to hear and comprehend music in one’s mind without physical sound present), and reading notation. Learning these fundamental skills typically requires substantial amounts of rote learning (i.e., repetitive actions) and dedication which typically leads to boredom; the foundation that these skills provide ensures that learning is more fluid thus building positive associations with playing and leading to prolonged learning.

A common and historical solution to help learners achieve their goals is an attempt to replace traditional lessons and tutoring with digital technology. This style of learning was originally based on CDs in which learners would follow along a series of guided lessons from their own home. Within the last 10 to 15 years, this style of learning has been adapted for mobile applications and implements gamified methods of playing musical pieces, as well as motivation through the use of gamification: adding leaderboards, badges and progressive user statistics. However, the issue with this style of learning is that it offers short term goals and ensures that the first few sessions of learning are satisfying and enjoyable which later leads to frustration when the content becomes more difficult and the goals require a lot more commitment without an engaging method of practice. Furthermore, their applications of gamification are also deemed as an afterthought and do not benefit the experience greatly. The idea of replacing the whole journey of individual learners with one solution is folly; learning styles vary greatly and the best methods for individual learners cannot be contained within one application.

Solutions found in research also share similar disadvantages in that a considerable amount of research is dedicated to only learning specific songs in novel ways; with the most recent trend to use either virtual or augmented reality. This once again offers a short-term goal with no real-world application as most learners, especially beginners, would not realistically learn all songs like this; but, if they could read basic sheet music then they would be able to apply this to a much larger array of objectives. Whilst some research focuses on building gamified practice of specific skills, their application of gamification is rudimentary and lacks novelty – using leaderboards, badges and avatars (common gamification tropes which are often added as an ‘afterthought’). Finally, the validation of these solutions lacks real-world application, focusing on whether or not their solutions will do what they had intended, rather than focusing on how it can fit within a learning system. There is a lack of research dedicated to building video games which can impart musical theory knowledge and practical skills whilst also having a meaningful way to validate it.

The development of learning-based games is significantly influenced by existing music education tools, which occasionally utilise gamification or virtual and augmented reality to engage learners. As delineated further in the [Background Research](#) and [Preliminary Research](#) chapters, these solutions tend to focus on short-term engagement, relying on surface-level interactions that fail to sustain long-term interest or foster transferable musical skills. The preliminary research that was conducted further highlights that while these tools may initially boost motivation, they often struggle to maintain user engagement as the learning material becomes more challenging. These shortcomings inform the development of our learning-based games by emphasising the need for a deeper integration of game mechanics that not only capture the player’s attention but also support the gradual acquisition of essential keyboard skills. By critically analysing the limitations of current models, this research aims to establish a framework that balances engaging gameplay with meaningful educational outcomes, ensuring that learners remain motivated while progressing towards their goals. This approach addresses the issue of high dropout rates among adult learners by creating a more immersive and rewarding learning experience that encourages sustained practice and skill development.

Whilst many solutions attempt to gamify (i.e., apply game-design elements and principles to) the entire learning process or add gamification to existing learning solutions, there is a lack of research dedicated to learning based games which help to practice these fundamental skills. This research outlines a novel approach to gamifying music learning in the form of prototype training games, contributing an original framework for designing and assessing said training games; with particular concern to the transferability and meaningful application of the acquisition of fundamental keyboard and piano skills. The key intention of these games

is to replicate a video game, and the high amounts of engagement that they elicit, whilst also being a method to passively acquire or improve specific skills. This research pursues a distinct and original approach to this issue with the hope that using game-based learning in this context will increase practice, reduce frustration, build positive associations with learning to play a key-based instrument (and as an extension, other instruments or possibly other areas of education that require rote learning) thus reducing the swift drop off rates exhibited by a vast number of beginners. As the late pioneer of video games Gerald A. Lawson once said, “To me, a game should be something like a skill you should develop — if you play this game, you walk away with something of value.” (Weber 2011). The implications of this research are not only applicable to that of music learning, but also other domains of learning that are increasingly using gamification to enhance the pedagogical experience – languages, exercise and even meditation practices. The research intends to define a standard which does not simply ‘add-on’ game elements to existing learning solutions, but integrates them from the ground up.

A valuable open-source set of repositories is also provided which can help expedite the development process of creating music-focused learning games; including integrating MIDI, synthesisers, procedurally generated music and content and implementing rhythm which can be used alongside player mechanics and animations. Whilst this implementation considers the Unity Engine, the programming and design principles are applicable to any video game development style. Finally, whilst this set of repositories, and the framework of developing such games is most useful for independent developers or researchers, there is no restrictions on these principles and tools to be used by larger teams; it is important to note, however, that the lessons and considerations were made specifically for independent developers and is most useful for this cohort.

1.2 Research Topics

There were three distinct areas of research that this doctorate was concerned with: keyboard learning (extended to general musicianship), video games and existing solutions to the key issue. Whilst not mentioned as a specific topic as it encompasses the entire research domain, the field of HCI is a considered overarching area as this research focuses on how users interact with digital artefacts using digital aided technologies.

The area of keyboard learning (or pedagogy for teaching children and andragogy for teaching adults) was an essential arm of this research which helped to realise the main reasons adult learners struggle to maintain consistent practice and achieve their personal goals. The topic also helped to define the key learning styles and theories which are most

closely related to the integration of game-based learning. The research topic of video games provided the backbone of the doctorate and helped to develop novel solutions in the form of a multitude of video learning-based games; the research explored theories of game design and gamification which helped highlight where existing solutions were falling short and how new solutions could remedy this problem. Existing solutions helped pave the way to a distinct and somewhat novel approach to solving the complex issue this research concerns itself with; guiding the researchers to the gap in knowledge of a lack of game-based learning regarding the practice of skills that typically require rote learning.

1.3 Problem Statement

The field of adult music education, particularly for beginner keyboardists, faces significant challenges that hinder sustained engagement and skill acquisition. A key issue is the high dropout rate among adult learners, often driven by a disconnect between their aspirations and the realities of the learning process. Many adult beginners lack the technical foundation required to apply knowledge effectively, encountering barriers in mastering fundamental skills such as rhythm, audiation, hand coordination, and notation reading. These essential skills are quite often acquired through rote learning (or repetitive practice) which can be a process that is perceived as tedious and discouraging.

While digital tools and gamified solutions have attempted to address these challenges, they often fall short. Existing gamified tools provide short-term engagement but fail to maintain long-term motivation as the content becomes more challenging. Additionally, these solutions frequently emphasise superficial gamification, such as leader-boards and badges, that do little to support meaningful skill acquisition or real-world application. Key challenges of this research include:

1. **High Dropout Rates:** Adult beginners in music education often drop out due to a disconnect between their aspirations and the realities of skill acquisition.
2. **Lack of Engagement in Fundamental Practice:** Essential repetitive practice is perceived as tedious, leading to disengagement and hindering skill development.
3. **Ineffective Digital Learning Solutions:** Existing digital tools and gamified learning approaches often provide short-term satisfaction but fail to sustain engagement and support long-term skill development.

4. **Inadequate Skill Transfer:** Solutions such as the "rolling note" graphics and light-up keys (or poorly designed gamified learning methods) may impair proper technique and limit the transfer of skills to real-world playing.
5. **Research Gap in Music Education Games:** There is a lack of validated video games specifically designed to teach musical theory and practical skills through repetitive practice.
6. **Complexity in Game Design and Pedagogy Integration:** Balancing engaging game design with educational goals is challenging, requiring the integration of music pedagogy, game design theory, and educational technology.
7. **Need for Effective Assessment Methods:** Developing methods to evaluate both engagement and skill transfer, particularly over extended periods, is complex and often overlooked in this research domain.
8. **Limitations of Emerging Technologies:** VR and AR face issues such as accessibility, cost, and lack of tactile feedback, limiting their practicality in music education (often being used as a gimmick to attract research funding or consumer sales).
9. **Scalability Issues:** Existing solutions rarely offer frameworks for broader application or adaptation to diverse learning needs.

A critical gap exists in the design and assessment of video games specifically tailored to teach fundamental keyboard skills through engaging, game-based methods. Addressing this gap requires a nuanced integration of game design principles, music pedagogy, and effective assessment methodologies.

1.4 Research Motivation

Adult beginner musicians often struggle to maintain engagement and acquire foundational skills, leading to high dropout rates. Traditional methods fall short in addressing these issues, while existing gamified solutions often lack depth and fail to ensure long-term motivation or skill transfer. To address these needs, this research seeks to:

1. **Enhance Engagement:** Develop gamified tools that integrate engaging gameplay with effective pedagogical strategies.
2. **Reduce Dropout Rates:** Create tools that sustain motivation by addressing barriers to repetitive practice.

3. **Support Skill Transferability:** Ensure that skills acquired through gamified tools can be meaningfully applied to real-world musical contexts.
4. **Broaden Applicability:** Establish scalable solutions that can extend to other domains reliant on rote learning, such as language acquisition or technical skill development.

By addressing these goals, this research aims to contribute a robust framework for game-based learning, bridging the gap between immersive gameplay and effective skill acquisition across multiple educational contexts.

1.5 Research Questions

Building on the problem statement and key challenges outlined, the research addresses two specific questions. The original question which covers the much broader issue laid out in the [Overview](#) is summarised as:

- **How can video games help to reduce the high early dropout rates which are exhibited by adult, casual and independent beginner keyboardists?**

This question was explored during the beginning of the thesis in which the literature review, in conjunction with early primary research, highlighted the gap in knowledge regarding game-based learning and key-based instrument practice (specifically, practising fundamental skills which independent adult beginners would benefit most from). Whilst one can rather safely assume that a video-game experience would yield higher rates of engagement, especially as the target population for this research were adult beginners who had interests in video games, the research needed to explore how this could be achieved through a series of developments and assessments in an attempt to answer the question:

- **Can adult, casual and independent beginner keyboardists passively acquire or improve specific skills, which typically requires rote learning and have meaningful real-world application, through playing video games?**

If the research could prove that a learning-based game could be a valid method of practice and the play sessions would be able to improve specific skills, which had real-world applications, then the future directions would be to validate this over long periods of time and with more serious applications (exploring other types of learners and installing such methods in more traditional styles of learning such as classrooms).

Aims

The overarching aim of this research is to explore, develop, and validate gamified learning tools that address the key challenges in music education for adult beginner keyboardists. These tools aim to transform the learning experience by combining engaging gameplay with pedagogical consistency, creating a more approachable pathway for skill acquisition. By addressing critical issues such as motivation, engagement, and skill transfer, this research sets out to redefine how fundamental musical skills can be learned effectively and enjoyably. Specifically, the research aims to:

1. **Create Engaging Tools:** Design gamified tools that seamlessly integrate gameplay with effective pedagogical strategies, fostering a more immersive and enjoyable learning experience.
2. **Enable Skill Transfer:** Develop solutions to ensure the meaningful transfer of acquired skills to real-world contexts, empowering learners to apply their knowledge practically.
3. **Sustain Long-Term Impact:** Investigate the long-term effects of gamified learning tools on learner motivation, engagement, and retention, ensuring sustained benefits beyond initial usage.
4. **Establish Scalable Frameworks:** Create adaptable frameworks for the design and assessment of educational games, enabling broader applications across diverse learning domains.

Taken together, these aims aim to help support the design of new approaches to music education, and help foster the development of innovative practices in gamified learning and skill development.

Objectives

To help realise the aims of this research, a series of objectives has been outlined to guide its design, implementation, and evaluation. These objectives provide a clear roadmap for addressing the identified challenges and achieving meaningful outcomes which are expounded upon throughout this thesis. These objectives are summarised as:

1. **Tool Development:** Develop a suite of gamified learning tools specifically tailored to the needs of adult beginner keyboard learners. These tools will focus on core skills such as rhythm, notation reading, and hand coordination, while ensuring a balance between engagement and pedagogical effectiveness.

2. **Framework Creation:** Establish a scalable and adaptable framework for designing and assessing gamified learning tools. This framework will integrate game design principles with established music pedagogy, ensuring relevance and effectiveness across various educational contexts.
3. **Empirical Validation:** Conduct mixed method studies to evaluate the educational effectiveness, engagement, and real-world applicability of the developed tools. This process includes both short-term and long-term assessments to capture a comprehensive understanding of their impact.
4. **Long-Term Analysis:** Assess the sustained impact of gamified learning tools on learner engagement, skill retention, and motivation through extended studies. This analysis will identify key factors that contribute to long-term success and guide future development.
5. **Knowledge Sharing:** Provide open-access resources, including code repositories and design principles, to support the wider development of gamified educational tools. This ensures that the insights and innovations from this research benefit educators, developers, and learners across multiple domains.

Beyond meeting the specific needs of our target audience, this research sought to develop and disseminate valuable methodologies and frameworks that can contribute to future advancements in gamified learning.

1.5.1 Significant Original Contributions to Knowledge

The contributions, in which originality and significance can certainly be argued, are summarised with three distinct points:

- Artefacts in the shape of novel prototype video games
- An original framework for designing and developing musical training games with repositories which others can use specifically for music games (but the principles do apply to other learning games)
- An original method of assessing gamified training tools which considers transferability and real-world applications

The artefacts that have been outputted are novel but were constantly reviewed with the intention of being valuable to the target population of this research. Whilst research within

this field often develops solutions for the sake of novelty, using new technologies in a lot of cases, this research attempts to develop novel solutions without over designing ideas or using technology for the sake of using it. Thus, the final artefacts are both novel whilst also retaining meaningful applications to real-world situations, which are highly functional for both the learner and the developer or teacher. To the knowledge of the authors, there are very few, if any, attempts of using game-based learning within the context of acquiring skills that require rote learning in regard to musical keyboard education. Finally, when seeking advice or guidance on designing and developing such concepts, there was a lack of data. Thus, a key contribution is a framework for future researchers, or developers, to adhere to when developing such learning-based games whilst also offering insights into how to assess such concepts in a meaningful way. As mentioned, a repository with code that was used throughout the project is offered and can help expedite the development process for potential future researchers in this field.

1.6 Thesis Structure

This thesis is comprised of 8 chapters in total, which includes 4 experimental chapters. The remaining 4 chapters are the introduction, background research, preliminary research and a final discussion chapter. The background research covers 3 distinct subjects in which this research is founded upon: keyboard and piano pedagogy, video games and existing solutions. Through the review of literature, the gap in knowledge is explored, whilst the preliminary research that was conducted simultaneously helped to provide primary data to the support the findings of the literature. The preliminary research chapter outlines the development of the LUMI and consequent mini games that were used for practice alongside or within the application. An in-depth review of the games is outlined in which limitations of using VR and AR are discussed; finally, the key limitation of poor assessment methods and a lack of organisation is discussed. These limitations led to the first set of developed mini games which is outlined in the first experimental chapter.

Chapter 4 explores the suite of mini games that was created, which offers an in-depth report of the various prototypes made during this stage. The overall development process and pipeline is discussed, whilst mentioning key pitfalls to avoid and design principles to adhere to. This is followed by a discussion of the first study which was conducted to assess the mini games and to determine an ideal audience, narrowing in on how to assess the validity of these games regarding their engagement and educational impact. The initial study showed a need for specificity in which Chapter 5 discusses the various games that were designed and developed for the specific purpose of improving a learners ability to read basic music notation.

Chapter 5 also describes the second study which was conducted to assess the novelty of the solutions, pursuing a more quantitative and replicable approach to assessing both engagement and usability – using questionnaires which have previously been validated within this area of research. Chapter 6 then discusses the final prototype game which was developed and used within a longitudinal study. The chapter describes a pilot study that would be a much smaller scale instance of the final longitudinal study which would help validate the methods of engagement, usability and pedagogical value; improving upon the key limitations found for larger scale studies. The final experimental chapter provides significant details on the continuation of the development of the final prototype game, named ‘The Crypt of Notation’, before delving into the details of the longitudinal study that was conducted to help assess the game’s learning potential in real-world contexts.

The final chapter helps to summarise the findings of the whole doctorate whilst also providing the major contributions that this research helped to create. The contributions are related to three key areas: design and development principles for future researchers as well as the key lessons learned and insights gained regarding the assessment of such novel concepts. The author hopes that future researchers or developers can learn from and expedite the process using the contributions – leading to the development of solutions which offer transferable skills and meaningful applications to learning to play key-based instruments (and potentially, apply this to other instruments or areas of learning).

1.7 The Placement Company

This thesis covers work undertaken within an engineering doctorate. The entirety of this research was undertaken at formerly, ROLI, now, Luminary (ROLI 2022), based in London. The company was focused on keyboard manufacturing regarding the ‘prosumer’ market before this research took place. During the course of the doctorate, the company shifted to manufacturing hardware which was tailored to the consumer market in the form of a fully light-up RGB keyboard named, LUMI Keys. LUMI Keys (ROLI 2020) was built with a companion learning application and this research helped to improve the ecosystem of the software by developing video games that worked either alongside or within the learning application. The insights gained throughout this research have helped guide the development of such games within the learning application whilst also helped to make further considerations to enhance the experience of beginner keyboard learners using prototyping and extensive user research.

1.8 Accompanying Materials

The artefacts that have been discussed can be viewed through accompanying materials. This includes playable prototypes of many of the games discussed in the thesis as well as videos and screenshots of the games. Whilst not all games are mentioned in the thesis, most prototypes and concepts can be viewed at:

- [GitHub Repositories](#)
- [Prototype Sample Footage](#)

Chapter 2

Background Research

2.1 Chapter Introduction

This literature review covers two distinct subjects upon which this research is founded: keyboard pedagogy and video games. Within keyboard pedagogy, the definition of a musician and the consequent skills that make learning to play key-based instruments are explored. The exploration of learning to play an instrument, and the target learner groups that this research is particularly concerned with, is defined. This is followed by a review of relevant literature, as well as drawing upon primary research and personal reflection, to help understand why there is a fast dropout rate exhibited by significant numbers of keyboard beginners, particularly adults. In the context of this research, the main reason is described as a lack of skill and the lack of correlation between required effort inputted to learning and the lack of effect outputted. Various definitions are offered to help understand what a skill is in this context, how one acquires such a skill, and the relevant learning theories that relate to acquiring or improving a skill. The final section of this review, video games, helps to define what a video game is, how gamification and game-based learning is used within a pedagogical view, and how it has not been utilised correctly for the purposes of training specific skills related to playing an instrument. The section offers various theories of game design which have been considered throughout this research and helped to create a novel method of acquiring, or practising, skills that are imperative to playing key-based instruments. Despite advancements in digital tools and traditional pedagogies, the learning journey for beginner keyboardists remains fraught with challenges. Existing approaches frequently lack mechanisms to sustain engagement and provide incremental, measurable progress. This gap is particularly pronounced for adult learners, who often struggle with the steep learning curves of notation reading and technical execution. Consequently, there is a critical need for solutions that balance skill acquisition

with motivational engagement (Ahmed 2017, ?) in which we believe game-based learning approaches are the solution.

2.2 Keyboard Learning

This section is used to build the foundation of the main issue this research helps solve, and furthers current solutions in pursuit of reducing the high amount of early drop outs observed with beginner keyboardists. Specifically, the definition of what it means to be a musician and by extension, the very skills that comprise learning to play keyboard or any particular key-based instrument is explored. This is then followed by relevant literature which discusses how one learns to play a key-based instrument and how digital technology has advanced in this field, specifically, digital solutions for independent learners. Specific learner types are explored, in which the research begins to narrow in on who suffers the most from early drop outs, and would benefit from gamified learning. Literature is explored into reasons for observed high drop-out rates and how the use of video games can help to solve this issue. As the main reason for the observed dropout rates is defined as a lack of skill, at least in the context of this research, the final area of literature concerns skill acquisition.

2.2.1 Musicianship

Musicianship, as a concept, is contentious in its scope and definition. By nature, the quality of music is subjective, and opinions on what constitutes musical skill vary greatly from person to person, making it challenging to define and objectify. Traditional pedagogical frameworks tend to prioritise measurable competencies like rhythmic, tonal, and notational skills, which are contained in models from West's 'The Big Five' (West 2015a). But contemporary scholars like Gordon (?) urge a more inclusive approach; one that brings attention to audiation (the ability to internalise and comprehend what one hears and plays) as the true foundation of musicianship. It reflects wider tensions between rigid, skills specific learning and flexible, open approaches. Literature on musicianship was consulted to define musicianship and supplied insights into areas of knowledge and skill for which the most rote learning is needed, the perfect places for a novel game based practise solution. Definitions range greatly, but the Wests 'The Big Five' taxonomy proved to be most suitable for this study, particularly ones which include aspects of individual creativity and innate musical ability. Audiation is the focus and five key areas of instrumental ability are identified as fundamental. These are areas that are not so much just mastered through hours and hours of practise, but also have the opportunity for the structured framework of musicianship itself. This research brings

these perspectives back together by devising tools which maintain structured skill acquisition frameworks that nevertheless emphasise audiation and creativity.

Rhythmic ability can be defined as one's skill at performing rhythms in the context of steady time. One's rhythmic ability is independent of one's notation ability. A student may have a well-developed internal sense of rhythm without the ability to read rhythmic notation, and vice versa

Tonal ability is the skill of differentiating pitch in the context of a tonality. As with rhythmic ability, a student's tonal ability is independent of the cognitive function of understanding notation. A student may have a well-developed sense of pitch without any cognitive ability to read tonal notation, and vice versa

Notational ability is the skill of reading and writing music on a musical staff. More experienced musicians could become sight readers or at least be able to hear music through reading notation and see common patterns. Many pop and folk artists sing and play beautifully without knowing how to read notation. However, it is important to note that these artists were already familiar with music from an early age. An inexperienced adult learner will find this difficult but learning to read and improve their sense of tonality are required to succeed – like learning any language

Creative ability has many definitions (Running 2008). 'I find it helpful to think of musical creativity simply as the student's ability to generate musical ideas apart from that which is externally dictated. Even when students are proficient at reading notation, using their instruments, differentiating pitch across a range of tonalities, and internalizing complex rhythms in the context of steady time, they are missing a crucial component of musicianship if they have not developed some sense of independent musical thought.' (West 2015a)

Executive ability refers to physical attributes using an instrument. Edwin Gordon makes a distinction between executive skills and audiation skills. Executive skills are the skills involved in physically manipulating the instrument (posture, hand position, range, facility, breath support, embouchure, tone production, etc.), commonly referred to as "technique." (Gordon 2012)

This framework of musicianship does contain specific objectives for learning, but it is important to note that not mastering these elements does not mean one will not become a very competent musician; rather, as West says, a musician needs not only reads the music but feels and hears it too. Among other things, West also points out, that traditional practise and

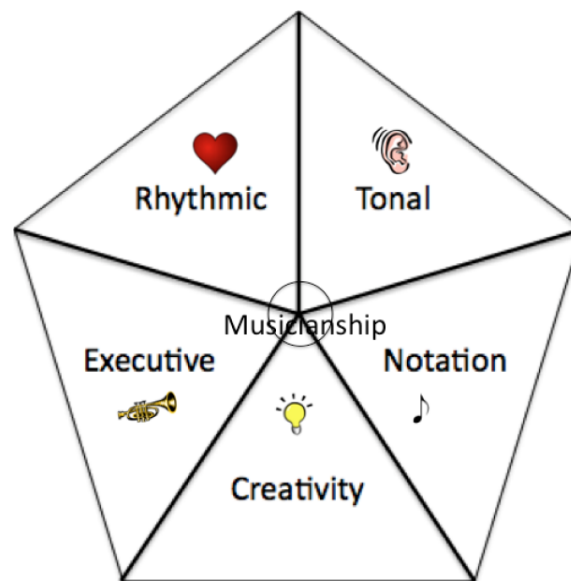


Fig. 2.1 The 'Big Five' Skills by (West 2015a)

big band practise (the main focus of West's research) does teach executive and notational skills, but do not teach creative, rhythmic and tonal skills. Casual learners who use apps and technology to learn, the opposite could be said for them, focusing on their creative outputs more so than ability to play with proper form and to read musical notation, and using games to strengthen that rhythm. Though West's framework provides a rich taxonomy for musicianship, its practical uses in pedagogies of tradition tend to be concentrated towards rote learning and extensive practise. Digital tools are much more innovative than that, but they tend to focus on generic skills rather than a holistic approach, causing the learner to have fragmented progress, and no real world applicability. These limitations highlight the necessity of a more integrated and game-based framework for skill development using video games (Zatorre 2022).

2.2.2 Learning An Instrument

Learning to play an instrument can be seen as quite the endeavour and the study of playing an instrument is an activity which has evolved over the course of centuries. Whilst some instruments are considered 'easier' to learn than others, one must have at least some level of desire or passion to progress to any stage of playing an instrument. Traditional instruments such as piano, violin and guitar are typically associated with frustration when it comes to learning to play them, even at a low level (particularly in the context of trying to play existing musical pieces with the instrument – this is informed through primary research). The piano is one of the most popular instruments for beginners to pick up (Clark 2021, Green 2017) as

there is an obvious relation to pitch and keys in an ascending fashion, as well being a great instrument for rich improvisation. However, reading musical notation for the piano is rather complex and is considered one of the hardest to understand. With any instrument, there needs to be a natural balance of challenge, frustration and boredom, as Levitin et al. (2002) suggests: “devices that are too simple tend not to provide rich experiences, and devices that are too complex alienate the user before their richness can be extracted from them”. Playing key-based instruments does not quite match this balance as they can be considered too complex which leads to alienation and a sharp rate of dropouts.

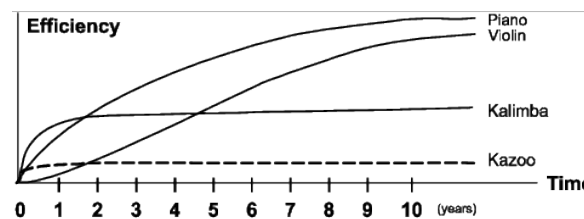


Fig. 2.2 Approximate learning curve for the (a) kazoo, (b) kalimba, (c) piano and (d) violin, within a period of 10 years

From Traditional Methods to Gamified Learning

The path to proficiency in music, especially on an instrument like the piano, can be discouraging for beginners. Research by Jorda (Jordà 2004) reveals that acquiring competence through traditional methods often takes years, leaving many learners disheartened by the slow pace of progress. Many authors describe the learning curve as the time it would take to either ‘master’ their instrument (Wanderley and Orio 2002) or perhaps reach a stage in which they can express themselves freely (Clark 2021, Green 2017); typically, it is suggested that it requires 10 years to reach this ‘mastering point’ (Jordà 2004). In contrast, gamified learning, exemplified by projects like LUMI, seeks to address this challenge by embedding game mechanics into music education. Through mini-games focusing on note recognition, rhythm, and hand coordination, gamified learning transforms practice into an enjoyable and dynamic experience. The immediate feedback provided during these short practice sessions enhances the sense of progress, reducing frustration and motivating learners to persist.

Highlighted by the findings from Chapter 4, the LUMI project has evolved to incorporate flexible, gamified learning environments that allow students to practice at their own pace. This shift is particularly crucial for overcoming psychological barriers that often hinder consistent engagement in traditional music lessons. By moving away from rigid practice routines and toward flexible, gamified experiences, our game-based approach promotes continuous, enjoyable learning, a theme central to the findings in Chapter 4.

Adapting the Learning Curve: Insights from Early Research

The development of LUMI's gamified tools was shaped by early user feedback, which highlighted some initial design limitations. Early prototypes were seen as more like drills than games, offering limited interactivity and engagement. Feedback discussed in Chapter 5 emphasized the need for a more immersive and interactive experience. Additionally, there was a lack of an effective framework for measuring the transferability of skills acquired through these games, which posed challenges for assessing their educational impact.

Chapter 6 addresses these challenges, focusing on refining the games to target specific musical skills. One key innovation was the introduction of "Note Reader Adventure," a game designed specifically to improve notation reading. This game shifted its focus from basic recognition tasks to more complex, skill-specific exercises that integrated rhythm, hand coordination, and dexterity. Through these refinements, the LUMI project moved towards a more pedagogically sound, research-driven approach, aligning game mechanics with core learning objectives.

Refining Gamified Tools for Mastery

As detailed in Chapter 6, the evolution of LUMI games represented a pivotal moment in gamified music education. Skills such as rhythm, audiation, hand coordination, and notation reading were carefully considered during game design, as these are crucial for musical proficiency. West (2015) notes that notation reading is a common stumbling block for beginners, making it a priority in the development of tools like "Note Flash" and "Note Trainer." These games gradually increase in difficulty, providing progressively more challenging tasks that adapt to the learner's skill level. The goal is to foster mastery, encouraging learners to become more independent as the games reduce feedback and place greater emphasis on real-world performance.

Bridging to Real-World Application: Insights from Pilot Studies

Building on Chapter 6's findings, a pilot study confirmed the potential of gamified learning in enhancing music skills. Participants who engaged with the refined "Note Reader Adventure" showed significant improvements in notation reading, validating the hypothesis that gamified learning leads to better skill acquisition. By incorporating RPG-style progression, rhythm challenges, and audiation exercises, the game became more immersive, which further enhanced learner engagement and educational outcomes. Unlike traditional practice tools, which often offer delayed feedback and slow progress, the gamified tool provided immediate feedback, significantly boosting learner motivation.

The study's real-world design was pivotal in exploring whether game-based learning could maintain engagement outside of controlled environments. The flexibility offered by the gamified tool proved crucial in encouraging sustained engagement, as learners could practice in their own time and receive real-time feedback. This approach, explored in Chapter 6, demonstrates that gamification not only makes learning more enjoyable but can also significantly improve the overall learning experience compared to conventional methods.

A Narrative Approach to Learning

In Chapter 7, the development of “The Crypt of Notation” represents an exciting step forward in gamified learning. Drawing from previous research (Brett, 2020; Brett, 2021), this new game integrates a narrative structure into the learning process. The game's protagonist, Maalik, must battle the antagonist, Yalla, with musical notation as the central mechanic. This storyline provides a clear purpose for players, deepening their emotional investment and making the learning process feel more meaningful. By aligning the game's educational objectives with its plot, the game encourages players to engage in skill development while progressing through the narrative.

In addition to the captivating narrative, the game's design incorporates a mix of hand-crafted and procedurally generated levels, ensuring both structure and variety. These levels reinforce rhythm and notation reading while using environmental audio cues—such as rhythmic background music and dynamic sound effects—to support pedagogical goals. These features encourage players to internalize timing and note recognition in context, making the learning experience more immersive and engaging.

Long-Term Engagement

The longitudinal study described in Chapter 7 aims to evaluate the long-term effectiveness of “The Crypt of Notation” in improving music notation reading. By comparing participants' pre- and post-test scores over a week-long study period, the research assesses whether the gamified learning tool leads to more significant improvements than traditional methods. The study also explores key factors such as practice frequency, feedback, and the learning environment, all of which contribute to skill retention and muscle memory development.

The study will determine if improvements in notation reading extend to other areas of music playing and whether gamified tools, as a whole, provide better engagement and motivation compared to traditional tools. It is expected that participants who engage more frequently with the game will experience greater skill improvement, validating the hypothesis that gamified learning is a more effective and enjoyable alternative to traditional methods.

Table 2.1 Findings of the reviewed sources for sections 2.2.1 and 2.2.2

Reference(s)	Frameworks/Methods	Findings/Contributions	Potential Themes
(Gordon 2012, West 2015a).	West's "Big Five" taxonomy; Gordon's audition focus; qualitative review.	Identifies five key skills (rhythmic, tonal, notational, creative, executive) and contrasts traditional rigid vs. creative learning, emphasising auditions role in structured skill acquisition.	Blending traditional and creative methods.
(Clark 2021, Green 2017, Levitin et al. 2002)	Analysis of traditional vs. gamified learning.	Gamified tools balance challenge and engagement, addressing dropout causes and offering motivational strategies, highlighting balance for sustained learning.	Gamification and game-based learning as a teaching tool.
(Jordà 2004, Wanderley and Orió 2002).	Gamified developments studies; gamified tool effectiveness.	Evidence of gamification enhancing learning with specific mini-games, boosting motivation and demonstrating feedback-driven engagement improvement.	Immediate feedback in games.
(Brett et al. 2022 2021, Zatorre 2022)	Pilot studies on skill transfer and retention.	Validates gamified tools for improving notation reading and flexibility, enhancing engagement outside traditional settings with real-time feedback.	Practical skill transfer applications.

2.2.3 Learner Types

Demirtaş and Süral (2017) helped to define the individual learning styles regarding piano learning in an effort to make learning courses more effective for individual learners. Their study consisted of 133 music teachers and suggested that there are four learning styles:

Independent: independent learning styles relates to individual learners. Such students can categorize pieces of music they practice, analyse and interpret them from their own point of views. They prefer to learn on in a solitary fashion and exhibit high self-confidence. Independent learning styles can have some drawbacks in terms of students' vocational experience and performance (i.e., lack of tutoring can lead to poor form)

Analytical: Students who prefer analytical learning style adopt a conceptual view. Students try different methods and "... adopt solution-oriented approach in an effort to reach a solution." They prefer individual learning as well and such students like to work in safe learning environments and they like to divide their works into smaller parts by analysing challenges they encounter

Dependent: Students in a dependent learning group wait for an external warning. Guidance of someone else comforts students and makes students work better when they organize their studies. When they start to decipher a new notation, they first need to hear it from someone else and they always consult their works to be checked by someone. In the stage of working on a musical piece, they try to reach audio-visual resources and they play them by imitating rather than mastering n a musical piece, they try to reach audio-visual resources and they play them by imitating rather than mastering. A student using a dependent learning style has a more artistic and musical character as they access to various resources

Affective: A student adopting affective learning style looks for a familiar tune in a musical piece. Such students can better work if they like the pieces of music they play. They mostly prefer to play their pieces over and over in a wholly way. They always expect to take positive feedbacks during piano courses and if they take a negative feedback, they alienate themselves from the course; they can easily learn as they have high levels of motivation

2.2.4 Individual Differences in Musical Learning Ability

Understanding why certain individuals find learning a musical instrument easier than others requires examining a multitude of factors including cognitive, biological, and environmental. Musical aptitude is influenced by a combination of innate abilities, prior exposure, and learned skills. For instance, research suggests that individuals with higher auditory working memory and fine motor skills may excel more naturally in musical activities (Levitin 2006, Zatorre and McGill 2012).

Several studies have highlighted the role of genetics in musical learning. Research shows that individuals with denser gray matter in regions associated with auditory processing and motor control, such as the auditory cortex and prefrontal cortex, tend to demonstrate advanced musical skills (Gaser and Schlaug 2003). Additionally, specific genes which are often associated with language acquisition, have also been linked to musical aptitude, suggesting that some learners may possess a genetic predisposition to grasp musical concepts more intuitively (Sadakata and Oie 2010).

Early exposure to music during childhood has also been identified as a critical factor (and commonly accepted among many people). Studies indicate that children who grow up in musically rich environments are more likely to develop a natural sense of rhythm, pitch, and tonal awareness (Hannon and Trainor 2005). Conversely, individuals who are introduced to music later in life may find it more challenging to learn due to reduced neuroplasticity and limited prior exposure. The same can be applied to learning other domains which are complex and content rich (mainly, languages). This idea is rather obvious: any adult who tried learning a language claims how difficult it is whereas those who are bilingual or speak multiple languages from an early age never stress the same difficulty (it is just second nature).

Differences in learning styles and personality traits can further explain disparities in musical learning. For example, extroverted individuals may thrive in collaborative, performance-based settings, whereas introverted learners might benefit from solitary practice and reflection. Similarly, individuals with high levels of perseverance are more likely to overcome the challenges associated with learning an instrument, regardless of initial aptitude (Duckworth et al. 2007). Of course, such research is subjective and never truly set in stone but can help give further evidence to the differences in individuals.

These findings suggest that while some individuals may exhibit a natural inclination toward musicality, others may require tailored instruction to accommodate their cognitive and environmental backgrounds. Educators frequently utilise this understanding to create more personalised learning pathways, which could potentially leverage game-based learning tools to provide adaptive feedback and support. The idea of this research was to offer solutions that catered to individuals of varying backgrounds, rather than offering a blanket solution.

By integrating these insights into existing frameworks, such as West's "Big Five" skills, music educators and developers of learning solutions can design their tools to address individual needs, ensuring that learners of varying abilities have equal opportunities to succeed. Many marketplace and research solutions still do not consider this whereas this research tries to strive to oppose this perspective; offering multiple solutions and understanding the individual differences that will reflect their engagement and potential to acquire and retain new skills.

Defining Specific Groups Using Market Research

Before developing a solution, it was essential to determine the target audience for the game-based learning tools. Initially, the demographic for the research was broad, encompassing adult casual keyboard learners. User research conducted by the placement company, along with a review of relevant literature and informal conversations with learners at all skill levels, helped identify the most suitable audience for this method of learning and practice. Additionally, third-party consumer research undertaken by a data company specialising in user groups for specific use cases provided valuable insights for the placement company (ROLI 2022). Although the full data cannot be disclosed, a summary of the key findings is outlined below. The objective of the research was to identify consumer and hobbyist segments and explore how to effectively engage with them when developing a roadmap for educational tools. This research was pivotal in shaping the design of the game-based learning solutions introduced in Chapter 5, and further refined in Chapter 6, where the focus shifts toward developing a pedagogically sound, game-based system for improving musical notation reading skills. Insights from this research will also be reviewed in Chapter 7, as the tools are iteratively tested and refined for broader user engagement.

The analysis featured 23 consumer and hobbyist participants, focusing on both the UK and US across various locations. The findings revealed that most casual consumers had limited knowledge of electronic music and music creation, with little understanding of music theory or the basic concepts of song composition. A common theme emerged where most beginners viewed music primarily as an expressive outlet, aspiring to play their favourite songs rather than becoming full-time composers or producers. The research also highlighted a strong interest in educational tools and gamified learning, though it was clear that consumers wanted authentic, tangible, and transferable musical skills to stay engaged.

This user research identified two primary groups: consumers and hobbyists. Consumers included novices, instrumental learners, and production dabblers, while hobbyists were made up of lapsed, instrumental hobbyists, and hobbyist producers. Below, we will explore two specific user types from the research: novices and lapsed. These groups were selected based on their relevance to the ROLI target demographic and the solutions in the form of practice games developed in Chapter 5. Other groups were excluded, as they represented advanced learners who were not interested in learning an instrument.

Novices

Novices are individuals who lack technical musical knowledge and tend to view music on an emotional level, using it primarily for personal enjoyment. While many aspire to learn

to play music, they generally have no clear plan for how to begin their journey and require assistance to take the first step. For novices, learning music is typically driven by a desire for self-improvement and to express themselves through their favourite songs. Their primary motivation is to boost self-esteem, alleviate stress, and engage in a solitary hobby initially, although they may eventually hope to share their musical skills with others.

Novices prefer learning experiences that are explicit and feature short bursts of highly rewarding tasks. They gravitate toward music that is popular and may favor applications with a structure similar to language learning platforms such as Duolingo (Shortt et al. 2021), offering a steady, gamified learning mechanic. As such, they are an ideal target group for practice games, making them the focus of this research. The goal is to build a learning progression that minimizes cognitive load, providing rewards that encourage further practice and eventual mastery. This focus on engagement and motivation aligns with the findings discussed in Chapter 6, where we refine the game design to cater to this group's need for enjoyable and rewarding experiences that encourage long-term learning and practice. Chapter 7 further explores the effectiveness of these tools as they are tested with the novice group in real-world settings.

Table 2.2 User Groups Defined By Third Party Market Research

Demographic Information	User Group	
	Novices	Lapsers
Current Focus	Getting Started	Getting Back Into Music
Musical Aspiration	Playing Favourite Songs	Returning To Old Skill Level
Technical Capability	None	Low
Instrumental Capability	None	Low
Musical Drive	Expressive	Expressive

Lapsers

Lapsers are individuals who previously engaged with music but gave it up due to a disruptive life event, such as moving to university or having a child, which made it difficult to maintain a musical practice. Some lapsers have since returned to music, aiming to regain their previous level of proficiency by using the same methods they employed in the past. Others have the same long-term goals but have yet to take the first step in re-engaging with music.

Lapsers' view of music is strongly influenced by their previous experience, and they are motivated to relearn old skills as a path to self-improvement. While they have lower expectations of digital learning tools, many are open to exploring technology as a means to

re-enter music. They are often more comfortable with traditional learning methods, such as reading sheet music, which they associate with their previous musical training. The design of games in Chapter 5 was intended to cater to this group by providing tools that bridge traditional learning methods with more accessible, gamified systems. For lapsers, the goal is to provide intuitive practice tools that help rebuild muscle memory and rhythm recognition without overwhelming the learner, as outlined in our later study's design principles. This design consideration, which is further elaborated in Chapter 6, ensures that the game-based approach resonates with lapsers by offering a familiar yet engaging structure that rekindles their interest in musical practice.

In this way, the user research conducted provided foundational insight into the target audience for the practice games, as well as key motivations and preferences that guided the iterative development process in Chapter 5. The focus on both novices and lapsers aligns with the primary objectives of creating an engaging, effective learning experience that bridges the gap between beginner musicians and more experienced learners who have lapsed in their practice. The iterative development and testing in Chapter 7 will further refine these tools based on feedback from lapsers, ensuring the system works for a broad range of users with varying experience levels.

2.2.5 Dropouts and Game-Based Learning in Music Education

The ABRSM surveys offer significant insights into trends in music learning within the UK. The most recent survey, conducted in 2020, included over 2,000 teachers, 1,500 children (aged 15-17), and 1,500 adult learners (18 and over). The findings suggest that while children are more engaged in both creating and playing music than adults, both groups show a 20% decline in instrumental playing, and there has been an 11% decrease in children attending music lessons since 2014. Notably, nearly two-thirds (64%) of children who play an instrument report using digital resources, such as YouTube and learning apps, to support their practice. Furthermore, both adults and children rated the value of digital technology in their musical progression highly, with scores of 7 or higher on a 10-point scale in 2020. Teachers across all music fields also reported integrating digital technology into their lessons by 2020, with 90% indicating their use of digital tools. However, despite these technological advancements, only 30% of adult learners who undertook music exams managed to complete grade 1 before dropping out. This dropout phenomenon underscores the importance of sustained motivation and consistent practice, factors that teachers frequently cite as crucial for progress (61%) (Gerelus et al. 2020, Ruth and Müllensiefen 2021).

Table 2.3 Findings of the reviewed sources for sections 2.2.3 and 2.2.4

Reference(s)	Frameworks/Methods	Findings/Contributions	Potential Themes
(Demirtaş and Süral 2017)	Defined four learning styles (independent, analytical, dependent, affective) via a study of 133 music teachers.	Highlights varying learner needs and preferences, emphasising personalised instruction for effective piano learning.	Personalised learning in music education.
(Gaser and Schlaug 2003, Levitin 2006, Sadakata and Oie 2010, Zatorre and McGill 2012)	Examined cognitive, biological, and genetic influences on musical aptitude.	Identified factors like auditory memory, motor skills, genetics, and gray matter density affecting learning ability.	Cognitive and biological influences on learning.
(Duckworth et al. 2007, Hannon and Trainor 2005)	Studied early exposure and perseverance in musical learning.	Found early exposure enhances neuroplasticity and skill acquisition; perseverance aids progress irrespective of initial aptitude.	Impact of early exposure and perseverance.
(Shortt et al. 2021)	Investigated gamification in novice learning contexts.	Gamified tools like Duolingo-inspired platforms offer structured, rewarding learning mechanics that engage novices.	Gamified learning for novices.
(ROLI 2022)	Third-party consumer research on user groups (novices, lapsed).	Identified motivations and learning barriers; novices seek engaging starts, while lapsed prefer tools aiding skill recovery.	Tailored tools for specific learner groups.

Dropout Predictors in Adult Learners

The ABRSM surveys reveal several key factors contributing to adult learners abandoning their musical studies. These include a loss of interest, financial constraints, or the perception that lessons are unnecessary for recreational purposes. Adult learners who achieve higher exam grades or demonstrate consistent progress tend to remain motivated and continue their studies, with skill development correlating strongly with continued engagement (Ruth and Müllensiefen 2021). The transition from adolescence to adulthood is often a key

predictor of dropout, as young adults prioritise other pursuits, such as academics or personal interests. A study of over 3,000 adults from the Swedish Twin Registry found that dropout and continuation were influenced by factors such as age at the start of learning, teaching style, and the learning environment. Particularly, social interaction with peers emerged as a significant factor in sustaining motivation (Chi-hung and Hartwig 2011, Theorell et al. 2015).

Adult learners face even greater challenges in music education, with research indicating that traditional teaching methods may not fully engage them. Placement studies show a strong desire to learn, but financial pressures and methods not tailored to diverse learning styles often result in high dropout rates. (Cremaschi et al. 2015a) identified four main reasons for these dropouts:

- Institutional teaching methods that fail to address student motivations
- A lack of enjoyment in the learning process
- Cognitive and time-related barriers that prevent progress
- Financial constraints

Lack of Skill and Correlation Between Effort and Effect

Understanding that dropout rates among beginner keyboard learners are a troubling concern, particularly for adult learners, and is brought on due in part to the belief that their musical abilities are not progressing, is crucial. Playing an instrument like a keyboard takes a lot of patience and you don't really learn a lot, even after a long while, often with very unrealistic expectations, or exaggerated claims stipulated by the marketing for training applications. One issue we have identified, especially for independent learners, is with skills such as reading music or linking notation with keys, when the progression is too steep it can be frustrating and disengaging. Musical competence is an important factor contributing to persistence in learning, as (Mawbey 1973) showed that learners who achieve proficiency are more likely to continue their studies for that reason, since a manifestation of progress reinforces motivation. Yet, many adult beginners have problems reaching the skill level required for such momentum, especially when traditional approaches don't provide for accelerated learning.

As rote learning and the lack of immediate feedback are typical in most traditional pedagogical approaches, they often fail to engage learners (Suzuki 1983). Moreover, quitting was often promoted by learners who felt inadequate when compared to peers, due to comparison or a lack of social validation (Wanderley and Orio 2002). A major problem is that the learning methods in the home environment often do not provide sufficient motivation that is often provided in classroom or tutor led contexts. Those who support gamified learning

say that motivating barriers can be overridden through interactive and rewarding practice environments. This work builds on these critiques with gamified solutions that aim to lower cognitive barriers, and sustain engagement, especially for adult novices.

Addressing Dropouts Through Game-Based Learning

Given the challenges identified in traditional methods, particularly for adult learners, game-based learning presents a promising solution. This research has followed a systematic progression in developing and validating game-based approaches for music education. Beginning with multiple prototype mini-games in our first cycle of development (highlighted in Chapter 4), the focus was refined to specific skills like notation reading based on qualitative assessment. The work then evaluated different categories of games in Chapter 5, from basic training tools to fully gamified experiences, revealing that more game-like approaches could maintain pedagogical value while increasing engagement. Building on these findings, Chapter 6 presented a pilot study comparing our most promising prototype against traditional training methods, demonstrating the potential of game-based learning while highlighting areas needing refinement.

Game-based learning transforms repetitive foundational practice into something enjoyable and rewarding by integrating musical learning into engaging gameplay. For instance, games designed to improve skills like note recognition, rhythm, and scale familiarity mirror traditional learning objectives but present them in a more engaging and accessible format. These game-based solutions provide learners with flexibility, as they can practice anywhere, anytime, without being constrained by fixed schedules or physical locations. The development of the ‘Note Reader Adventure’ game, described in Chapter 6, demonstrated how gamifying music practice can improve motivation and skill acquisition. The mini-games within the LUMI platform, with their focus on incremental progress and immediate feedback, provide learners with tangible improvements, reducing the frustration often experienced with slow traditional methods.

This chapter builds on these previous discussions by presenting a more refined and validated game prototype, ‘The Crypt of Notation,’ discussed in Chapter 7. By implementing narrative elements, a more robust onboarding process, and improved game mechanics, this version of the game aims to create a more immersive and motivating experience for learners. The game’s narrative arc and the integration of supportive characters align with earlier findings that emphasised the importance of engagement and meaningful progression in game-based learning (Brett et al. 2021 2020). These elements aim to combat the disengagement factors that often lead to dropout, such as lack of enjoyment or progress.

While traditional music education methods face considerable challenges in reducing dropout rates, particularly for adult learners, game-based learning offers a promising alternative. By embedding educational content within an engaging, interactive game framework, as detailed in Chapters 4, 5, and 6, learners can experience consistent, visible progress and maintain motivation. The shift from simple gamification to more immersive game-based learning models, such as ‘The Crypt of Notation’ discussed in Chapter 7, addresses key barriers contributing to high dropout rates. These methods provide greater engagement, consistent feedback, and flexible practice opportunities, presenting an innovative solution to the challenges facing adult learners in music education.

2.2.6 Skill Acquisition

One of the key reasons for high dropout rates in music learning is the lack of skill acquisition, a challenge directly tied to inconsistent practice routines and insufficient skill development. Skill acquisition, as defined in the literature, refers to the ability gained through practice or training, enabling individuals to perform effectively across various tasks (noa 1996, Salmela and Pärnistö 2009). In the context of music education, skill acquisition involves capabilities developed through practice, rather than being innate (Attwell 1990). This framework is essential for addressing dropout rates, as it highlights the importance of structured practice and the development of core competencies in music learning.

In our first study (outlined in Chapter 4), this concept is examined in depth, emphasising that skill is a measurable competency that can be developed over time with repetition. It contrasts with knowledge, which is acquired once and revised, and abilities, which are often innate. This is particularly relevant in music education, where foundational skills require consistent practice and repetition, a process that is often overlooked or poorly managed in early learning stages. By focusing on methods that promote skill acquisition through repetition and structured practice, this research provides insight into how such practices can reduce dropout rates.

We later expand on this in Chapter 6, demonstrating how game-based learning tools can enhance skill acquisition. Prototypes like Note Reader Adventure (formerly Music Graveyard) illustrate how game mechanics can make skill development more engaging and less frustrating for beginners. By reducing cognitive load and providing structured, incremental practice, the game fosters competence in core music skills, such as note recognition, rhythm, and finger placement. These insights are built upon in Chapter 7, where The Crypt of Notation refines the approach, incorporating personalised and adaptive learning experiences that further support skill acquisition. The longitudinal study discussed in Chapter 7 evaluates how these

Table 2.4 Findings of the reviewed sources for section 2.2.5

Reference(s)	Frameworks/Methods	Findings/Contributions	Potential Themes
(Gerelus et al. 2020, Ruth and Müllensiefen 2021)	ABRSM surveys, UK (2020): over 5,000 participants (teachers, children, adults).	Highlights digital tools' role in supporting music learning; identifies high dropout rates linked to motivation and practice gaps.	Digital integration in more classical music education.
(Chi-hung and Hartwig 2011, Theorell et al. 2015)	Swedish Twin Registry (3,000 adults); teaching and environment analysis.	Social interaction and tailored teaching styles emerge as key motivators to sustain adult learners in music education.	Social and environmental factors on music education.
(Cremaschi et al. 2015a)	Dropout analysis in traditional learning settings.	Identifies four primary dropout causes: unengaging methods, lack of enjoyment, cognitive/time barriers, and financial constraints.	Barriers in traditional teaching methods.
(Mawbey 1973, Suzuki 1983)	Skill acquisition and rote learning studies.	Highlights the importance of achieving musical competence as a motivator; identifies challenges with slow progress in traditional approaches.	Competence as a motivator for learning.
(Wanderley and Orio 2002)	Studies on peer comparison and validation in learning contexts.	Shows how feelings of inadequacy and lack of social validation contribute to dropouts among learners.	Impact of peer dynamics on engagement.
(Settles and Meeder 2016b)	Adaptive learning tools with immediate feedback mechanisms.	Validates the effectiveness of real-time feedback and incremental progress in reducing learner frustration.	Immediate feedback in gamified tools.

game-based strategies help players build and retain music skills, validating the hypothesis that such tools can enhance music education outcomes and reduce dropout rates.

Rote Learning

Rote learning, traditionally associated with passive memorisation through repetition, is often seen as outdated in modern educational practices. However, it remains crucial, especially in the early stages of music education and certain other disciplines (such as sport and language learning). In the context of music, rote learning is essential for mastering foundational skills such as scales, chords, and finger placements, which require constant repetition to build muscle memory and proficiency. As highlighted by Suzuki (Shinichi Suzuki 2023), the philosophy of consistent encouragement and repeated practice plays a significant role in music education, where repetitive listening, score reading, and practice help solidify essential techniques.

Although newer learning theories, like associative learning and spaced repetition, have emerged to replace or refine rote learning methods, rote techniques still hold value. This is evident in the research of Ahmed Ahmed and Ahmad (2017), who found that students often use rote learning, sometimes unknowingly, as part of their learning process. He argues that rote learning contributes to becoming a lifelong learner, motivating students, especially early in their education, by providing structure and boosting confidence through assessments. Donnison (Donnison and Penn-Edwards 2012) further supports this by emphasising that rote learning is not necessarily meaningless but plays an important role in building knowledge and motivation.

In music education, this idea of repetition and structured practice aligns with the application of rote learning, especially in the context of learning instruments like the keyboard. Children, with their ability to focus and revise, are often able to absorb and internalise these repetitive tasks more easily. The importance of rote learning is particularly relevant to the foundational elements of musicianship, which form the basis of more complex skills and technique development over time.

Interestingly, modern teaching strategies are beginning to integrate rote learning into more dynamic and engaging structures. For instance, game-based learning, as discussed in Chapter 6, can incorporate rote learning by using feedback loops and incremental rewards in games like Note Reader Adventure. These games reinforce repetitive learning in an engaging way, avoiding monotony. This concept is further developed in Chapter 7 with The Crypt of Notation, where narrative-driven progression enhances rote learning by contextualising it within a broader, motivating storyline. Such methods ensure that repetition remains meaningful and engaging, leading to better retention and addressing the risk of learner burnout or dropout.

Thus, rote learning, while often criticised, is not obsolete but rather integrated into modern educational frameworks in ways that make it more interactive and motivating, especially in

fields like music where repetition is essential to mastery. By combining traditional approaches with innovative game-based strategies, rote learning continues to serve as a valuable tool in education.

Skill Acquisition: Rote Learning vs. Gamified Approaches

Skill acquisition remains a cornerstone of musicianship and is frequently approached differently in the literature. For some, the fact that rote learning can be used to develop foundational skills through repetition (Suzuki, 1983) has since been defended as one solution to reducing monotony. Spaced repetition and immediate feedback are more easily incorporated in gamified tools like Note Trainer (featured in Chapters 3 and 4 and inspired by Settles (Settles and Meeder 2016a)) which makes repetition of practise less cognitively taxing and more engaging. This research combines these approaches by creating a hybrid model where structured repetition is combined with gamified interactivity.

Kinaesthetic Learning

Kinaesthetic learning, which emphasises physical interaction and muscle memory, plays a pivotal role in the development of music skills, particularly in instrument learning. This approach is central to the design of various learning systems, as highlighted in Chapter 4, where kinaesthetic feedback is shown to enhance the learning process. For instance, when learning to play an instrument, the physical movement required helps solidify the connection between action and musical comprehension. Chapter 6 builds on this concept in Note Reader Adventure, which offers real-time auditory, visual, and kinaesthetic feedback through interaction with a MIDI keyboard. This multi-sensory experience strengthens the learner's ability to link visual notation with physical movement, facilitating both immediate understanding and long-term retention.

In Chapter 7, The Crypt of Notation refines the kinaesthetic approach by guiding players toward proper finger placements and hand positions as they progress through levels. This progression not only strengthens muscle memory but also improves dexterity and retention, key factors in musical skill development. Such a kinaesthetic approach aligns with research on active learning preferences, where students often show a preference for physical, engaging learning methods over passive observation. As noted by Riazi (Riazi and Riasati 2007), students who are actively engaged in hands-on activities tend to demonstrate greater retention and skill development, reinforcing the role of kinaesthetic feedback in effective learning environments.

While kinaesthetic learning is a central focus of this research, it is important to recognise that learners typically do not adhere strictly to one style of learning. Most learners exhibit a blend of the three primary learning styles: visual, auditory, and kinaesthetic. In the context of this research, the solutions developed prioritise kinaesthetic learning through physical devices, such as keyboards. However, the systems also integrate auditory and visual elements to support multi-sensory engagement. The use of rich visuals and sound not only aids in skill development but also helps learners form associations between the physical movement and the cognitive task at hand. This multi-faceted approach is in line with findings from studies on learning styles (Price et al. 1981), (Riazi and Riasati 2007), which suggest that a mixed approach to learning, involving physical, auditory, and visual components, often leads to better outcomes.

This hands-on approach, with its emphasis on physical interaction and muscle memory, supports the active learning preferences that are becoming increasingly prominent in educational research. The trend toward embodied learning, as discussed by Nadyrova (Nadyrova 2016), further underscores the value of combining physical movement with cognitive tasks in the development of complex skills like playing a musical instrument.

Equivalence Based Instruction

Equivalence-Based Instruction (EBI), a technique developed by Sidman (Sidman 1971 2009), involves teaching students to associate different sets of stimuli. In the traditional process, a learner is taught to correlate Set A to Set B, and Set B to Set C. Once these connections are established, equivalence is formed, meaning that Set A is associated with Set C. EBI can be seen as an extension or refinement of rote learning, enhancing memorisation by forming stronger associations. This method is particularly beneficial in contexts where repetition and solidifying connections are essential for deeper learning.

In music education, EBI is an effective technique for linking musical notation with corresponding sounds and finger placements, thus making the learning process more intuitive. As discussed in Chapter 4, EBI facilitates the connection of these diverse stimuli—visual, auditory, and physical—by associating musical notes (visual cues) with their corresponding sounds (auditory cues) and the correct finger placements (physical cues). This multi-sensory approach not only accelerates learning but also helps learners develop a more comprehensive understanding of music concepts.

Chapter 6 highlights how EBI is incorporated into the design of Note Reader Adventure, where visual cues, such as glowing notes, are paired with auditory feedback and physical interactions. This game-based learning approach enhances the EBI process by reinforcing the connections between notation, sound, and movement, creating a cohesive and engaging

learning environment. By aligning these multiple forms of stimuli, the learning process becomes more dynamic and effective, fostering quicker mastery of music skills.

Further advancing these techniques, Chapter 7 delves into *The Crypt of Notation*, where EBI methods are integrated into the game's narrative and gameplay elements. These elements serve to reinforce the associations between musical notation, sound, and physical action in a more interactive and immersive way. By embedding the learning process into the gameplay, the game promotes a deeper and more intuitive understanding of music concepts, thus enhancing skill acquisition.

EBI has proven to be successful in various educational contexts beyond music, including reading, geography, money skills, and sorting tasks for both typically developing children and those with Autism. For example, Zinn et al. (2015) found that EBI was significantly more effective in teaching basic course-related vocabulary (e.g., drug names) than traditional methods like flashcards. Participants in the EBI group learned twice as quickly and with fewer errors, demonstrating the technique's effectiveness in fostering quicker and more accurate learning. In music education, similar EBI applications, such as the Light-Up Key method, can be seen where Stimulus A = Sound, Stimulus B = Light, and Stimulus C = Finger position/muscle memory, further reinforcing the multi-sensory connections central to EBI.

Spaced Repetition

Spaced repetition is a technique designed to improve memory retention, especially for complex information such as musical notation and finger placements. This method involves reviewing material at progressively spaced intervals, which enhances long-term retention while reducing cognitive overload. The technique is grounded in the principle that information is more likely to be retained when revisited at intervals that align with the learner's forgetting curve (Ebbinghaus 1913). Early iterations of spaced repetition were built on the concept of graduated-interval recall (Pimsleur 1967), but the approach has since evolved to incorporate adaptive algorithms that personalise learning based on the learner's performance.

In the context of music learning, spaced repetition offers significant benefits. Chapter 4 of *Note Reader Adventure* introduces this method to enhance long-term retention of musical skills. The game's adaptive algorithms refine the approach, optimising the timing of skill reviews so that learners encounter material at moments when they are most likely to need it, without feeling overwhelmed. This approach draws on the foundational work of (Ausubel and Youssef 2010) and (Settles and Meeder 2016b), who highlighted the importance of tailoring review intervals to a learner's individual progress. By incorporating these adaptive

principles, Note Reader Adventure ensures that practice sessions are engaging and effective, helping learners avoid the pitfalls of massed practice or cramming.

Building on these principles, Chapter 7 of Note Reader Adventure integrates spaced repetition into *The Crypt of Notation*, further personalising the experience. In this chapter, the game's adaptive algorithms ensure that players revisit key concepts at optimal intervals, reinforcing essential musical skills over time. This personalised approach promotes consistent practice and prevents cognitive overload, fostering a deeper connection to the material and long-term engagement. As noted by (Settles and Meeder 2016b), the use of personalised learning techniques—such as Half-Life Regression—has been shown to increase both retention and engagement by accounting for individual differences in learning progress.

While traditional spaced repetition has primarily been applied to language learning, its integration into music education, as demonstrated in Note Reader Adventure, is a promising innovation. The challenge of learning music, which involves not only recalling individual notes and finger placements but also understanding broader concepts and patterns, benefits greatly from the personalised nature of spaced repetition. By continuously adjusting to the learner's evolving skill level, the game provides a dynamic, effective approach to mastering music theory and performance. Moreover, as pointed out by (Settles and Meeder 2016b), combining spaced repetition with other educational methods—such as tutoring or peer learning—creates a more holistic and engaging learning experience, one that is far superior to the one-size-fits-all approach commonly seen in many traditional music learning applications.

The success of these adaptive spaced repetition models underscores their potential in reshaping how we learn complex subjects like music, improving both retention and engagement. Through iterative review based on performance and personalised difficulty, learners are supported in their long-term mastery of musical skills.

Revisiting Skill Acquisition in Chapter 7

Chapter 7 extends the focus on skill acquisition, moving beyond the prototypes developed in Chapters 4, 5, and 6 to the most refined version of our game, *The Crypt of Notation*. This chapter demonstrates how the game enhances the core music skills identified in earlier chapters, including rhythm, finger positioning, and audiation, through rigorous testing in real-world settings. The longitudinal study conducted in this chapter validates the effectiveness of the game in promoting skill acquisition over time, showing significant improvements in both qualitative and quantitative outcomes.

By integrating key principles such as structured practice, rote learning, kinaesthetic feedback, EBI, and spaced repetition, *The Crypt of Notation* provides a comprehensive framework for music learning that not only supports skill development but also maintains

learner engagement. The findings from Chapter 7 confirm that game-based learning tools can transform music education by improving retention, reducing dropout rates, and offering a more immersive, personalised learning experience. These insights provide a foundation for future studies, helping to further explore how game-based approaches can help redefine music education and promote long-term learner success.

As a promising avenue to address these challenges, gamified learning is proposed. Within a structured and motivating framework, foundational skills can be practised and mastered using interactive and engaging mechanics that enable the creation of an environment. The subject of this thesis is to explore the gap between both the current keyboard pedagogy (Deci and Ryan 2017) and the ways in which games are effective at providing students with motivation to learn.

2.3 Video Games and Gamification

As this research is focused on gamifying key-based instrument learning, it was imperative to conduct a review into gamification, game-based learning, and game design theory to help pave a way to a new and distinct approach of gamifying music learning. Below is a discussion of a popular theory of gamification, followed by a comparative review of gamification and video games within learning (referred to as game-based learning). Finally, popular game design theories are reviewed which were used throughout the process of developing novel practice tools during the entirety of this doctorate. While gamification has gained traction in music education, its application often remains superficial, employing badges or point systems that fail to address the underlying challenges of skill development. In contrast, game-based learning integrates educational objectives directly into gameplay, fostering experiential and sustained learning. However, a review of existing tools reveals that few have successfully aligned gameplay mechanics with the core skills necessary for musical proficiency, such as rhythm and notation reading (Al-Azawi et al. 2016a, Saarikivi et al. 2020).

2.3.1 Gamification: Yu-Kai Chou

Gamification emphasises human-focused design over function-focused design, prioritising human motivation throughout the learning process. For this research, Chou's definition of gamification (Chou 2019a) is adopted, with its eight core drivers, collectively called "The Octalysis," forming a foundational framework for the design and evaluation of gamified learning solutions discussed in Chapters 4, 5, and further elaborated in Chapter 6. These principles also underpin the design and assessment strategies employed in the extended

Table 2.5 Findings of the reviewed sources for section 2.2.6

Reference(s)	Frameworks/Methods	Findings/Contributions	Potential Themes
(Attwell 1990, Salmela and Pärnistö 2009)	Frameworks on skill acquisition and structured practice.	Defines skill acquisition as a measurable, practice-driven competency essential for reducing dropouts in music learning.	Importance of structured practice.
(Ahmed and Ahmad 2017, Donnison and Penn-Edwards 2012, Shinichi Suzuki 2023)	Studies on rote learning in early music education.	Rote learning remains critical for foundational skills like scales and finger placement; gamified methods enhance engagement.	Developing effective strategies for rote learning.
(Ausubel and Youssef 2010, Settles and Meeder 2016b)	Adaptive spaced repetition models and feedback mechanisms.	Spaced repetition enhances retention and reduces cognitive overload, supporting mastery of complex music skills.	Personalised retention strategies using adaptive learning models.
(Nadyrova 2016, Riazi and Riasati 2007)	Kinaesthetic learning and active feedback in instrument practice.	Kinaesthetic feedback fosters long-term retention, muscle memory, and skill comprehension through multi-sensory engagement.	Embodied learning techniques.
(Sidman 1971, Zinn et al. 2015)	Equivalence-Based Instruction (EBI); multi-sensory integration.	EBI enhances learning by linking notation, sound, and physical cues, creating intuitive connections for music concepts.	Multi-sensory educational approaches.
(Ebbinghaus 1913, Pimsleur 1967)	Spaced repetition and forgetting curve principles.	Reviewing material at optimal intervals improves memory retention and aligns with cognitive needs in music education.	Effective memory reinforcement using prior learning.

remote study of *The Crypt of Notation* detailed in Chapter 7, ensuring a cohesive alignment of game mechanics with pedagogical objectives. Below, the eight drivers of Chou's gamification framework, as applied throughout this research, are outlined:

1. **Epic Meaning and Calling**

This driver taps into players' emotional engagement by making them feel uniquely positioned to achieve something extraordinary. In games, this is often achieved through mechanisms such as "beginner's luck," exclusive rewards, or challenges that position players as the hero of their own story. This principle informed the design of introductory mini-games like *Note Flash* and the narrative-driven *Note Reader Adventure*, further evolved into *The Crypt of Notation* in Chapter 7. The narrative, centred on Maalik's call for aid against the antagonist Yalla, embodied this principle by motivating players to recover stolen songs and restore harmony, imbuing their gameplay with a sense of purpose.

2. **Development and Accomplishment**

This driver emphasises progress and skill mastery through mechanisms such as point systems, leaderboards, and badges. While the game featured in Chapter 6 explored levelling systems and feedback loops, *The Crypt of Notation* incorporated progressive difficulty and structured assessment frameworks, including redesigned Flash card and Notation Reading tests, as detailed in Chapter 7. These elements reinforced measurable skill acquisition, aligning with the study's aim to evaluate long-term engagement and effectiveness within real-world practice environments.

3. **Empowerment of Creativity and Feedback**

This driver appeals to players who enjoy solving problems uniquely or experimenting with different strategies. Chapter 6 highlighted improvisation challenges in *Note Reader Adventure*, which evolved into *The Crypt of Notation* by incorporating creative decision-making through procedurally generated puzzles and branching storylines. As demonstrated in Chapter 7, allowing players to strategise and adapt their gameplay enhanced their investment in both the narrative and their skill development.

4. **Ownership and Possession**

Players form a personal connection to the game through features like accumulating virtual assets or customising elements. In *The Crypt of Notation*, collectible in-game rewards and customisable abilities were key in maintaining engagement. Chapter 7's findings show that these mechanics not only enhanced retention but also reinforced the intrinsic value of consistent practice by making progress feel personally meaningful.

5. Social Influences and Relatedness

This driver encompasses competitive and cooperative elements, such as leaderboards and mentorship. Earlier research (Brett et al. 2021) cautioned against over-reliance on competitive features due to their potential to evoke negative emotions. Consequently, *The Crypt of Notation* focused on cooperative elements, with narrative-driven goals and character interactions fostering a sense of connection. Chapter 7 explores the potential for collaborative mechanics to be incorporated in future iterations to further enhance group learning dynamics.

6. Scarcity and Impatience

Scarcity appeals to players by leveraging the desire for rare opportunities or items. This principle was implemented in *The Crypt of Notation* through timed challenges and unlockable content, creating anticipation and encouraging consistent gameplay. Chapter 7's longitudinal study confirmed that these mechanics contributed to sustained interest and regular practice, critical factors for skill retention.

7. Unpredictability and Curiosity

Curiosity motivates players to explore and discover through unexpected or random outcomes. Inspired by this driver, *The Crypt of Notation* integrated surprise bonuses, hidden pathways, and procedurally generated puzzles. As detailed in Chapter 7, these features maintained engagement across diverse player preferences, ensuring the game's appeal to both novice and experienced learners.

8. Loss and Avoidance

This driver uses the fear of losing progress or missing opportunities to motivate players. Subtle streak-based rewards and temporary score multipliers in *The Crypt of Notation* encouraged consistent practice without inducing frustration. Chapter 7 highlights how these mechanics effectively balanced urgency with accessibility, fostering motivation rather than penalisation.

Chou's framework was pivotal in addressing gaps in existing gamified learning solutions, as observed in the game featured in Chapter 6 and then later used in the longitudinal study detailed in Chapter 7. Unlike commercial applications that often rely on superficial gamification strategies, this research embedded Chou's drivers deeply within game mechanics, creating cohesive and meaningful experiences. For instance, while the *Game of Tones* study (Raymaekers et al. 2014) demonstrated increased accuracy and motivation with gamified tools, it also highlighted limitations like short durations and small sample sizes (similar findings

were found also in (Gomes et al. 2016a)). By contrast, *The Crypt of Notation* addressed these issues by extending engagement over a week-long study and refining mechanics to improve usability and accessibility.

As a method to increase learner motivation and engagement, gamification has become popular, but the depth and effectiveness of gamification continues to be debatable. The Octalysis approach that Chou devised includes comprehensive models for gamification, on one hand, but, on the other hand, emphasises psychological drivers like curiosity and reward. However, numerous critics argue that many applications operate at the mechanics of the surface that are prizes and badges, which yield no results and learning outcomes of any kind (Deterding 2011). This work remedies these shortcomings by embedding the gamification principles inside of pedagogically robust designs where game mechanics are directly tied back to the development of skills.

The deliberate application of gamification principles underscores the necessity of cohesive, player-centred design in educational games. As demonstrated in Chapter 7, transforming rote learning into engaging, gamified experiences improves skill acquisition, engagement, and overall user satisfaction. This research not only validates the potential of gamified solutions in music education but also highlights pathways for future innovations, ensuring learning becomes both effective and enjoyable.

Many gamified solutions in music education fail to transcend surface-level engagement. Features such as leaderboards and rewards, while motivating in the short term, often lack the depth required for meaningful learning. This inadequacy highlights a critical gap: the absence of immersive, research-driven game-based learning solutions that prioritize skill transferability and long-term engagement of learners (Deterding et al. 2011, ?).

2.3.2 What Is a Video Game?

To address the challenges posed by research into music learning through video games, it is essential to first clarify what constitutes a video game, distinguishing it from gamified learning tools and learning-focused games. Esposito offers a useful definition: “A videogame is a game which we play thanks to an audio-visual apparatus and which can be based on a story” (Esposito 2005). A game, specifically, is a fictional activity governed by rules, played voluntarily. Eric Zimmerman refines this definition, stating that it is “a voluntary interactive activity, in which one or more players follow rules that constrain their behaviour, enacting an artificial conflict that ends in a quantifiable outcome” (Tekinbas and Zimmerman 2003). Although this definition works well for many games, it does not necessarily cover games that lack a quantifiable outcome, such as simulation-based games, which will be relevant in later sections. This distinction will become particularly important when examining how game-

Table 2.6 Findings of the reviewed sources for section 2.3.1

Reference(s)	Frameworks/Methods	Findings/Contributions	Potential Themes
(Chou 2019a)	Chou's Octalysis gamification framework with eight core drivers.	Provides a comprehensive model emphasizing motivation through elements like progress, creativity, and social influence.	Player-centered motivational design.
(Brett et al. 2021, Gomes et al. 2016a, Raymaekers et al. 2014)	Iterative design studies and comparative analysis of gamified tools.	Highlights limitations in surface-level gamification; validates immersive and research-driven designs for skill transfer.	Depth in gamification for skill retention.
(Al-Azawi et al. 2016a, Saarikivi et al. 2020)	Review of existing music apps and game-based learning tools.	Few tools successfully align gameplay mechanics with essential skills like rhythm and notation reading.	Skill-focused game-based learning.
(Deterding et al. 2011, ?)	Critiques of superficial gamification in educational tools.	Superficial elements like badges and leaderboards lack depth, emphasizing need for meaningful, pedagogically robust solutions.	Overcoming shallow gamification pitfalls.
(Deterding 2011)	Situated gaming and psychological engagement studies.	Explores psychological drivers like curiosity and reward; critiques shallow applications in learning environments.	Embedding psychology in game design to enhance engagement.

based learning can be applied to music education and how it intersects with the interactive environments we discuss in Chapter 7.

In practice, playing a video game involves making decisions or taking actions within a structured framework: "Play is the free space of movement within a more rigid structure. Play exists both because of and despite the more rigid structures of a system" (Tekinbas and Zimmerman 2003). The key component that distinguishes a video game from other forms of play is the audio-visual apparatus: the electronic system of input and graphical devices. While many video games incorporate a story element, this is not a universal requirement

(for example, in simulators or non-narrative games). Despite this, video games generally involve simulated environments where players interact with the world according to rules and restrictions set by developers.

This foundational definition makes it easier to conceptualize and compare video games to tools categorised as 'serious games'—which, in many cases, resemble gamified learning tools more than traditional games. This distinction connects directly to the work in Chapter 4, where we explore how games can be designed for music learning, ensuring that they are both educational and engaging. Our game discussed in Chapter 6 extends this concept by focusing specifically on the intersection of game-based learning and music notation, exploring how game mechanics can support skill acquisition in a more focused and systematic way. Furthermore, as detailed in Chapter 7, the evolving design and testing of our 'Note Reader Adventure' game demonstrates how these concepts are translated into a practical tool for improving musical notation reading skills.

Differences Between Gamification and Game-Based Learning

Gamification, the idea of sprinkling game-like elements onto non-game activities, has become a popular approach in education. In music, this often translates to tools that help practice specific skills such as rhythm or scales, or work through pieces. This trend is apparent in other areas too, such as fitness applications or language learning software. The problem with these implementations is that their use of gamification often stops at the surface, adding points and badges without really rethinking how learning happens.

Game-Based Learning (GBL), in contrast, employs games as integral components of the learning process, either by designing new educational games or incorporating existing ones into curricula (Al-Azawi et al. 2016c). The key difference can be summarised as: gamification aims to transform the entire learning experience into a game, while GBL uses a game as a component within the learning process. For instance, gamification might use points and leaderboards in a practice tool such as *Piano Marvel*, relying on extrinsic motivation. However, GBL might employ a game such as *Minecraft*¹ to teach logical thinking in core subjects (Al-Azawi et al. 2016a, ?). This distinction is crucial, especially in music education, as GBL has the potential to significantly transform how musical skills are learned, acquired and retained over time; with the idea being to build positive relationships with learning and therefore encourage frequent practice.

Recent advancements have seen video games evolve into powerful educational tools. For example, *Lumosity's*² brain training games demonstrate how gamified elements can

¹<https://www.minecraft.net>

²<https://www.lumosity.com/>

enhance cognitive functions, while *Duolingo*³ leverages game mechanics to facilitate effective language learning (Saarikivi et al. 2020, ?). These examples highlight the potential of video games to create immersive and engaging environments for mastering complex skills such as music notation and rhythm. We tried to consider implementing learning into existing games but also use them as a muse or inspiration for our own games; rather than looking to how existing solutions have implemented game theory, we decided to look at how true video games encourage exploration and consistent play time.

The emergence of platforms like *Synthesia*⁴ and *Melodics*⁵ exemplifies the integration of game mechanics within music learning. *Synthesia*, often described as a "piano-hero" style experience, allows learners to follow visual prompts in a rhythm-based environment. *Melodics* emphasises bite-sized practice sessions tailored to user progression. Research-focused initiatives such as our own LUMI Keys further explored the potential of adaptive learning combined with gamified exercises, targeting foundational music theory and keyboard techniques (Saarikivi et al. 2020, ?). Despite these advancements, gaps remain in the way of addressing sustained engagement and comprehensive skill transfer, areas in which this research aimed to innovate.

Examples of GBL include using games such as *Age of Empires* to teach history or *Minecraft* for developing basic logical skills within a given context. More pragmatic examples include games specifically designed for training in medical or business contexts. GBL has several benefits:

- Problem-solving through experiential learning, not rote instruction.
- Learning through doing, where failure is an integral part of the learning process.
- Feedback mechanisms that promote self-correction and growth.
- Gradual skill development, ideal for mastering complex skills over time (such as playing a musical instrument).

While gamification is widely applied in music education, its overuse or improper application can hinder meaningful learning. For example, gamifying traditional methods often introduces superficial elements rather than transforming the learning experience. In contrast, game-based learning (GBL) offers substantial advantages in skill training, particularly when repeated exposure aids in skill retention. GBL can be highly effective for teaching musical

³<https://www.duolingo.com/>

⁴<https://synthesiagame.com/>

⁵<https://melodics.com/>

fundamentals like rhythm and finger technique by encouraging frequent practice within an engaging context.

GBL offers a more immersive alternative to gamification by integrating learning objectives into the core gameplay. While GBL is celebrated for its potential to foster experiential learning (?), critics highlight that overly game-like designs can detract from educational goals (Al-Azawi et al. 2016c). This research balances these concerns by developing games that emphasise both engagement and the structured acquisition of musical skills, as seen in prototypes like 'The Crypt of Notation'.

This research, therefore, focuses on leveraging GBL principles alongside game design techniques to develop novel solutions for acquiring keyboard skills. The goal is to create games that engage learners in ways similar to entertainment-focused video games, while also cultivating transferable skills. As discussed in Chapter 4, this process involves designing structured, flexible games that align with educational goals, while exploiting the repetitive and immersive qualities of gameplay to strengthen competencies such as rhythmic precision, fingering techniques, and music notation reading. Chapter 6 also explores how these principles were applied to the development of a game designed to improve notation reading skills—using refined game mechanics to foster deeper engagement and skill acquisition. Building on this, Chapter 7 evaluates how these design elements have been integrated into the most recent version of the game, *The Crypt of Notation*, and the impact on skill acquisition.

In Chapter 5, we further explore how game-based solutions were designed and assessed for improving music notation reading, focusing on developing games that both support foundational skill acquisition and facilitate their transfer to broader musical learning.

Linking Game-Based Learning to Notation Skills in Chapter 6

As discussed in Chapter 6, the research journey has led to a clearer understanding of how game-based learning can be effectively applied to music education. Our initial studies revealed challenges faced by beginner musicians, such as difficulty in maintaining consistent practice routines. This was addressed through a more targeted approach, focusing specifically on games that aim to improve music notation reading. The most recent findings suggest that game-based learning, as opposed to merely gamifying traditional learning tools, offers particular promise in this area. Games designed with this focus, as seen in the pilot study of the Note Reader Adventure game, not only increase engagement but also show potential for improving musical notation reading skills, as demonstrated by the significant improvements observed in accuracy and real-world application.

Thus, integrating game-based learning into music education is more than a mere extension of gamification. It represents a shift towards using game mechanics to create immersive

and pedagogically sound learning experiences that directly target musical skills, particularly in areas such as notation reading, rhythm, and finger techniques. The next sections of this thesis will detail how the insights gained from our previous studies were implemented in the design of this game, aiming to balance educational goals with the inherent enjoyment of gaming. Chapter 7 provides a detailed overview of the evolution of the game prototype and the subsequent study that tested its effectiveness in a real-world setting, highlighting how it has progressed from a basic tool to a fully developed learning environment.

This chapter also ties back to the previous work, demonstrating how lessons learned from earlier iterations of the game have led to refinements in both gameplay and assessment strategies. By bridging these ideas, we explore how game-based learning can become a powerful tool not only for skill acquisition but also for maintaining learner motivation and engagement in the long term.

2.3.3 Game Design Theories

The evolution of our understanding of game-based music learning underlined the crucial role that game design theories played in the development of our educational prototypes. These theories directly shaped our approach, particularly in crafting engaging games that effectively balance entertainment with music learning. By building upon established paradigms, we integrated key principles to enhance both the gameplay experience and the educational objectives related to music education. A central reference throughout our design process was *The 13 Basic Principles of Gameplay Design* (noa 2009), which provided a comprehensive framework of essential lessons for game development. These principles, as mentioned in Chapter 4, guided us in maintaining balance between user engagement and educational value in our game designs.

In Chapter 7, the insights from these foundational principles were re-examined, particularly in light of the findings from the longitudinal study and the iterative game development process. The game, *The Crypt of Notation*, benefited from these principles through enhanced narrative, refined gameplay mechanics, and user-centred design, which all played a role in fostering both engagement and effective music learning.

The key principles from this framework that informed our approach to game design were:

- **Direction:** Ensuring players understand their objectives at each stage of the game, thus improving accessibility and reducing cognitive load. This principle became especially relevant during the design of notation-based tasks in *The Crypt of Notation*, where the gameplay was structured to gradually introduce music notation through progressively more challenging levels, as noted in Chapter 6. The study in Chapter 7 revealed how

effective this approach was in enhancing player understanding and reducing frustration, which also supported the extended practice period in the longitudinal study.

- **Behaviour:** Structuring rewards and consequences based on the player's actions, reinforcing desired behaviours and progression. This concept was integral in our gameplay loops, where players were rewarded for mastering note reading and rhythmic tasks. As shown in Chapter 7, the game's rewarding system, which involved in-game incentives such as power-ups and progression through levels, kept participants engaged and motivated during the study, improving their performance compared to the standard training tool.
- **Progression:** Carefully pacing the gameplay to provide dynamic challenges and rewards. Our gam, discussed in chapter 6, used power-ups and experience-based progression to avoid overwhelming players while allowing them to build musical skills at their own pace. Chapter 7's findings highlighted that this principle was critical for ensuring sustained engagement over multiple practice sessions, with the game maintaining motivation and providing relief during difficult sections through balanced difficulty curves and progression systems.
- **Environment:** Designing a visually clear and navigable game world that communicates the player's actions and surroundings. This was a key consideration in *The Crypt of Notation*, where the game world needed to be both immersive and educational. Chapter 7 emphasised how the inclusion of narrative elements and supporting characters enhanced the overall usability of the game, helping to contextualise the learning environment and strengthen players' emotional investment in their progress.
- **Method:** Adhering to a structured development process to avoid arbitrary inclusion of elements. As shown in the iterative design process described in Chapter 5, and further refined in Chapter 7, this principle ensured that each design decision, from gameplay mechanics to narrative elements, was purposeful and aligned with both educational objectives and player engagement. The iteration process was critical in improving the game's onboarding experience and user interface, ensuring that all features served both the educational and entertainment needs of the players.
- **Foundation:** Establishing clear communication between the game and the player, tailored to the target audience. This principle was vital in ensuring that both novice music learners and general gamers could easily navigate the game's mechanics and narrative. Chapter 7 illustrated how the redesigned game structure, which included

a more intuitive onboarding process and tutorial elements, improved the players' understanding of the musical learning goals and the game's narrative.

Game Design Documentation and Iterative Game Development

A major aspect of this research involved understanding the game development process itself, focusing on the importance of structured design documentation and iterative cycles. Drawing from the literature (Colby 2019, Ryan 1999) and industry best practices, we followed an iterative development model involving short cycles of design, prototyping, and user testing. This model, emphasised in Chapter 5, was particularly crucial in the educational game space, as real-world feedback from target users ensures the relevance and effectiveness of game designs.

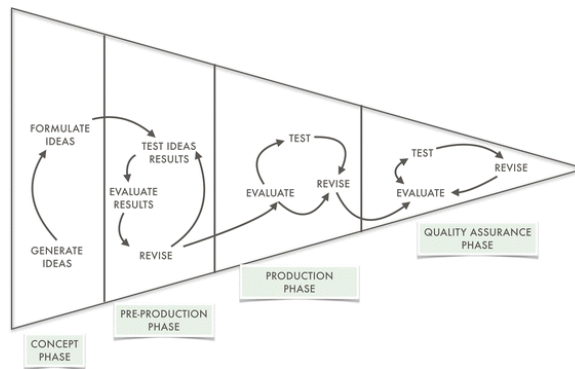


Fig. 2.3 Fullerton's Model of Iterative Game Production (Denham 2016)

As noted in Chapter 7, this iterative model was vital in addressing limitations identified in earlier stages, particularly with regard to gameplay mechanics and assessment methods. By incorporating user feedback from previous studies, we were able to fine-tune both *The Crypt of Notation's* gameplay and its assessment tools. This ensured that the final version of the game, tested through the longitudinal study, was not only more engaging but also better aligned with its educational objectives.

The iterative process followed the phases outlined by Fullerton (Denham 2016): concept, pre-production, production, and quality assurance helped us to refine the game based on feedback, ensuring that the game was both pedagogically sound and engaging. As demonstrated in Chapter 7, *The Crypt of Notation* benefited from this process, with changes made to its narrative, interface, and technical elements based on prior evaluations.

Juice

The concept of "juice" (Hicks et al. 2019) played an important role in maintaining player engagement through satisfying feedback for in-game actions. In *The Crypt of Notation*, juice in the form of visual effects (VFX) and sound effects (SFX) was thoughtfully integrated to support player motivation during repetitive tasks, such as practicing music notation and rhythmic accuracy. Games that were developed in earlier stages of research (highlighted in chapters 4 and 5) emphasised the importance of this feedback in ensuring sustained engagement during extended practice sessions, with participants expressing enjoyment in the sensory rewards, which made the learning experience more enjoyable.

However, we remained cautious not to overwhelm players with excessive juice, ensuring that the visual and auditory effects enhanced the learning experience rather than overshadowing the educational content. This careful balancing act contributed to the game's success in keeping players engaged throughout the longitudinal study, discussed further in Chapter 7.

Gameplay Loops

The core gameplay loop is essential for engaging game design. These loops involve repeated actions that players can master over time; a concept central to our design of mini-games. As explored in Chapter 6, the core loop in *The Crypt of Notation* revolved around reading and playing musical notation, which players practiced in various contexts. This loop not only facilitated mastery of musical skills but also kept players engaged by providing a sense of progression as they improved their abilities.

In Chapter 7, findings from the longitudinal study confirmed that the evolving nature of the gameplay loop helped maintain player interest. As players progressed, the loop evolved to provide new challenges, ensuring that their skills continued to develop while keeping them motivated to continue learning.

Flow and Difficulty

The principle of "flow" (Chen 2007) was crucial to ensuring players stayed engaged without feeling frustrated. To achieve this, the game's difficulty was calibrated to increase gradually, with varying levels of challenge designed to keep players within their optimal zone of engagement. As described in Chapter 6, *The Crypt of Notation* used power-ups and strategic difficulty curves to provide relief during challenging sections, ensuring a balanced and motivating experience for learners. Chapter 7 demonstrated that this approach was effective in maintaining engagement over extended practice periods, with players reporting higher satisfaction and confidence compared to the standard training tool.

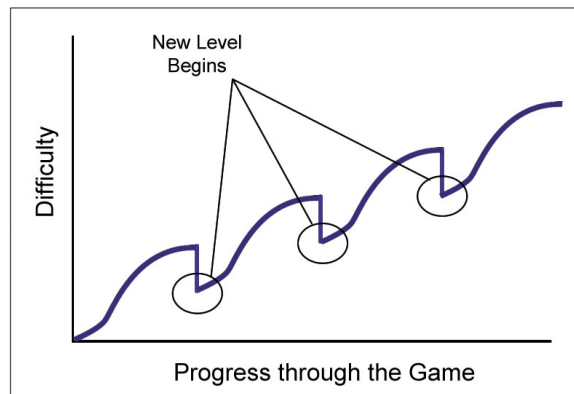


Fig. 2.4 Implementing difficulty using ‘A Series of Ascending Arcs’ (Holleman 2019)

Effective educational games maintain a balance between challenge and accessibility, aligning with Csikszentmihalyi’s flow theory (Csikszentmihalyi 1990). Poorly designed games risk losing this balance, either overwhelming learners or failing to provide adequate stimulation. This research applies principles of flow and progressive difficulty curves, as seen in prototypes like ‘Note Reader Adventure,’ ensuring sustained engagement while supporting long-term skill acquisition.

2.4 Conclusion

This literature review highlights a key reason for early dropout among adult beginner keyboardists, particularly those learning independently: the lack of fundamental skills and the resulting frustration from the perceived lack of progress despite significant effort. As stressed by beginners in literature, primary research, and personal reflections, a core desire is the ability to play unfamiliar pieces fluidly. This outcome remains elusive without musical skills, leading to further frustration when consistent effort yields minimal results. While the keyboard is a popular instrument for beginners, the learning curve is demanding, requiring substantial commitment. This, combined with a lack of engaging practice mediums, often leads to early dropout. Utilising musicianship frameworks, this research targets specific skills where novel game-based learning solutions can be most effective. By defining specific user and learner groups, these solutions are designed with a particular demographic in mind, ensuring transferable skills with real-world, long-term effects.

The second part of the literature review focused on video games and gamification, outlining a framework for later game design. A review of gamification in research and commercial settings highlights its poor implementation and shows that it is not a complete solution for gamifying learning and practice. This distinction is explored by defining game-

based learning. As explored in the next chapter, most existing solutions treat gamification as an afterthought, neglecting game-based learning in their learning or practice solutions. Consequently, this research employs game-based learning to develop novel practice solutions in the form of video games. To ensure effective concepts, an evaluation of game design theories was conducted, defining key theories used in developing engaging practice games. The aim is to create a distinct form of practice that could potentially replace other recreational activities, such as playing video games.

The next chapter, the preliminary research, systematically reviews existing solutions in literature and the marketplace. Using our own video game research, specific concerns and limitations are outlined, leading to the identification of a critical gap: a lack of solutions utilising effective game-based learning for meaningful practice that develops skills applicable to real-world applications. This gap is further emphasised by the fact that current solutions often focus on either engagement or skill acquisition, rarely achieving the right balance. This research addresses this gap in music education: the lack of comprehensive, game-based learning tools that combine immersive engagement with pedagogically sound skill acquisition frameworks. Traditional methods often rely on rote practice, while existing gamified tools prioritise superficial incentives over deeper learning. This presents a significant barrier for adult learners, especially those seeking accessible and structured ways to master foundational keyboard skills. The preliminary research also discusses initial concepts developed to address this gap, forming the foundation of this doctorate and leading to novel artifacts in the form of games and assessment methods.

In summary, this literature review has revealed a critical gap in music education: the lack of comprehensive, game-based learning tools that combine immersive engagement with pedagogically sound skill acquisition frameworks. Traditional methods often fail to engage learners due to their reliance on rote practices, while existing gamified tools prioritise superficial incentives over deeper educational outcomes. Current research-driven and industry solutions frequently focus either on engagement or skill acquisition, rarely achieving a meaningful balance between the two. This gap presents a significant barrier for adult learners, especially those seeking accessible and structured ways to master foundational keyboard skills. By addressing this gap, this research aims to create innovative game-based learning tools that align gameplay mechanics with educational objectives, targeting both engagement and real-world skill transfer. These tools are designed to offer adaptive learning pathways, immediate feedback, and immersive practice environments, thereby bridging the disconnect between current methodologies and learner needs. The subsequent chapters will detail the design, iterative development, and validation of these solutions, showcasing their potential to redefine music education for diverse learner groups, particularly adult novices.

Table 2.7 Findings of the reviewed sources for sections 2.3.2 and 2.3.3

Reference(s)	Frameworks/Methods	Findings/Contributions	Potential Themes
(Esposito 2005, Tekinbas and Zimmerman 2003)	Definitions of video games and play dynamics.	Defines video games as structured, interactive, rule-based activities with audio-visual mediums; highlights their educational potential.	Differentiating games and gamification.
(Al-Azawi et al. 2016c, Saarikivi et al. 2020, ?)	Comparative studies of gamification and game-based learning (GBL).	Highlights GBL's advantages for music learning by integrating skill acquisition with gameplay mechanics like rhythm practice.	Transformative potential of GBL.
(Denham 2016)	Iterative game development and design frameworks.	Fullerton's model of iterative development ensures alignment between game mechanics and educational goals.	Iterative design for skill-focused games.
(Hicks et al. 2019)	Concept of "juice" in game design.	Enhances player engagement through satisfying audio-visual feedback while avoiding overstimulation.	Sensory feedback for sustained engagement.
(Chen 2007, Csikszentmihalyi 1990)	Flow theory and difficulty calibration in games.	Balances challenge and accessibility to keep players engaged and motivated, avoiding frustration or boredom.	Balancing difficulty for optimal flow.
(Holleman 2019)	Difficulty progression using ascending arcs.	Progressive difficulty keeps learners engaged by gradually increasing challenges while maintaining accessibility.	Gradual skill development in gameplay.

Chapter 3

Preliminary Research

3.1 Chapter Introduction

This chapter explores the potential of game-based learning tools to enhance the acquisition of music notation reading and keyboard skills, and the methodological approaches used to address conflicting viewpoints in the literature. Specifically, it reconciles debates surrounding the limitations of rolling-note systems and the motivational potential of gamified learning tools. Rolling-note systems, while effective at reducing cognitive load for beginners, have been criticized for fostering dependency on visual aids and impeding skill transfer to traditional sheet music reading. Similarly, game-based learning tools have faced scrutiny for prioritising engagement at the expense of educational depth. This research addresses these gaps by integrating principles of gamification with established pedagogical frameworks to develop tools that enhance learner engagement while fostering meaningful skill acquisition. Through iterative design and evaluation, the developed solutions aim to balance accessibility and depth, making them particularly suitable for adult learners who face high dropout rates in traditional music education settings. The chapter outlines the steps taken to design, develop, and validate these tools, providing a foundation for their application in real-world music education contexts.

It highlights key research questions and objectives that frame the broader discussion on the effectiveness of these tools compared to traditional methods. The questions under consideration include:

1. Can a game-based approach improve the skill of reading music in real-world settings compared to traditional tools?
2. How do factors such as practice environment, frequency, technique, feedback, and individual differences affect long-term retention of music notation skills?

3. Are game-based tools more engaging than traditional learning methods?

These questions are central to evaluating the viability and effectiveness of game-based learning in music education. By examining the impact of game-based approaches on skill acquisition and learner engagement, this chapter seeks to determine whether they offer advantages over traditional methods in fostering sustained learning and practice. Chapters 5, 6, and 7 will delve deeper into these questions, presenting findings and exploring their implications for music education.

The integration of technology into education has transformed how students engage with learning materials, including music education. Game-based learning tools, which combine elements of play and pedagogy, hold promise for revolutionising skill acquisition in domains requiring repetitive practice. Although significant research has focused on the application of game-based learning in general education, its use in specialised fields like music education, particularly for improving foundational skills such as music notation reading and keyboard techniques, remains underexplored. Addressing this gap involves assessing whether such tools can mitigate the tedium often associated with traditional rote practice and improve learner persistence, especially among adult casual learners who frequently drop out during early stages of learning.

Learning and retention in music education is critical – identifying the barriers is equally as important. Common things beginners hate to do include repetitive tasks, for example, mastering music notation and keyboard techniques. Theories behind gamification and game design offer a framework for addressing these issues, not just in the way a class might be structured, but in development of the actual game itself, an approach which enhances the skill of the learner and their engagement while facilitating their meaningful practise. However, existing gamified tools, including those using rolling-note methods as well as other learning applications, often do not strike a balance between the responsiveness of video game style interaction and the serious practise of foundational skills. This disconnect is a key element in the need for new approaches that enable skill transfer to real world settings.

Different ways to bridge this gap have been approached in innovative prototypes. Beginning with VR and AR applications created for innovative ways to increase engagement; early iterations of game-based music learning tools developed alongside our industry partner, ROLI's Lightpad M offered tools for players to work with music and interact by littering virtual space with loops and sounds, drum kits and synthesisers all to stimulate creativity. Yet learner feedback, as well as educational theories, emphasised the importance of developing tools that are better attuned toward learning existing musical pieces and building a musical repertoire. These findings thus motivated transitions in the game-based design principles towards more structured practise focused designs.

Notable advances in technology have made it easier and more effective to use music learning tools. As an example, the integration of Leap Motion technology supported hand tracking to interact with a virtual keyboard to enhance the immersive practise experience for learners. We considered going further by adding AI avatars and connections with real world tutors that became particularly pertinent during the COVID-19 pandemic. Similarly, the mandated products like the LUMI keyboard alongside attached mini games showed how gamified instruments could fuse structured learning with entertaining playing mechanics.

Despite these advancements, existing solutions often fail to validate their effectiveness in practical contexts, relying on assessment methods that lack rigour or applicability to real-world music learning. Developing robust assessment frameworks and principles for designing impactful, transferable game-based tools remains an essential goal for researchers and developers. The challenges of VR and AR implementation, combined with the need for practical, engaging solutions, have informed the creation of mini-games and repositories aimed at supporting future innovations in music education.

By addressing the outlined questions and challenges, this chapter aims to provide insights into how game-based learning tools can complement and enhance traditional music education methods. It also offers principles and frameworks for designing tools that not only engage learners but also ensure the meaningful transfer of skills to real-world applications. Chapters 5, 6, and 7 will further analyse these principles, detailing case studies and providing a thorough evaluation of the potential for game-based learning to transform music education.

3.2 Justification of Methodological Approach and Addressing the Research Gap

The proposed methods across Chapters 4, 5, 6, and 7 aim to address the gap that has been proposed prior by systematically exploring how gamified tools can transform the music learning process. The studies in Chapters 4 and 5 provide initial, complementary approaches to understanding the impact of game-based tools on foundational skills. These chapters focus on key areas such as mitigating dropout rates, balancing educational value with entertainment, and iteratively developing tools that cater to both pedagogical goals and user engagement. Chapter 4 employs observational methods and user feedback to evaluate whether gamified mini-games can make the process of music notation reading more enjoyable and less monotonous for beginners. The emphasis here is on understanding the initial user experience and ensuring that the tools are appropriately challenging without becoming

overwhelming. This exploration is pivotal because it identifies how gamified experiences can not only support skill acquisition but also foster motivation and persistence.

Chapter 5 then refines these evaluations by introducing more rigorous measurement tools, including the Player Experience of Need Satisfaction (PENS) questionnaire and standardised assessments of engagement. These tools allow for a more precise analysis of how well the game balances entertainment with educational objectives. The integration of both qualitative and quantitative data ensures a comprehensive evaluation, which helps inform the design of gamified tools that can seamlessly embed learning goals within an engaging experience. Furthermore, this chapter's findings address an essential aspect of game-based learning - ensuring that the learning experience remains user-centred and adaptable to various skill levels, which is crucial for broadening the tool's applicability and enhancing its overall effectiveness.

The iterative development methodology highlighted in Chapter 4 also plays a critical role in addressing this research gap. The focus on testing and refining core gameplay mechanics before committing to complex game assets ensures that the game's design evolves based on user feedback, avoiding potential usability pitfalls. This approach not only enhances the educational value of the tool but also ensures that it remains technically feasible and scalable, which is vital for real-world application. The careful consideration of engagement metrics and usability concerns throughout the design and testing phases ensures that the final product can be effectively used by a wide range of learners, from novices to those who have lapsed in their music education.

Building on this foundation, the pilot study described in Chapter 6 takes a more focused approach to evaluate the pedagogical effectiveness and user experience of a specific game-based learning tool for music notation reading. This study is essential for testing whether a game-based tool can match or surpass traditional methods, such as flashcards or other notation practice tools, in terms of skill acquisition. By comparing our own developed game with a standard practice tool, the study aims to provide reliable data on whether gamified learning can offer the same or better results for adult learners. Additionally, the inclusion of a diverse participant pool, ranging from novice to experienced learners, ensures that the game's applicability is tested across various skill levels, further strengthening the potential for real-world adoption.

Chapter 6 also emphasises the importance of engagement and usability, crucial factors for adult casual learners who often struggle with persistence. The study's methodology, incorporating both observational methods and surveys, helps to ensure that the game's design is intuitive, enjoyable, and able to maintain learner engagement over time. This aligns with the overarching goal of the research: to explore whether gamified learning tools can break

the cycle of dropout and frustration commonly associated with traditional music education. By focusing on adult learners, the study ensures that the findings are directly applicable to the target demographic most likely to benefit from such tools.

In Chapter 7, the methodology takes the next step by introducing a longitudinal approach, allowing for a deeper exploration of skill retention and application over time. This study moves beyond short-term engagement and assesses the lasting impact of game-based learning on skill development and retention. By incorporating both skill acquisition and skill application tests, the study provides a comprehensive assessment of how well learners can transfer their newly acquired knowledge into real-world music performance. The inclusion of post-session surveys measuring engagement, motivation, and confidence further deepens the understanding of how game-based learning influences not only skill development but also the broader psychological factors that contribute to sustained learning and persistence.

The methodologies described in these chapters are crucial for addressing the research gap in game-based learning for music education. By systematically testing the efficacy of gamified tools in improving foundational skills like music notation reading, these studies offer valuable insights into how technology can enhance music pedagogy. The research not only explores the potential of game-based tools to engage and motivate learners but also examines how these tools can provide an alternative to traditional methods that may be less effective for adult learners. However, before we reached this stage, we had to understand which games and styles of teaching were most impactful for our target learner types. We began by developing a host of various game concepts which would later be integrated into a bespoke hardware solution (the *LUMI* keys, outlined in detail below). This preliminary research concluded with the need for a more detailed methodological approach that would help us answer the key research questions divulged in prior chapters and sections. The research, as illustrated in this section, was an iterative process that helped us create concepts and methods that would have an impact on the wider domain of music learning for both researchers and educators alike.

The methodological approaches in this research directly address the gaps and challenges identified in the literature review. Traditional music education methods, including rote practice and rolling-note systems, have been effective in building foundational skills but often fail to sustain learner engagement. Conversely, gamified tools excel in capturing interest but may lack the rigor required for meaningful skill acquisition. This research adopts an iterative development methodology to reconcile these conflicting approaches. By embedding structured learning objectives into engaging game mechanics, the tools developed in this study strike a balance between entertainment and education. For example, the "Maze Runner" game integrates triad formation into navigation mechanics, ensuring that

the gameplay directly reinforces musical concepts. User feedback and performance data collected during early prototyping phases informed design refinements, addressing usability concerns while maintaining pedagogical goals. This iterative process ensured that the tools were appropriately challenging without becoming overwhelming, a critical factor for adult casual learners. By systematically addressing these issues, this research provides a novel framework for using game-based tools to enhance foundational music education.

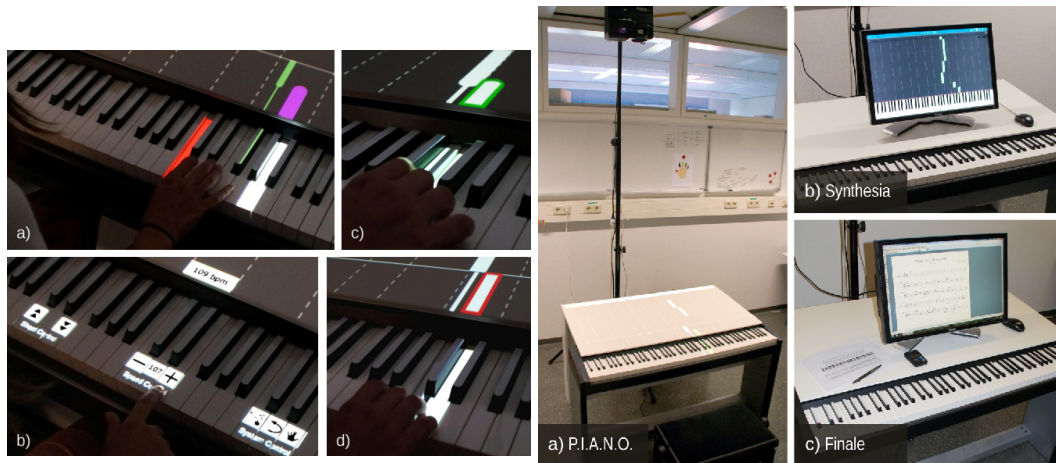
3.3 Existing Solutions

This section examines existing solutions from both the literature and commercial applications that address challenges in music learning, focusing on gamified approaches. By reviewing the "rolling style" notation and associated learning applications, we have evaluated their contributions and limitations in developing gamified practice tools targeting specific skills. Additionally, this review identifies the lack of game-based solutions for fundamental music skills, particularly for adult beginners, emphasising the necessity for gamified designs that foster engaging and transferable learning experiences. As highlighted from the findings in Chapter 6 and Chapter 7, integrating engaging game mechanics with educational content is critical for fostering consistent practice and skill acquisition. The successes of gamified solutions in domains such as language learning, typing, and fitness (detailed further below) provide critical insights for advancing music education tools tailored for novices.

3.3.1 Rolling Note Style and New Technology

As highlighted by the desires of the particular demographic this research is targeting, novices and lapsed learners, learning to play a piece of music was paramount. Whilst traditionally, one would study reading musical notation and learn to play a piece by reading its notation, modern solutions have attempted to reduce the cognitive load and stress of this task by digitalising reading music. This typically takes the form of a 'rolling note' style graphic in which learners simply hit the keys when instructed or follow lights on a keyboard (made popular by (Casio 2020)). One notable implementation, developed by Rogers et al. (2014), projected graphical notation onto a screen in front of a piano, guiding learners on which keys to press and providing performance feedback. Users reported a positive experience, with reduced cognitive load during practice sessions. However, as identified in Chapter 4 and reinforced by findings in Chapter 7, this method's reliance on an alternative notation system may hinder learners' ability to transition to traditional sheet music. Moreover, the short duration of studies like these limited insights into long-term engagement and the transferability of skills

to broader musical contexts. These concerns align with the methodological approach and findings outlined in Chapters 6 and 7, where the necessity for tools that internalise rhythm and promote long-term skill development was underscored.



(a) The P.I.A.N.O system in action

(b) The P.I.A.N.O system used in testing with Finale and Synthesia as comparison applications

Fig. 3.1 The P.I.A.N.O system overview and study comparisons. Evaluating a solution reliant on notation versus one that uses visual cues highlights disparities in usability (Rogers et al. 2014).

A similar system, developed by Raymaekers et al. (2014), employed scrolling graphical notation with a shooting game mechanic to sustain user engagement. Although participants responded positively, the system faced challenges, including confusion among experienced pianists and difficulty for beginners in keeping pace. As discussed in Chapter 5 and evaluated further in Chapter 7, such findings underscore the importance of balancing complexity and accessibility in gamified tools. Moreover, while these systems encourage practice, they often fail to encompass the depth of skills necessary for musical mastery, such as interpreting musical nuances and emotional expression. As Chapter 6 and Chapter 7 emphasize, designing systems that incorporate emotional expression, rhythm, and cohesive performance is essential for bridging the gap between gamified tools and holistic musical education.

The rolling-note style bears similarities to typing games like TypingClub¹, where users follow visual cues to type accurately. These systems, while engaging, have been critiqued for fostering dependency on visual aids, potentially limiting skill transfer. Lessons from typing games suggest that integrating auditory feedback and gradually reducing visual dependency could enhance skill internalization in music education. This approach is similarly reflected in the *Note Reader Adventure* pilot study described in Chapter 6 and the more refined version,

¹<https://www.typingclub.com/>

The Crypt of Notation, detailed in Chapter 7. These iterations integrate rhythm and note-reading into gameplay, encouraging internalisation through repeated exposure and auditory reinforcement.

Advances in AR/VR solutions, such as the "HoloKeys" system (Hackl and Anthes 2017), have introduced immersive experiences, allowing learners to practice on any keyboard using AR headsets. Products like the Oculus Quest (Meta 2020) demonstrate potential for enhancing accessibility and engagement. However, as discussed in Chapters 4 and 7, these technologies often fall short in capturing the deeper aspects of musical learning. For example, they focus primarily on sequential note-playing, neglecting broader skills like integrating emotional expression and cohesive performance. As we divulge in Chapter 6 and later reinforce in Chapter 7, addressing these gaps requires systems that prioritise developing rhythm, tone, and musical interpretation alongside technical skills; interweaving game mechanics and the core musical skills that are build the foundation of playing an instrument is a tricky but important balance to strike.

3.3.2 Insights from Other Gamified Domains

The application of gamification in fields such as language learning and typing has yielded valuable insights for music education. In language learning tools like Duolingo, users are motivated by game-like elements such as points, levels, and rewards, which promote consistent engagement and incremental progress. Similarly, typing practice games use mechanics that encourage repetitive, low-effort practice to improve speed and accuracy. These principles align with the iterative development approach described in Chapter 6 and demonstrated in the longitudinal study of "The Crypt of Notation" in Chapter 7, where games were designed to isolate specific skills while maintaining user motivation through progressive difficulty and engaging gameplay. While rolling-note systems and gamified music applications offer engaging avenues for practice, they must address the deeper complexities of musical learning to achieve sustained effectiveness. Chapters 6 and 7 underscore the importance of leveraging game mechanics to internalise musical skills, such as reading notation, rhythm, and audiation. The findings from the *Note Reader Adventure* pilot study and the refined *Crypt of Notation* highlight how integrating narrative elements, dynamic feedback, and skill progression can enhance both engagement and learning outcomes.

3.3.3 Market Research

The landscape of digital learning platforms reveals a complex relationship between technological innovation and educational effectiveness. As learners seek engaging and personalized

learning experiences, diverse application domains offer insights into designing more compelling educational tools. We explore how different different platforms, ranging from language learning to fitness tracking and music applications, have approached the challenges of user engagement, skill acquisition, and motivation.

Language Learning Platforms

Platforms such as Duolingo ² have been particularly effective in engaging learners by using streak systems, adaptive difficulty, and small, achievable goals. These elements help maintain user interest and motivation by providing consistent feedback and reinforcing a sense of accomplishment. For example, streaks reward consistent daily practice, while gamified levels and challenges keep learners striving for improvement.

In keyboard learning, similar mechanics could be applied by tracking streaks for consistent practice of scales or pieces and introducing adaptive challenges that respond to the learner's current skill level. For instance, if a learner struggles with specific chords or timing, the application could automatically adjust lessons to focus on these weak points. These paradigms were often consulted during the development of LUMI (see more details below) as such mechanics and existing solutions were proven to retain users over long periods of time.

Fitness Applications

Fitness apps such as Strava ³, Fitbit ⁴ and Zwift ⁵ have successfully integrated social competition and milestone achievements to encourage users to stay active. These platforms leverage leaderboards, challenges, and goal-setting to make repetitive physical activities engaging. Translating this approach to music learning, a platform could incorporate challenges such as "Play 10 Perfect C Major Scales This Week" or "Learn the First 8 Bars of a Popular Song." Social features, such as sharing progress or competing in friendly challenges with peers, could further increase engagement. During the development of LUMI, we often looked at Peloton as a flagship name ⁶ in which we based our landing screen on (it encourages repeat users by tying personal achievement and competition with others).

²<https://www.duolingo.com/>

³<https://www.strava.com/>

⁴<https://community.fitbit.com/>

⁵<https://www.zwift.com/uk>

⁶<https://www.onepeloton.com/en-GB>

Table 3.1 A Cross-Domain Comparison of Gamification Techniques and their Potential Adaptations for Keyboard Learning

Domain	Gamification Strategies	Lessons for Keyboard Learning
Language Learning	Streaks, adaptive challenges, rewards	Track streaks, adapt difficulty, reward milestones.
Typing Practice	Feedback, drills, progress tracking	Real-time errors, isolate weak skills, track progress.
Fitness Training	Social challenges, milestones	Leaderboards, challenges, rhythm battles.
Music Education	Lesson progression, gamified drills, scoring	Gamified rhythm drills, sight-reading, ear training.
Video Gaming	Narrative progression, immersive experiences	Unlock pieces, create narrative paths.

Music Applications

To gain an understanding of the breadth of the musical applications on the market, a systematic review of popular music applications was conducted to help decipher why users disengage quickly with them and how game-based solutions could help fill the gap (or at least help to further research and development into extending learning of adult beginners). Each application was reviewed based on five core concepts of the definition which was believed to be most appropriate for the core goal. These were: amount of enjoyment, using Fu et al. (2009)'s definition which comprises of concentration, immersion, goal clarity, challenge and feedback; also using theories of flow (Chen 2007, Johnson et al. 2018). The other criteria included pedagogical value (i.e., how much each application offered to a beginners learning and how meaningful it was to real-world applications), skill required (how versed a user needed to be with the software or application to use and understand it), complexity (i.e., usability) and time spent (i.e., how much time was needed to be spent to learn something valuable). The reviewed applications fit into specific categories and are designed to cater to various types of users. These categories were: professional, educational, and gaming. Professional applications included DAWs and synthesisers which offered little educational value and were used by specific individuals who were prosumers and not casual learners. Educational applications were essentially designed to be educational and teach users a specific instrument, music theory or how to create music. Finally, gaming applications were games which had a heavy feature of music or were rhythm-based; whilst they focused on music, they offered little to serious learning.

Professional applications were not suitable for the purposes of learning and few lessons would be gained in reviewing them further. The music games that were reviewed, in which a full list is made available in the Appendix, were highly enjoyable and played by a large audience but lacked little, if any, educational value. The 'musical learning applications' that were reviewed (Eli 2016) are designed to try and meet the needs of each one of the core concepts outlined. The history of this style of learning is rather old and originally took the form of CDs which could be on a PC. These solutions comprise of a series of lessons, typically a tutor would deliver learning content whilst demonstrating this on a piano with

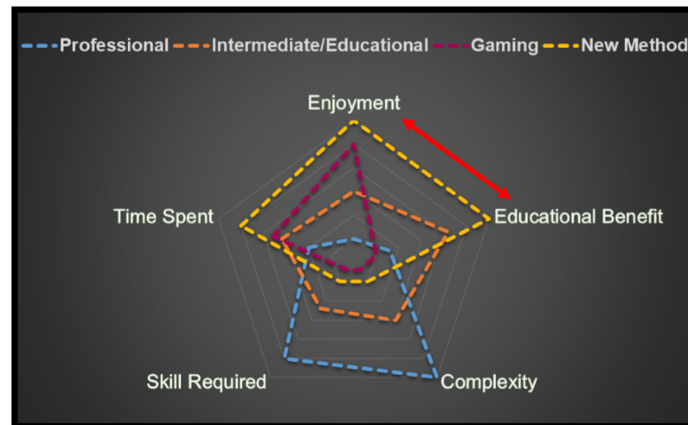


Fig. 3.2 The five key points of assessment: the solutions should cater to all criteria with a focus on educational benefits and enjoyment or engagement

the inclusions of specific pieces to practice, and the student follows along each lesson and progress over time. In the modern day, with the use of mobile devices, this style of teaching has been adopted in mobile application form. The concept stays relatively the same in that a series of lessons are followed by a learner, albeit, with more complexity by incorporating gamification (leaderboards, badges and points). Whilst these learning applications do offer rich learning in the form of lessons and interactive exercises, the problem still persists, as learners struggle to get past a certain point because they lack either the skill or knowledge to do so. They essentially ensure the first few hours are interesting and rewarding for the user by offering them simple tasks which provide high reward with low cost but once a certain point is reached, users lose interest and begin to feel frustrated as either the applications' content becomes too difficult, or remains too easy and lacks gratification. A final issue that was discovered with learning applications was their target demographic. Typically games, and generally any other software tools, are developed with a specific demographic in mind and will typically run user testing with these audiences to ensure that they will be able to retain them with specific design and mechanic choices. As the learning applications attempt to appeal to such wide audiences, it makes it difficult to pin point a specific target demographic, thus leading to difficulty in retaining any audience at all (as highlighted by (Bobbe et al. 2021)).

3.3.4 Solutions Tailored For Skill Acquisition

Current music learning applications often struggle to address specific skill acquisition needs for casual learners. Existing solutions on the market, including ear, rhythm and sight reading trainers (ABRSM 2018b, Ltd 2022, Pesek et al. 2020, ToneGym 2018), typically provide

functional or somewhat gamified approaches. However, these applications frequently fail to integrate gamification thoughtfully, often merely adding superficial elements such as leader boards and levelling systems without fundamentally reimagining the learning experience.

Although such training tools can be effective for highly motivated learners already passionate about their instrumental journey, they quickly become mundane and uninspiring for casual and independent learners. This gap in the market represents a significant opportunity for innovative educational technology that can merge meaningful skill acquisition with engaging gameplay mechanics.

Drawing inspiration from successful approaches in other learning domains, potential solutions emerge. Language learning platforms like Duolingo (mentioned previously) demonstrate the effectiveness of spaced repetition algorithms in reinforcing memory, a technique that could be elegantly adapted for keyboard skill development. By scheduling progressively challenging exercises that revisit complex concepts at strategic intervals, learners could internalize intricate musical elements such as chord progressions and rhythm patterns more naturally.

The world of typing practice offers particularly compelling parallels. Platforms like Typing Club⁷ and Epistory (Cactus Fishing Cactus) have successfully integrated immediate feedback, targeted skill drills, and comprehensive progress tracking to enhance typing fluency. These mechanics could be directly translated to keyboard learning, providing real-time corrections during scale and song practice, creating focused exercises that isolate specific technical weaknesses, and visualizing improvement to foster a sense of achievement.

Adaptive systems, exemplified by fitness apps such as Fitbit, further illuminate potential design strategies. By dynamically adjusting challenges based on individual performance, such an approach could ensure that keyboard learning remains simultaneously achievable and motivating. An application might, for instance, generate targeted mini-games that focus on sections where a learner consistently struggles, transforming frustrating technical challenges into engaging interactive experiences.

The social dimension represents another promising avenue for innovation. Just as fitness and gaming apps leverage collaborative and competitive features, a keyboard learning platform could incorporate virtual ensembles, rhythm challenges, and community-driven interactions. This approach could metamorphose what is traditionally a solitary practice into a vibrant, shared learning experience.

The research and marketplace currently lack comprehensive solutions that genuinely attempt to merge substantive video game experiences with meaningful musical skill acquisition. By drawing insights from successful learning technologies across diverse domains, it

⁷<https://www.typingclub.com/>

becomes possible to envision a new generation of music learning applications that are not just tools, but truly transformative educational experiences. To sustain learner engagement, the developed games throughout this research incorporated features such as incremental challenges, narrative progression, and immediate feedback. For instance, the "Maze Runner" game uses triad formation as a mechanic for navigation, blending educational value with interactive gameplay. These features respond directly to the conflicting demands for engagement and rigor identified in the literature review, providing a balanced approach that supports both motivation and skill development.

Literature Examples and New Technologies

There are some particular use cases of training tools that make use of gamified learning in some capacity within research. Typically, these solutions focus on three key skillsets: ear training (audiation), rhythm or reading notation (often labelled as 'sight-reading trainers'). One such example is Troubadour (Pesek et al. 2020), a gamified platform for ear training purposes. The platform was developed to support music theory classes at music conservatories. Essentially, the application is a series of ear training exercises displayed in a graphical and colourful fashion. The gamification includes achievements, badges and a progressive skill level which can be compared to other students on the application (using leaderboards). Whilst the use of gamification is substantial, this had little effect on the longevity of the use of the application; participants rarely played the game for more than a day or so at a time and whilst they would recommend to other learners, this was in the context of an academic setting (not representative of casual learners). There is a lack of solutions that cater to casual learners, as most research (Wang 2022a) focuses on existing students who are already enrolled in a school. Furthermore, the literature that was found is particularly concerned with younger audiences, typically those who are in primary or secondary school, with a lack of research for motivating adults using gamified tools. Thus, there is a gap in the literature which dedicates itself to using game-based learning to increase the rate of practice, helping to lower the dropout rates observed, in particular concern to adult, independent and casual beginner keyboardists. Beyond music education, gamification in other domains has showcased effective methods to sustain user engagement and skill retention. For example, Troubadour (Pesek et al. 2020) shares a similar use of gamified elements with language learning platforms, but the latter employs adaptive algorithms to keep learners in an optimal challenge zone. Translating this to music practice could involve dynamically adjusting lesson difficulty based on a learner's progress or even integrating AI-driven feedback to offer personalized tips.

3.4 LUMI Emerges

Whilst VR and AR allowed helped to create novel solutions for helping to play musical pieces or even for the sake of pure enjoyment in regard to music education, it was apparent that it would not be a particularly viable avenue due to inaccessibility of both cost and setup whilst also not fitting the company's ecosystem – offering rather complex solutions to absolute beginners was not a great method to increase onboarding rates. Based on these limitations and insights, which pointed towards beginners desires to play musical pieces more than create their own music, the company pivoted to creating combined hardware and software solutions that targeted purely mobile devices – eventually developing the LUMI (ROLI 2021) and consequent learning application also dubbed LUMI. The LUMI Keys is a 2-octave range MIDI keyboard in which the keys can be fully illuminated with any RGB colour. The keyboard uses DNA connectors (ROLI 2018b) which allows for multiple LUMIs to be connected to one another or any of the BLOCKS ecosystem. The keyboard offers per-key pitch bend and polyphonic aftertouch. It connects to any operating system using either USB or Bluetooth, in which the primary use was to connect it wirelessly to mobile devices which would run the LUMI learning companion application. The LUMI application is a suite of lessons and practice tools whilst also offering the rolling note style of playing. The application is one of the most graphical designs in this area and attempts to push the boundaries where other learning applications had not. The software and hardware combination is quite rare and is a somewhat novel approach to learning keyboard and whilst other keyboards and electric pianos had used light up keys to assist learning (Group 2019), LUMI was the first to make use of fully illuminated keys in any colour – using equivalence based learning theories to help reinforce the relationship between colour and sound.

However, the key issue still remained that beginner learners will eventually taper off and it was established already that the method of learning to play songs by following lights or actions was not ideal. The LUMI ecosystem was designed to make onboarding more approachable and easier for beginner keyboard learners but eventually would teach them how to play musical pieces purely from sheet music – the light up keys and rolling notation were simply a way to entice learners and increase their onboarding satisfaction. Combining the research issue of high amounts of beginner drop off with the need to increase retention within the LUMI application, practice games were developed which would either work alongside or within the application; the hope was to create a platform of practice that would encourage learners to persist beyond the beginning stages of their learning journey and return to the learning application. The games were considered as either a reward for learners who had completed a lesson or a song whilst also being a way to reinforce particular skills and knowledge related to their recent lessons, for example, a practice game that could help

reinforce the relationship between a physical key and the name of a specific note (later relating this to a note on a musical staff).

3.4.1 Practice Games Using New Technology For The LUMI Application

The developments began by looking towards using VR and AR for the purposes of practice alongside the LUMI learning application. Although limitations were considered, it was deemed more appropriate to build VR/AR practice games and tools as it was not the sole hardware beginners would purchase but an add-on that could make use of learners who already had access to VR technology. Furthermore, it would help the LUMI system stand out amongst the many other learning tools and software that were already found in the marketplace – at the current state of writing, there was nothing similar to be found in the marketplace at this stage. A small selection of practice games using mostly VR hardware were developed with additional investigations into how AR could be used, and the potential it had for future iterations. Using the research’s definition of musicianship, specific skills were chosen to build practice games around. These included practicing reading basic notation, basic rhythms, recognising pitches and patterns (audiation) as well as executive functioning skills, mostly relating to hand and finger skills.

For the most part, the HTC Vive was used (HTC 2016) for the VR prototypes whilst later developing for the Oculus Rift (Meta 2020). The HTC Vive was chosen as it is considered somewhat of the ‘gold standard’ for VR and its capabilities did not limit ideas, allowing development of what was deemed appropriate for this level of research. The Oculus was later used for portability and cost related reasons - being a lot more accessible, not requiring a high-performance PC to run and considerably cheaper meant it was a lot more appealing to the target population. All of the VR and AR prototypes were developed using the Unity Engine with C#. For the AR solutions, a Microsoft HoloLens was used (Microsoft 2020), which had also been used in other research (Rigby et al. 2020), mostly because it was one of the few AR headsets which had the capability required – a high enough field of view and the ability to run third-party developed applications. The majority of the AR headsets were not nearly as robust and their lack of documentation meant it was incredibly tricky to develop for. The exploration of AR solutions was only on a surface level as the technology was not advanced enough at the time to actually develop meaningful and market standard games or applications.

A notable mention was a VR game which intended to help beginners improve their overall sense of rhythm and understand different styles of rhythm found across genres. The game

LUMI KEYS SPECIFICATIONS

Keys: 24 full spectrum illuminated keys featuring ROLI Brightkey™ technology.

Key Size: DS 5.5°, 9.67mm wide high keys, 19.4mm wide low keys

Key Plunge: 10mm, 92% plunge distance of a grand piano

Octave Range: 2 octaves with octave shift buttons for a full 7 octaves

Modular Design: 8 DNA connectors for connecting additional LUMI Keys or ROLI BLOCKS

Battery: Rechargeable Lithium battery (2,300 mAh) for 6 hours of fully illuminated playing. 4-5 hours charge time.

Connectivity: Bluetooth 5.0 and USB-C port (MIDI out and power)

Bluetooth Range: 15 meters (50 feet)

Dimensions: (L x W x D)
282mm x 141mm x 27mm
(11" x 5.5" x 1")

Expressive Performance: pressure responsive keys featuring Polyphonic Aftertouch

Weight: 600g (1.3lbs)



Fig. 3.3 The 'LUMI' specification used in the Kickstarter campaign

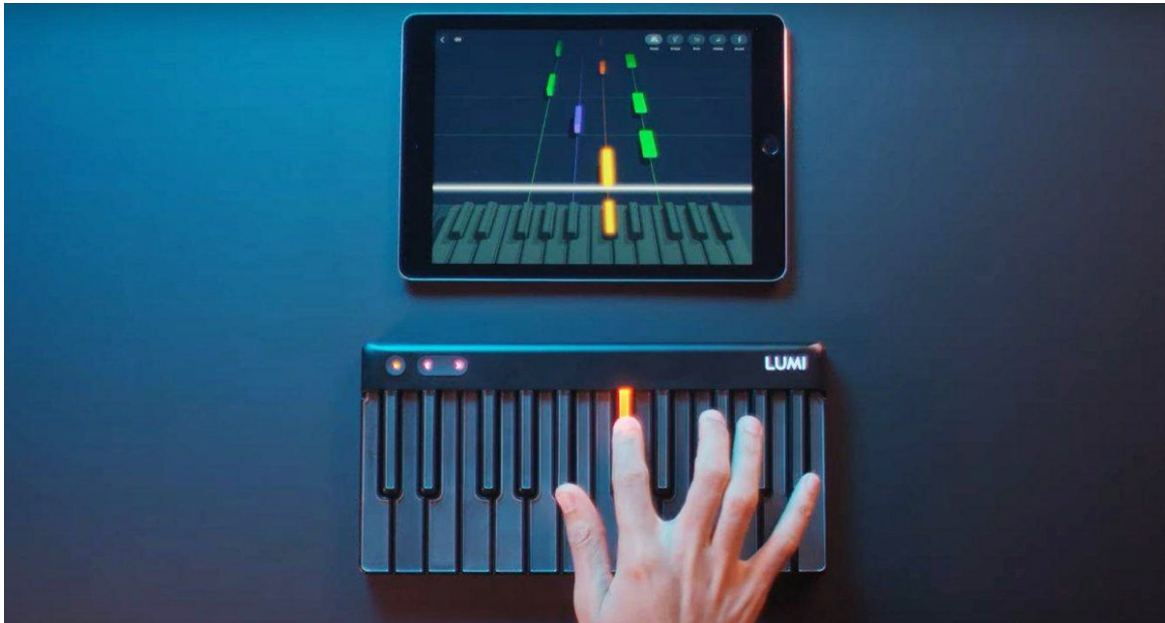


Fig. 3.4 The 'LUMI' keyboard and companion learning application in which a user plays through a song using 'rolling notes'

was inspired by other rhythm games which were developed for VR, specifically, games and Fitterer. There were discussions around whether or not this research should focus solely on the development of rhythmic skills for beginners and consider using pre-existing video games and the custom solutions to determine how useful they would be for real world applications of playing keyboard and piano; future chapters delve into why this option was not chosen for this research and why the choice to investigate reading musical notation was investigated instead. The game placed learners within a graphical tunnel in which animations flashed to the beat; blocks would spawn from the start of the tunnel and move towards the player where the player had to smash them with their controllers or hands. The difference in this game and the market place ones was that there was a focus on specific rhythms, for example, 4-4 time which was believed to have more real-world application to playing keyboard and piano.

Using VR and motion controllers was an insightful endeavour but there was a desire to incorporate the LUMI into the solutions, considering that these practice games were supposedly working alongside with the LUMI ecosystem. Therefore, the Leap Motion (Sharma et al. 2018) was implemented to develop further solutions which were adopted from similar literature (Das et al. 2017). In his work, a HoloLens is used in conjunction with a Leap Motion in which graphical notation is displayed and players can use their hands to play physical keys when the note visuals approach the specific keys. Whilst his work was novel,

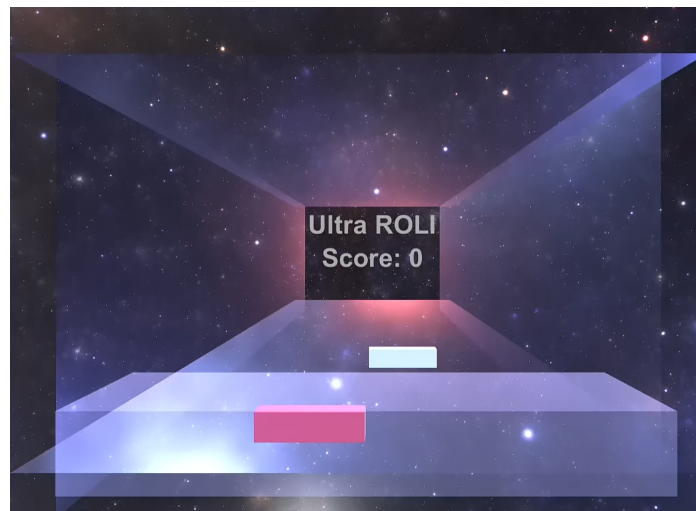


Fig. 3.5 ‘Ultra ROLI’, a VR rhythm game in which players must hit blocks using motion controllers to a set tempo and time signature (in this case, 4-4 time)



Fig. 3.6 Various hardware which was used for the AR and VR developed solutions

there were limitations, which include the accessibility of this hardware to a greater audience as well as real world applications of such technologies.

There was a desire to extend these solutions and attempt to track individual fingers in which an AI system could watch and teach learners what fingers and hand shapes were most appropriate for specific parts of songs. Tracking whole hands was easy but the Leap Motion was not robust enough to track individual fingers on a level of specificity that was required, not only this but it was difficult to get the hand tracking consistent when playing – often losing tracking altogether. Later, a developed solution managed to track the LUMI within a virtual space using Vive trackers (HTC 2020), which are physical trackers that can be attached to objects to track their position and orientation in real time. The solution tracked the hands above the keyboard so users could feel a physical keyboard and also see it in real time within the virtual world; a key issue that was discovered with VR solutions was the lack of tactile feedback as most solutions used virtual instruments.

3.4.2 Limitations Of New Technology

Of course it is — educational use of XR technologies has gone from strength to strength, through augmented reality (AR), virtual reality (VR) and mixed reality (MR). The applications of these are in delivering immersive and interactive learning experiences, and given how skills training (such as in music education, fitness, language acquisition and business training) lends itself to such. In this section we provide a review of the state of the art in XR learning games, covering their applications, strengths and weaknesses in various domains.

XR technologies have been used in music education to develop interactive environments that provide learners opportunities to practise skills such as notation reading, rhythm training and pattern recognition. AR applications like those discussed in (one from ZarApps 2022), for example, add virtual sheet music to a physical keyboard so that learners can visualise and connect theoretical knowledge to physical action. Platforms developed for use of VR, including Melody VR (MelodyVR 2023) and Virtuoso (VR 2020), let learners play with virtual instruments in a realistic musical environment. Indeed, as we describe in the literature review and subsequent chapters, these tools have common limitations such as a lack of hand tracking and cumbersome hardware requirements. For example, the Leap Motion can also track hands but is not precise enough to support things such as individual finger movement on a virtual keyboard (Motion 2019). In addition to this learners must understand the technology and then learn by themselves in this fashion, often leading to poor practice.

Beyond music education, XR learning games have shown promise in other domains:

- **Fitness Training:** VR platforms like Supernatural (Supernatural 2021) and FitXR (FitXR 2020) use gamified workouts to engage users in physical activity, often providing real-time feedback and tracking progress. These systems leverage immersive environments to motivate users but require sufficient physical space and can be cost-prohibitive due to hardware requirements.
- **Language Learning:** Applications such as MondlyAR (Mondly 2018) use AR to simulate conversational practice with virtual characters, helping learners build confidence in speaking a new language. These tools emphasise contextual learning, which is especially effective in language acquisition, though their reliance on high-quality speech recognition and natural language processing remains a challenge (Smith and Lee 2020).
- **Business and Professional Training:** Platforms like Strivr (Strivr 2022) and Immerse (Immerse 2010) use VR to train employees in soft skills (e.g., communication, negotiation) and technical skills (e.g., equipment handling). These tools can replicate

real-world scenarios with high fidelity, making them particularly useful for industries like healthcare and manufacturing. However, they often require substantial investment in both content development and deployment infrastructure.

Despite their potential, XR learning games face several overarching challenges. Accessibility remains a critical issue, as high-quality XR systems are often prohibitively expensive for individual users or smaller educational institutions. Additionally, the usability of these technologies can be hindered by hardware limitations, such as tracking precision and field-of-view constraints. For instance, tracking physical objects within VR often requires external hardware like sensors or cameras, which can disrupt immersion if they fail to function consistently (Johnson and Brown 2023). Not only this, but the setup of such hardware can involve such commitment, beginners who are not fully invested in their learning will not have such desires to commit their time to it.

Another key limitation is the meaningful integration of XR into pedagogical frameworks. While XR technologies excel at creating engaging and immersive environments, their impact on long-term learning outcomes is still an area of ongoing research. In music education, for example, learners may struggle to transfer skills acquired in a virtual environment to physical instruments (Taylor and Green 2022). Similarly, in language learning, the simulated contexts provided by XR may not fully capture the nuances of real-world communication (Davis and Carter 2021).

Nonetheless, recent advancements in XR technology are addressing some of these challenges. The development of standalone VR headsets such as the Meta Quest 3 (Meta 2023) and AR-enabled devices like Apple Vision Pro (Apple 2023) is making these tools more accessible and user-friendly. Furthermore, advances in AI-driven hand tracking and object recognition are improving the fidelity and interactivity of XR applications. Platforms like Mozart 360 (360 2014) and VR Piano Academy (Academy 2023) are exploring ways to integrate these innovations into music education, aiming to bridge the gap between virtual and physical learning.

Overall, XR learning games represent a dynamic and rapidly evolving field with significant implications for education and training. While current applications across multiple domains demonstrate the potential of these technologies, addressing their limitations in cost, accessibility, and pedagogical effectiveness makes realising their full potential questionable.

3.4.3 Mobile Practice Games For The LUMI Application

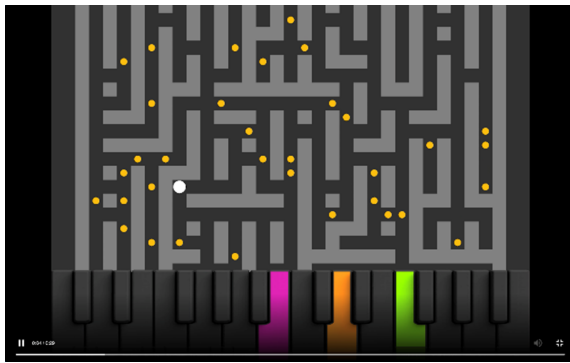
Based on the limitations of VR and AR prototypes, there was serious considerations to what practice games would be suitable to work within or alongside LUMI which would work on

predominantly mobile devices. The prototypes needed to incorporate music, a pedagogical component and resemble a video game, striking a balance between all three gave way to a plethora of ideas. Working alongside the lead game developer at ROLI, a multitude of mini games, ranging from simple flash card style guessing games to games which replicated existing ones but would be played with the LUMI or required a particular skill to execute a mechanic were developed.

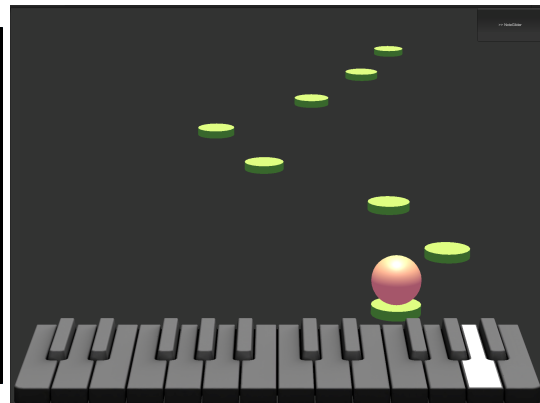


Fig. 3.7 An early concept of ‘Superluminal’ a game which is played using notes of a scale to navigate through space

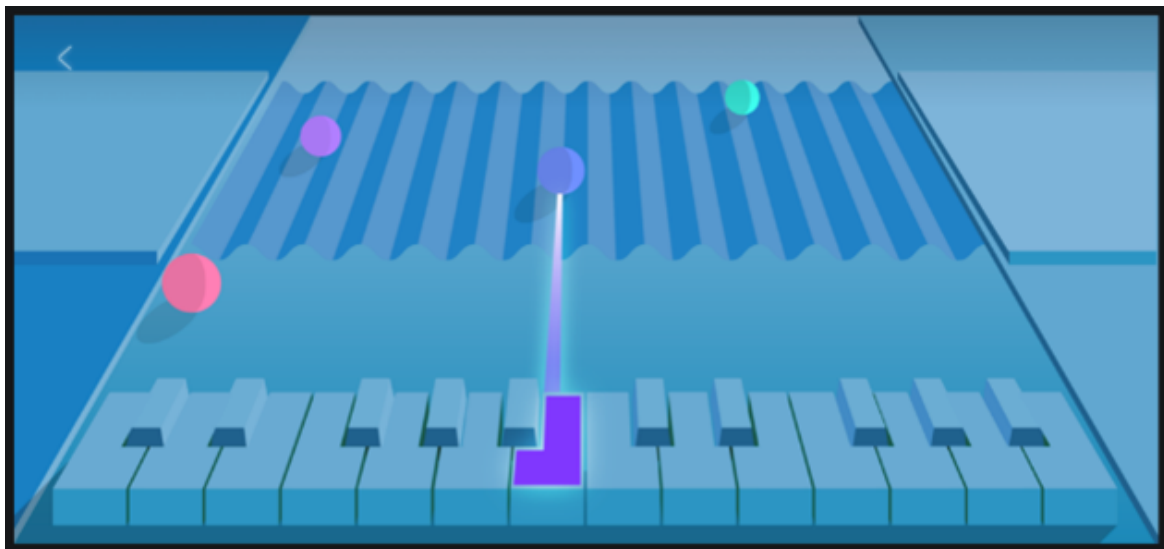
The developed solutions included games that would help learners practice reading musical notation using a ‘Space Invaders’ style of gameplay where notation and note names fall from the top of the screen and must be destroyed before reaching the bottom. A game was developed which required knowledge of scales where players could fire down lanes corresponding to notes in a scale to destroy incoming hazards. There were ideas which revolved around the use of particular hand positions, working with triads, to navigate through a maze, resembling the style of ‘Pacman’. There was a huge bank of game ideas, many of which are not mentioned here but the entire list of ideas is made available and is accessible in the appendix.



(a) 'Maze Runner' a practice game which uses triads to navigate through a maze



(b) 'Note Jump' by playing notes the 'player' jumps from one platform to the next



(c) 'Scale Shooter', another practice game which helps learners recall specific scales

Fig. 3.8 Various practice games developed for the LUMI application

Illustrating Flow in LUMI Games

The "Space Invaders" game provides a clear example of how flow was integrated into the design. By starting with slower-falling notes and gradually increasing speed, the game ensures that learners build confidence before facing more complex challenges. Additionally, learners are given immediate feedback—successful destruction of notes triggers visual and auditory rewards, reinforcing correct responses (Malone 1981). These design choices align with flow principles by maintaining a balance between challenge and skill (Csikszentmihalyi 1997).

Similarly, the "Maze Triad" game leverages circulation to foster exploratory learning (Jenkins 2004). Although the game requires learners to form specific triads to navigate the

maze, its open-ended layout allows players to experiment with different routes and strategies. This design promotes deeper engagement by combining structured learning objectives with opportunities for creative exploration.

To ensure that these games remain pedagogically effective, regular iterations are informed by both player feedback and performance data. For instance, early playtesting (mostly internal) revealed that some players struggled with recognizing accidentals in the "Scale Hazard" game. In response, a dynamic hint system was later implemented, in which players would receive visual cues about correct notes when they consistently miss targets. This not only improved player's progress but also reinforced the relationship between note names and positions, a key learning outcome of this research (Kiili 2005).

3.4.4 Development Which Lacked Validation

Whilst the research began to open new doors into the realms of novel approaches to gamified practice, it was clear that these solutions needed more scope to avoid over developing and never reaching any concrete conclusions. Some of the developed games would perhaps be highly pedagogical but may lack any sense of game design or gamification, whilst some concepts would be the opposite and could be highly engaging but not particularly educational in context to the key learner groups. Whilst there was an ability to discover new ideas and prototype them rapidly, they were only being tested internally and the games were only being played from the perspective of developers and designers. What was required was a model of assessment which could be built upon and use to create an iterative flow of design, develop and test. Not all the games could be taken forward so there was a key decision to build a small suite of mini games to begin the first round of assessment. What was required was a range of games from the least gamified and most pedagogical to the opposite of this spectrum; this would help define the fine balance between video game and pedagogical value, whilst ensuring that all games featured music at their foundation.

3.4.5 Game Flow and Pedagogical Relevance

Game flow, a concept rooted in Csikszentmihalyi's flow theory (Csikszentmihalyi 1997), emphasises maintaining a balance between the challenge presented by a task and the learner's skill level. In the context of gamified music education, achieving flow ensures that learners are not bored by overly simple tasks or frustrated by excessive difficulty. This principle directly supports educational outcomes by keeping learners engaged, a critical factor in skill acquisition for beginner musicians (Sweetser and Wyeth 2005).

In designing the LUMI games, flow was a guiding framework. Games such as the "Space Invaders"-style notation practice were later designed to dynamically adjust speed and complexity, ensuring a gradual but consistent progression of difficulty. This approach aligns with scaffolding, a pedagogical strategy where challenges are incrementally increased as learners demonstrate mastery of foundational skills (Wood et al. 1976). By integrating game flow principles, the consequent games that were designed from this stage aimed to foster sustained engagement, ensuring that users are motivated to continue practising and improving. With the notion that they would want to return and practice as they enjoyed it rather than feeling as though they are forced to do so.

Critical paths and core circular goals also became important to the design process (Jenkins 2004). Critical paths represent structured sequences that guide learners toward specific learning objectives—such as recognising note positions or mastering scales. For instance, the "Scale Hazard" game required players to fire at incoming threats based on scale knowledge, which builds note recognition and familiarity with scale patterns. Circulation, in contrast, introduces exploratory elements, allowing learners to experiment with different approaches while still progressing along intended learning trajectories and allows them to repeat these segments to various outcomes. This was later exemplified in the "Maze Triad" game, where learners navigate through obstacles by forming correct triads that would repeat in their patterns, blending skill-building with an open-ended game mechanic. However, with all the games at this stage, their level of complexity and variation was minor and such concepts had to be integrated into existing and new games that were later designed.

The blending of such elements and by drawing inspiration from other games in different domains, our games aimed to achieve a balance of structured learning and exploratory engagement, a combination that has been shown to enhance knowledge retention and learner satisfaction (Kiili 2005). As we have reiterated before, the idea was to create experiences that included such paradigms to mimic a true game experience with the hope to encourage learners to return as they found it enjoyable; pairing this with educational takeaways was the ultimate goal.

3.4.6 Validation and User Feedback Methodologies

The initial development of practice games for the LUMI ecosystem revealed a critical limitation: the exclusive reliance on internal testing by developers and designers. Our proposed validation strategy aimed to systematically assess the pedagogical effectiveness and user engagement of these prototypes through a comprehensive, nuanced approach

By interweaving quantitative and qualitative assessment techniques, we sought to uncover deeper insights into gamified learning solutions. The research would therefore be focused

on understanding the delicate balance between educational content and game mechanics, a persistent challenge in educational technology design. Our methodology moved beyond surface-level evaluation, targeting the complex interactions between learning objectives and user experience; eventually striving for purely quantitative methods for achieve replicability (something that is often overlooked in this domain).

Controlled group testing emerged as a key idea. This would enable rigorous comparisons between traditional learning methods and our gamified solutions. We could measure critical outcomes such as skill acquisition, learning effectiveness, and user motivation across different game prototypes. Complementing this, one-to-one user testing through walkthroughs and in-depth interviews would also help us capture the nuanced user experience that quantitative metrics alone could not reveal. We began to aim for semi-structured interviews with individuals as we believed user studies with groups where the discussion is about individual skill and learning preferences would not be fruitful.

A longitudinal assessment approach was proposed. This would help address the crucial question of long-term learning outcomes and engagement/retention over time. By tracking a learners' progress across multiple sessions, we could investigate skill retention, sustained engagement, and the games' capacity to facilitate meaningful musical learning. This method would not only show learning outcomes over time but highlight how engagement with a gamified approach may encourage overall interest in learning (by building positive association between learning and engaging methods).

Our proposed methodologies represented a shift from internal perspective to user-centred design. We aimed to transform our game development process from an intuitive exercise to an empirically validated educational tool. This approach acknowledged the complex challenges of creating educational technologies that are both engaging and pedagogically robust.

The validation methodologies in this research are designed to reconcile the need for engaging user experiences with robust educational outcomes. Quantitative tools like the Game Experience Questionnaire (GEQ) and System Usability Scale (SUS) measure engagement, usability, and overall player satisfaction. These metrics provide valuable insights into whether the games maintain an optimal balance between challenge and skill, a critical factor for achieving educational success.

By combining these methods, the research evaluates not only the immediate effectiveness of the gamified tools but also their long-term impact on learner engagement and skill retention. Longitudinal studies track metrics such as retention rates and skill progression over multiple sessions, providing a comprehensive assessment of the tools' ability to support sustained learning.

Future research required careful participant selection, ensuring a diverse cohort of beginner keyboard learners with varied musical and gaming backgrounds. Ultimately, our validation strategies represented an exploration of how technology can reimagine musical education. By embracing empirical standards and creative innovation, we sought to open new pathways for assessing musical learning experiences that utilised technology in ways traditional methods had not attempted thus far.

Evaluation Frameworks for Gamified Learning

To assess the effectiveness of our games, we needed to adopt established quantitative and qualitative evaluation frameworks commonly used in game design and educational research. One of the methods we decided to use later was the Game Experience Questionnaire (GEQ) (IJsselsteijn et al. 2013), a widely recognized tool for evaluating player experience across dimensions such as flow, immersion, and enjoyment. The GEQ provides insights into whether learners remain in an optimal flow state during gameplay, a critical determinant of both engagement and educational success. As with many research projects, we adopted the questionnaire to fit the needs of this project. We also used the System Usability Scale (SUS) to this end as well within the last two studies to understand how usability may have had an impact on the practice sessions during gameplay.

Similar to the GEQ, the Intrinsic Motivation Inventory (IMI) (Ryan and Connell 1982) which helps measure learners' self-reported interest and perceived competence was considered as such a method would work well alongside sessions of gameplay (i.e., to be used during post session feedback). This tool would have helped identify whether the gamified elements genuinely motivate learners or if they detract from the educational objectives. For example, early prototypes of the "Maze Triad" game were revised after feedback indicated that some learners found its mechanics more frustrating than engaging, underscoring the importance of balancing challenge with player capability. If we were to use the IMI in a more involved capacity, further findings may have been uncovered. Instead, we adopted our approach to reflect the paradigms of these tools to help gain insights based around our key goals; no one survey or tool would help uncover the whole truth of a situation, but a combination of them would bolster our research rigour.

We also planned to track longitudinal metrics such as retention rates and skill progression over multiple sessions (to help reflect real-world practice). These metrics would provide data on each games' effectiveness in promoting sustained engagement and long-term learning. For instance, by monitoring how often learners return to each game and how their notation-reading accuracy improves over time, we would be able to gauge its impact on building foundational musical skills.

Finally, qualitative methods such as semi-structured interviews and cognitive walk-throughs helped supplement quantitative findings (Lewis 1982). These approaches would help capture nuanced user feedback on game mechanics, aesthetic design, and perceived educational value, offering a holistic view of the learner experience. Although we eventually strived for a more quantitative approach in the end, one cannot deny the need for a mixed-method approach to gather all key insights, especially in the field of user testing.

3.5 Chapter Conclusion

Whilst a significant proportion of the literature, as well as solutions found in the marketplace, attempt to replace the traditional style of learning to play a piece of music (i.e., sheet music), these solutions are not adequate; they often lead to poorer form when playing, do not reflect the depth and expression of a piece of music and have a lack of application outside of this play style. More recent solutions that attempt to gamify the whole process of the learning journey with the use of mobile applications (i.e., music learning applications) have helped to increase accessibility and portability of learning. However, these solutions help to inspire beginners to start their journey but there is seldom research or efforts made to help ensure the longevity of a learners journey is ensured, typically leading to frustration or boredom and eventual drop out.

A more appropriate use of digital technology is increasing motivation in areas of learning that are imperative, but also associated with tedium. Thus, the belief of this research is that video games are best as a supporting aid to a learners journey; this approach attempts to ensure that the learning journey is never abandoned. Whilst there is some research in this field, which specifically focuses on rhythm, ear and notation reading (or sight-reading training), these solutions attempt to add gamification to existing learning tools or methods. Not only this, but the methods of assessment of all the solutions found were on a surface level; they helped to ensure that a learner improved within their developed solutions but never explored how this could transfer to real-world applications of learning, particularly over long periods of time.

From these findings there appeared to be a gap in the research of music learning, specifically concerning key-based instruments, in which the use of game-based learning could be used for the purposes of meaningful practice. This research explores a somewhat novel approach to music learning in conjunction with video games, whilst offering novel methods of assessment. The sole purpose was to ensure that such solutions could have meaningful transferability and real-world applications which would help to increase the longevity of independent adult beginner keyboardists.

To this end, various gamified solutions were developed in pursuit of attempting to merge game-based learning with meaningful practice. The literature review established that using new technology or the 'rolling-note' style of learning to play a piece of music would cause further complexity or shortcut techniques that would lead to poorer performance and be detrimental to future playing and learning. Therefore, a host of mini games was developed with the goal to improve specific fundamental skills that can increase the quality of learning and playing of a piece of music. However, there was a lack of specificity, organisation and no tangible way to assess such games in this pursuit during the first cycle of development. A framework of design, development and assessment was required if such novel concepts were to be developed in a meaningful way. This chapter demonstrates how the research reconciles conflicting viewpoints in the literature by integrating the motivational strengths of gamified tools with the pedagogical requirements of skill acquisition. By iteratively developing and validating solutions that address barriers to learning, this work provides a framework for creating engaging, meaningful, and transferable learning experiences in music education. The methodologies outlined here lay the foundation for evaluating these tools in real-world contexts, as discussed in subsequent chapters. In the next chapter, the first round of mini games which had some of form of structure is discussed, focusing on the development of such games and includes the first round of assessment which is improved upon throughout this research.

Chapter 4

Developing Games For Rote Learning

4.1 Chapter Introduction

Previously discussed, the initial prototypes were developed for the purposes of music creation in conjunction with various HCI technologies and mediums such as VR and AR. During this stage, the placement company was seeking new ideas to promote the joy of making music and to lower the barrier of entry of creating music; attempting to become the 'Guitar Hero' (Hemingway 2010) for keyboard and piano, albeit, with newer technology. Small prototypes were developed using the HTC Vive (HTC 2016), the PSVR (Sony 2018) as well as delving into AR, mostly with the Microsoft HoloLens (Taylor 2016). Based on the limitations mentioned previously with VR and AR pursuits (inaccessibility and complexity), the placement company began to develop a roadmap that focused on keyboard and piano education from a more classical perspective, rather than the creation of music itself.

The goals proposed for such a solution were to create a graphical and engaging way to learn pieces of music ranging from classical to modern, with a focus on teaching beginner keyboardists and pianists the basics of playing their instrument. This approach aimed to introduce beginners to the more traditional side of keyboard and piano, delving into reading music and the typical instructional methods one would expect to find from traditional teachers or educational resources (Palmer et al. 2005).

As previously mentioned, the final product that emerged from this stage was the LUMI and its companion learning application, which incorporated mini-games designed to help practice specific, foundational skills. The list of potential game ideas seemed endless, however the team recognized a critical gap in their development process: the lack of a systematic method of assessment and iterative development. To address this, a comprehensive suite of games was developed with a structured approach to creation, testing, and refinement.

This chapter, and the study that we discuss within it, aims to make a significant contribution to understanding the intersection of educational technology and music learning. By creating and rigorously evaluating a suite of mini-games, the research sought to explore the delicate balance between engaging gameplay and meaningful musical practice. The primary objectives were to determine the most effective types of games for musical education and develop a robust methodology for assessing their engagement and learning potential.

The chapter provides an in-depth exploration of the game development process, detailing the various prototypes created during this stage. It outlines the development pipeline, highlights key design principles, and discusses potential pitfalls to avoid. The subsequent study was crucial in assessing the mini-games and identifying an ideal target audience, providing valuable insights into how gamification can be effectively applied to musical education.

Through this iterative approach, the research began to uncover the nuanced relationship between learning and gaming in the context of musical instruction. The findings from this chapter not only guided the direction of the doctoral research but also laid the groundwork for the more comprehensive game developed in later stages of our studies. By capturing feedback from current beginners and potential instructors, the research refined its methodology and gained critical insights into the potential of gamified musical learning.

As we discussed, rote learning was the style of learning that these games focused on (repeating practice which was often deemed as boring and a lack of solutions were designed to make it more engaging). Rote learning was specifically chosen because it aligned perfectly with the style of game that could be played during short moments of downtime, such as commuting, at the end of the day, or during free time. This cohesion between short but satisfying gameplay and learning that requires repetition was a core rationale for selecting rote learning. Moreover, the approach addressed a critical insight from learners who often struggled with mechanical skills like correct fingering, reading musical notation, and maintaining rhythmic precision, yet found traditional practice methods monotonous. By transforming these essential skills into engaging game mechanics, the research aimed to build positive associations with learning, potentially reducing dropout rates and encouraging longer-term musical education. The game design strategy sought to make repetitive learning not just bearable, but genuinely enjoyable, thus lowering psychological barriers to skill acquisition (Palmer et al. 2005).

4.2 Developing the Mini Games

Each mini game was developed so that the core mechanics were driven by the learning component (e.g. practicing scales can be used to drive the mechanics for a game where playing corresponding notes destroys enemies); these learning components are derived from the pre-defined set of skills which require rote learning. Drawing upon paradigms from gamification, game theory and current applications on the market, the games to be original in their nature whilst also create an engaging environment for practice. Design considerations for each game are discussed and what is believed to be the negative and positive aspects of each, in hope that others will be able to take the imparted knowledge and build upon this to create their own novel experiences.

4.2.1 Game Selection Process

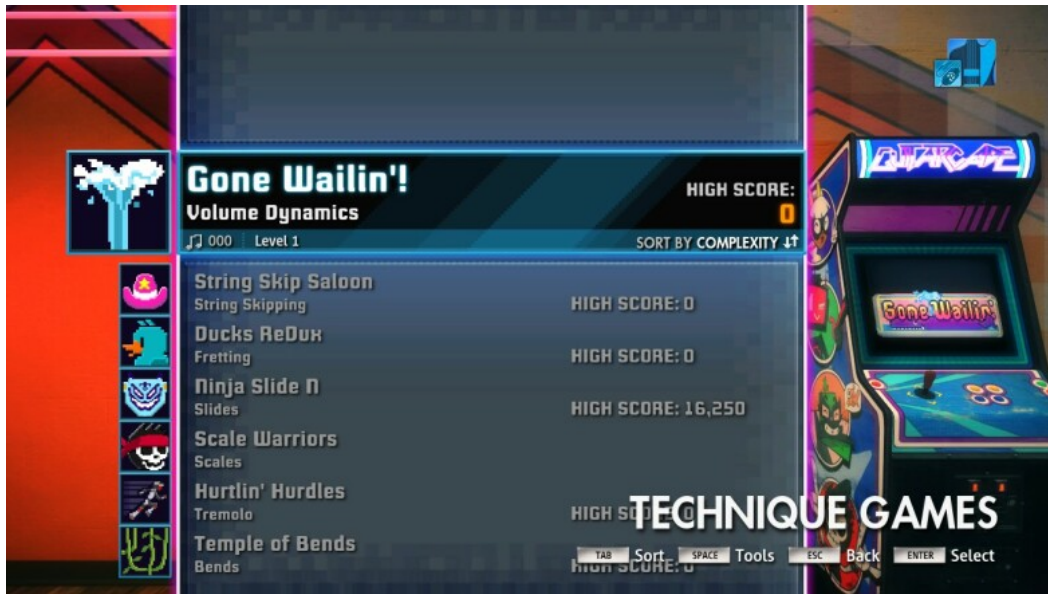
In selecting which games to include in our suite, we focused on creating mobile-style games that were simple, repetitive, and encouraged gradual skill progression. This design decision was driven by the understanding that short, engaging gameplay loops keep players motivated to return repeatedly, reinforcing learning and skill acquisition through frequent practice. We looked for mechanics that allowed players to achieve incremental improvement with each session, mirroring the ‘bite-sized’ sessions found in casual mobile games. Furthermore, the rigid structure of traditional practice methods, often requiring dedicated spaces, can hinder motivation and consistency. In contrast, mobile games offer a flexible and accessible platform, enabling practice in diverse environments. This can reduce the psychological barriers associated with practice, such as the perceived effort and time commitment.

The decision to include repetitive but engaging games was based on experience with skill-building games and mobile games that had simple but satisfying mechanics, which often employ straightforward mechanics that repeat in cycles, gradually increasing in difficulty (also known as the saw-tooth model). This structure allows players to experience a sense of mastery while steadily being challenged. Furthermore, mobile games are often known for their ability to create addictive loops through minimal input mechanics, such as tapping or swiping, which we adapted to allow for more sophisticated input using the keyboard.

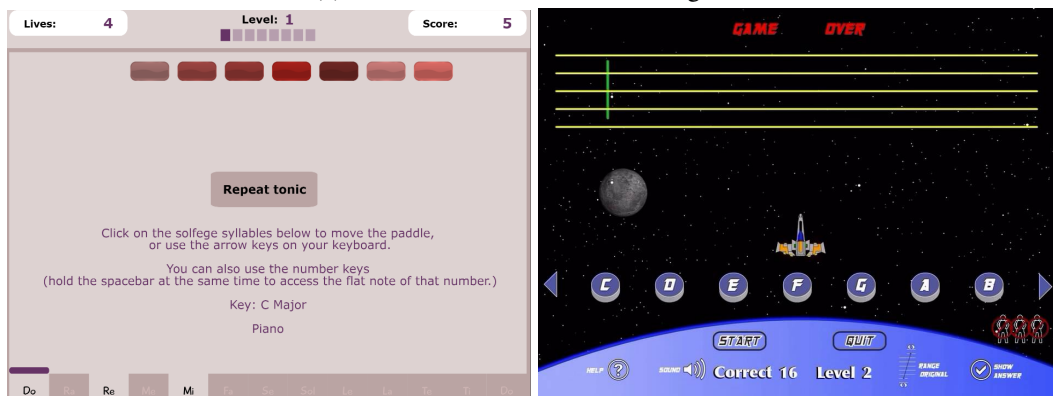
By selecting mechanics that were intuitive and quick to pick up, players could focus on specific skill areas — such as rhythm, accuracy, or recall — without being overwhelmed by complex controls. These choices aligned with the goal of creating games that not only taught musical skills but also mirrored the accessibility and reward structure typical of mobile games, ensuring they remained engaging while promoting exponential skill development through frequent, low-pressure practice sessions.

4.2.2 Inspirations

Developing each game was typically supported by borrowing ideas or designs from existing games or learning tools, whilst also adhering closely to the game design principles that were established. For this suite of mini games, ideas were borrowed from existing learning games such as those found in classrooms, which included simple flash card and ‘repeat after me’ style games as well those on the web (Colin 2016, Music 2022). The concept of developing a host of small games inside an existing platform (the LUMI application) was based on the concept where other games implement smaller style games within their own; these examples include Mario Party (Nintendo 2020b), WarioWare (Nintendo 2020c) and Rocksmith (Graham and Schofield 2018). Particular attention was paid to Rocksmith as it was one the core concepts that this research attempted to replicate, albeit using the keyboard as the main controller rather than a guitar. Rocksmith had featured a ‘Guitarcade’ which was a series of arcade style games that helped build particular skills when playing the guitar – practising scales in a racing style game or playing chords to shoot zombies.



(a) Rocksmith's 'Guitarcade' mini-games



(b) Audiation game featured in the online collection of practice games developed by Theta, a take on Breakout
 (c) 'Staff Wars', a simple note reading practice game which has a 'Star Wars' theme and a timer for added agency

Fig. 4.1 Various inspirations which were reviewed when developing out mini-games

Other inspirations included typing games, most notable was noa, where one must type words to destroy oncoming waves of enemy ships, and later expanding this idea to be horizontal to reflect real world applications of reading a musical staff. Finally, inspirations were based on mobile games, particularly Ketchapp and noa but replacing the core mechanic of simply touching or hitting a key, with playing specific keys. Whilst more games were reviewed and consulted at this stage, they were mostly used for discussion points or to borrow specific designs – a full list of games is made available in the appendix.

Encouraging Improvisation

Improvisation in music can be defined as the spontaneous creation or variation of musical elements in real-time performance. It involves creating original musical content on the spot, often within a given framework of chord progressions, scales, or rhythmic patterns. In the context of music education, improvisation is a valuable skill that encourages creativity, develops a deeper understanding of musical structures, and enhances overall musicianship.

While the mini-games developed in this research primarily focus on foundational skills such as note recognition, rhythm, and scale familiarity, elements of improvisation are incorporated in several ways:

1. **Note Flash:** Although primarily designed for note recognition, this game is extended to include improvisation by challenging players to create short melodies using the flashed notes as starting points.
2. **Note Typer:** The game's core mechanic of responding to falling phrases was adapted to include improvisation challenges, where players are given a starting phrase and are encouraged to create variations or extensions (this was quite often a natural process that players adopted without needing to be prompted).
3. **Note Stack:** This game was somewhat lacking in encouraging improvisation but could incorporate improvisation by allowing players to create their own patterns within a given scale, rather than strictly following a predefined sequence (this mode was later added based on feedback gathered).
4. **Crossy Notes:** The ascending scale mechanic in this game was later expanded upon to include improvisation challenges, where players must create short melodic patterns within the current scale to navigate special obstacles (in certain levels, objects were spawned in ways to encourage this behaviour rather than continuously tapping forward).

While these games focused more on structured learning and skill development, future iterations included a greater emphasis on improvisation. This involved adding "freestyle" modes where players are given a backing track and encouraged to improvise within certain parameters, and incorporating challenges that require players to complete or extend given musical phrases in creative ways.

Balancing Engagement and Meaningful Practice in the Mini-Games

In developing our suite of mini-games, we faced the recurring challenge of striking an optimal balance between engagement and meaningful practice. Our approach to this balance was

multifaceted, guided by the principle that effective learning tools must be both entertaining and educationally valuable.

At the heart of our design philosophy was the integration of learning objectives into core gameplay mechanics. Each game was crafted to ensure that its primary interactions directly contributed to musical skill development. For instance, Note Flash's rapid recognition and playing of notes seamlessly combines a fun, reflex-based game with essential skill-building. Similarly, Note Typer's falling phrases not only create a sense of urgency and challenge but also reinforce note reading and finger dexterity.

We recognised the potential tedium in traditional practice methods and sought to transform these routines through gamification. By incorporating elements like high-scores, multipliers, and progressive difficulty, we imbued potentially monotonous exercises with a sense of achievement and progression. Visual and auditory rewards, such as the satisfying explosions in Note Typer or the growing tower in Note Stack, provide tangible feedback that makes achievements feel more concrete and satisfying.

While immediate engagement was crucial, we also focused on long-term skill development. Games like Note Stack and Crossy Notes start with simple concepts but progressively introduce more complex musical ideas, ensuring that players are consistently challenged as their skills improve. This approach aims to maintain short-term interest while fostering meaningful progress over time.

Feedback mechanisms played a vital role in our games, serving the dual purpose of enhancing engagement and promoting self-assessment. Visual cues, score systems, and post-game summaries not only gamify the learning process but also provide valuable insights for focused practice. These features allow players to track their improvement over time, adding an element of personal challenge that keeps them coming back for more.

Understanding the diverse needs of our players, we implemented a range of customisation options. From adjustable difficulty levels to the ability to focus on specific musical elements, these features allow players to tailor their experience to their current learning goals and preferences. This flexibility ensures that players can find the right balance of challenge and accessibility, regardless of their skill level or learning style.

4.2.3 Development Process

It is the belief of this research that when developing new solutions for an issue which allows for such a large array of ideas, rapid prototyping is key and this was also backed up by the supporting literature. It allows one to not get distracted by over graphical solutions in which too much time is focused on aesthetics rather than function and meaning. Developing in such a quick fashion, especially ideas which require some complex principles such as rhythm and

syncing MIDI interfaces, can be seen as a somewhat tricky undertaking. Fortunately, with the advent of game engines, this process is less overwhelming. The Unity Engine (Technologies 2005) was used to develop of prototypes as it is lightweight and offers packages which assisted in the development (it helps shortcut game development pressures such as physics and collision modelling, creating UI functionality and allows projects to be built to mostly any platform with ease). Below is an outline of the development pipeline that was adhered to, walking through the step-by-step process of initial concept to prototype.

Development Pipeline

A typical pipeline of development was followed which included internal and external testing (using Fullerton's model (Denham 2016)). This process was useful and it could be used iteratively by looping the entire process – from brainstorming an initial idea to external testing (i.e., testing on the public) this could be repeated on what was discovered through testing until a solution that was satisfactory of the aims that had been set out to achieve was found. Each step is listed below:

1. Brainstorming Ideas

Each concept began with creating new ideas for possible products that could be added to the ever-expanding portfolio. This typically began with group sessions which focused on a single idea, for example 'A game which helps beginners learn the basics of rhythm' or 'A game which centres around a beginner learning to read basic musical notation'. Ideas would be discussed and eventually a list of the favourite ideas was created (typically by voting); concepts would be hand drawn concepts later draw out more complex designs digitally of the most favourable concepts. A key lesson learnt was to not just consult gamer archetypes or developers but expand the discussion circles to anyone who had an idea – some of the best ideas came from those who were not too involved with the development process and allowed creativity to flow.

2. Internal Prototyping

Once an idea had been decided upon, occasionally deciding on the top three ideas, prototyping would begin. As mentioned, the Unity Engine was used to allow for rapid prototyping and built a set of classes and namespaces, using C#, which could be called upon, rather than having to create similar functionalities every time a new prototype was to be developed. There were functions which were required across prototypes, such as adding and tracking score, linking MIDI actions to specific mechanics using event triggers and more complex functionality such as generating scales. Inheritance was used to implement these

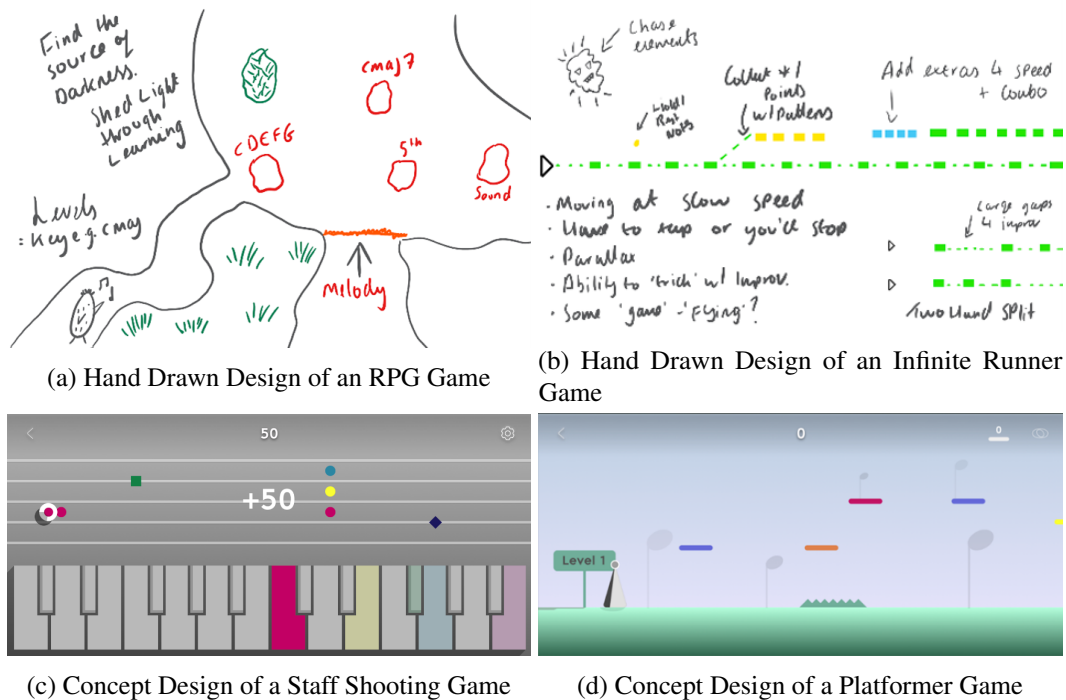


Fig. 4.2 Concept Designs For Various Learning Mini Games

functions within smaller classes and individual games. For example, one script would handle adding score which would execute other actions such as updating UI and a child script could make use of this by calling upon the adding score function when the player completes a correct action within a specific game – ensuring that developers would not have to write a scoring script for every single game.

Finally, the development team made use of source control, using Git and GitHub to store the repositories. The source code for all of games was available across the company to allow anyone to add their own mechanics and implement their own code, using their own branches. All games were contained within one project which could later be built within the LUMI application, ensuring that it would work with the application and match the design of the entire ecosystem. Source control was also used by the individual researcher - it is a practice which should always be followed, as it allows for retrospective glances of older work, prototyping smaller sections of games without affecting the entire project and works as a way to back up work. Whilst the repositories cannot be made publicly available (as it breaks IP laws), code snippets are made available on GitHub which gives developers access to the aforementioned parent classes and namespaces – if anything they are useful to study to understand the principles of SOLID coding (Kexugit 2014) and act as a foundational pieces for developing music games, especially educational ones.

3. Internal Deployment, Validation and Testing

Once a prototype was developed, it would be deployed to the local builds which the entire team could access. TestFlight was used for distribution as well as using the App Centre as the ROLI build architecture was mostly Apple dependent. All team members played the games and gave feedback, rather than just being played by the designers and developers. This helped to notice any major bugs and points of frustration whilst also regularly meeting to discuss how to improve upon the experience based on the feedback given. It was important to test on non-developers and designers to ensure that it could be played without much assistance before the games were showed to the wider public audiences. It was clear when a prototype was highly engaging and received positively by the excitement across the company; seeing large gatherings around a team member playing the game or being requested to play regularly.

4. Production Development

Once a handful of games were tested internally, it was somewhat obvious which prototypes were the most well received (a lot of this boiled down to observing players for the first time whilst asking open-ended questions; the initial response spoke a thousand words). These prototypes were taken further and were developed to a production level that would be appropriate enough to show to the public. This entailed fixing the bugs and points of frustration, adding more detailed design rather than simple white boxing (Zammitto 2018) and ensuring that the overall UX flowed well enough that the researcher would not have to interfere with the users too much at runtime.

5. External Testing

The final step of the pipeline is external testing. At first, the play testers were either friends or family of team members, rather than showcasing to unknown members of the public. This was to avoid showing something which may have been reviewed negatively and then be spread around to a wider audience and because it was opportunity to test on those who had no idea of what the internal goals were without the need to actually recruit.

If an idea seemed to catch the attention of a wider audience, these ideas would be taken further by testing on the public and the first study of this research, which is outlined below, is the first iteration of this testing. Once the games had been tested, feedback was taken onboard and the team went back to the brainstorming stage to discuss potential extensions of each game or whether the idea should be halted and look to another direction.

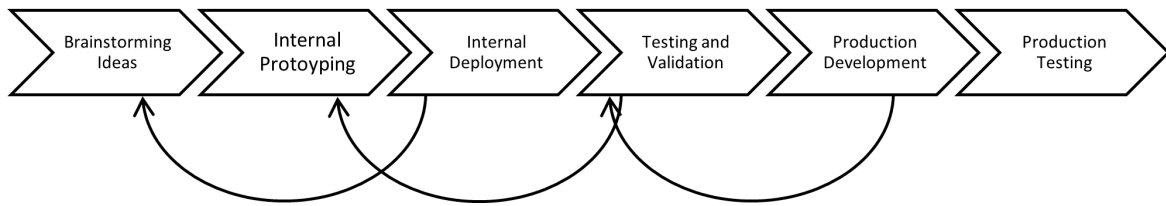


Fig. 4.3 Overview of the Development Pipeline; iteratively cycling between internal discussions and brainstorming until an idea was formed before cycling through development and testing until a feasible prototype was developed that was appropriate for public review

4.2.4 The Mini Games in Detail

Using the above methodology, four prototype games were developed which made up the suite of mini games. Each game is described below before discussing the intended learning objectives, and the potential extensions of each prototype.

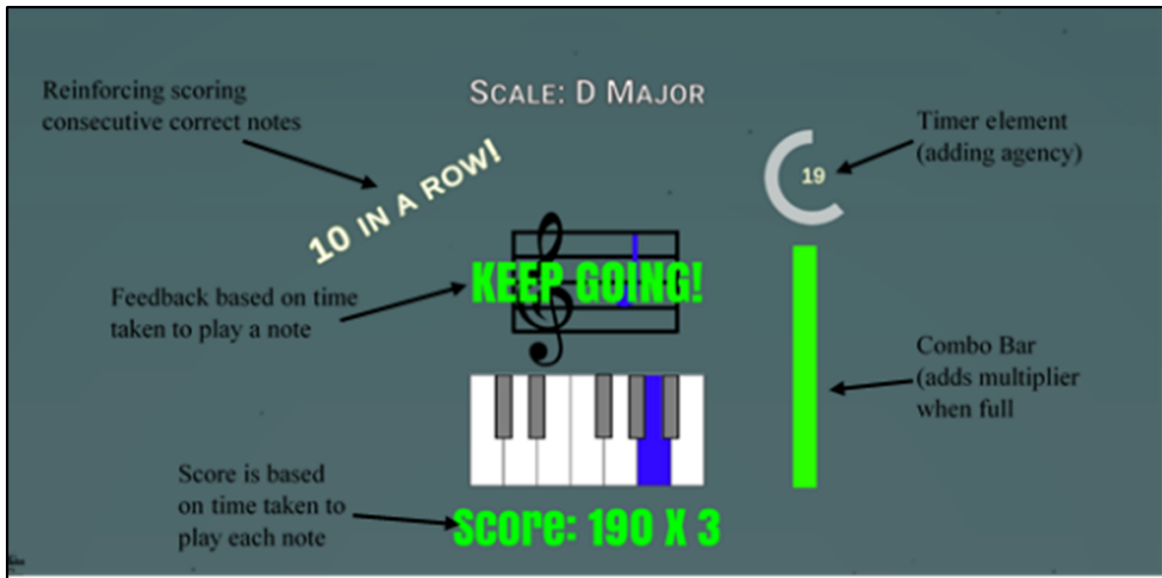
Note Flash

This is a game in which a visual cue flashes on the screen (either a note shown as a letter or in notation) and players must play the corresponding key. The loop of the game is to get the highest score possible within a set time limit; the faster you press the corresponding key after it is shown, the higher score you are rewarded with. If users get five notes in a row correct then a multiplier is applied to the score.

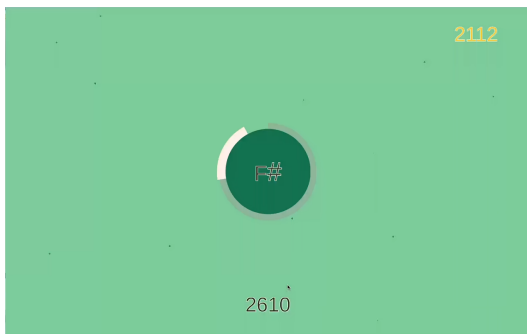
Players are encouraged using mostly positive feedback loops, i.e. playing a correct note is signified by a positive and encouraging bell sound which increases in pitch with each consistent note played. Whilst this is positive (rewarding for good behaviour), the idea of building up a number of consistent notes in a row means that the more consecutive notes a player scores, the more investment they have made and will want to avoid playing an incorrect – this is what is called a sunk prison cost, based on Chou’s definition within his gamification research (Chou 2019a).

Intended Learning Objectives

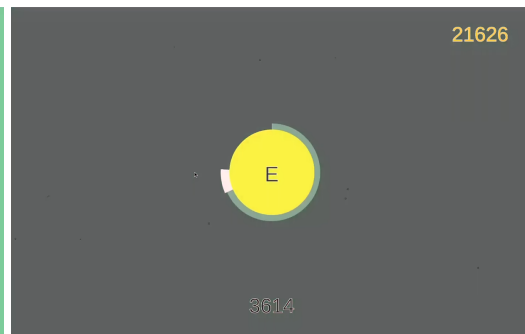
The main aim of the game is to help beginners build association between notes on a staff or letter representations of notes and physical keys on the keyboard as well as familiarise themselves with the pitch of each note. The objectives can be extended, such as learning scales by showing notes in a specific pattern, basic rhythms and reading more complex notation. It is intended to be played by beginners initially but extending the purposes of this



(a) Annotated screenshot of Note Flash version 1



(b) New Design of Note Flash using notation



(c) New Design of Note Flash using letters



(d) Note Flash implemented into the LUMI application

Fig. 4.4 Mini Game One: Note Flash

game also broadens the scope of what type of learner it can cater to; notations of chords, rhythmic notation and playing in specific keys.

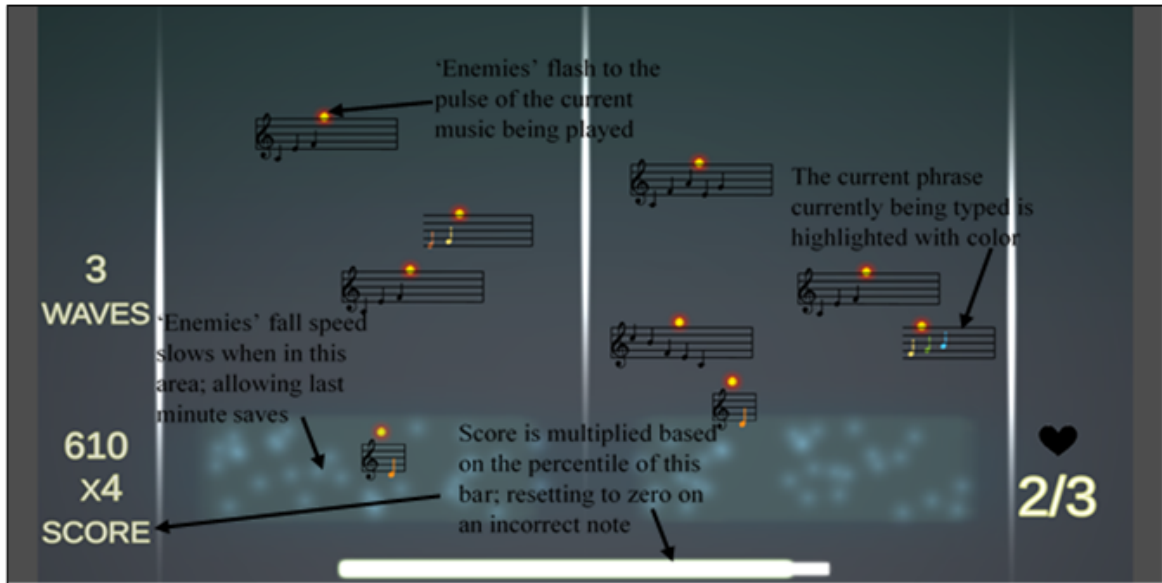
Extensions of the Game

- To avoid pressure felt from the timer element, a ‘level mode’ was created; in this version, players must fill a bar up by playing corresponding notes. Once the bar is completely full, the game is won. Just like in the original version, the quicker a note is played, the more the bar will fill. The idea that players’ actions contributes towards a win state should hopefully give a sense of satisfaction and accomplishment (rather than always having to beat their previous score to ‘win’)
- To help reduce frustration of the players that have to constantly look at both the screen and the keyboard, a variation was developed in which a visual cue (a note, chord etc.) appears on screen for a brief moment before disappearing; after it disappears, players are given a set amount of time to play the note. If they do not play the note in time then they will lose a life and eventually lose the game. To complete a level, players must successfully play a total of notes

Note Typer

The core loop of Note Typer is to prevent ‘enemies’ falling below the screen. Phrases (enemies) fall from the top of the screen. If they fall beneath the screen then the player loses a life (with three lives available in total). To destroy an enemy, players must play out each phrase (the order does not matter, i.e. they could play the last phrase to appear before playing the one closest to the bottom, and this actually results in a higher score, a ‘close call’ score is added depending on how close the enemy is to the bottom of the screen – playing on the ‘Evanescent Opportunities’ driver of gamification (Chou 2019a)). The enemy phrases appear in waves and increase in quantity of enemies and the speed of the enemy with every other wave; this regular up and down motion of difficulty is referred to as ‘a series of ascending arc’ (Holleman 2019) and ensures the game has moments of rest rather than continuously ramping in difficulty. Each ‘phrase’ is designed to help improve fingering skills at the keyboard; using ‘thumb under’ techniques, improving ‘five finger position’ and so on.

Player actions are reinforced with positive feedback loops; playing a note in each phrase omits a friendly chirp sound in the pitch of that note (reinforcing audiation) and destroying an enemy results in the phrase ‘exploding’ into smaller pieces (increasing the amount of ‘juice’ (Hicks et al. 2019) adds to satisfaction and overall engagement. In addition to this, there is also a ‘power bar’, which fills up on each consecutive note played in a row and requires five



(a) Annotated Screenshot of Note Typer



(b) Older version of Note Typer using letters and (c) Older version of Note Typer using letter phrases to improve finger techniques



(d) 'ZType' the game which helped inspire Note Typer

Fig. 4.5 Mini Game Two: Note Typer

consecutive correct notes to be filled. Upon being filled a multiplier of the player's score is applied and this also unlocks a 'weapon' which destroys all enemies within a certain range. Rhythm has also been implemented; using the algorithm from previous prototypes players are rewarded extra points for playing with the tempo but this is not strictly necessary to destroy enemies; this tempo is denoted by the flashing of 'enemies'.

Intended Learning Objectives

The learning objectives are similar to Note Flash, but focus more on hand coordination and rhythmic skills. As with Note Flash, the learning objectives are extended, helping learners to play with two hands both together and independently whilst also sequencing notes in patterns which help specific finger techniques (for example, reiterating the five finger position).

Extensions of the Game

Initially, the game was designed with enemies falling at random positions across the entirety of the screen. The concept of 'two-hands mode' was introduced as an extension for those that wanted to practice similar concepts but with two hands. A split down the middle of the screen was made: notes that fell on the left side were to be played with the left hand and vice versa. Later, chords were introduced; either side could produce chords (although typically it was the left hand to reflect real-world applications) and players must play chords seen on the left whilst also having to play phrases on the right. This led to the idea of having the chords and phrases generated in a way that would create something similar to an actual song which should help to increase general competency with music and engagement. To make the game feel less monotonous a 'quick tap' mechanic was added; during each session a series of notes or just one note will spawn in quick succession and the player must tap the corresponding key as quickly as they can. The idea behind this was to help break up the session and add an extra layer to the game. This is in line with the use of unpredictability found within gamification theories (Chou 2019a).

Note Stack

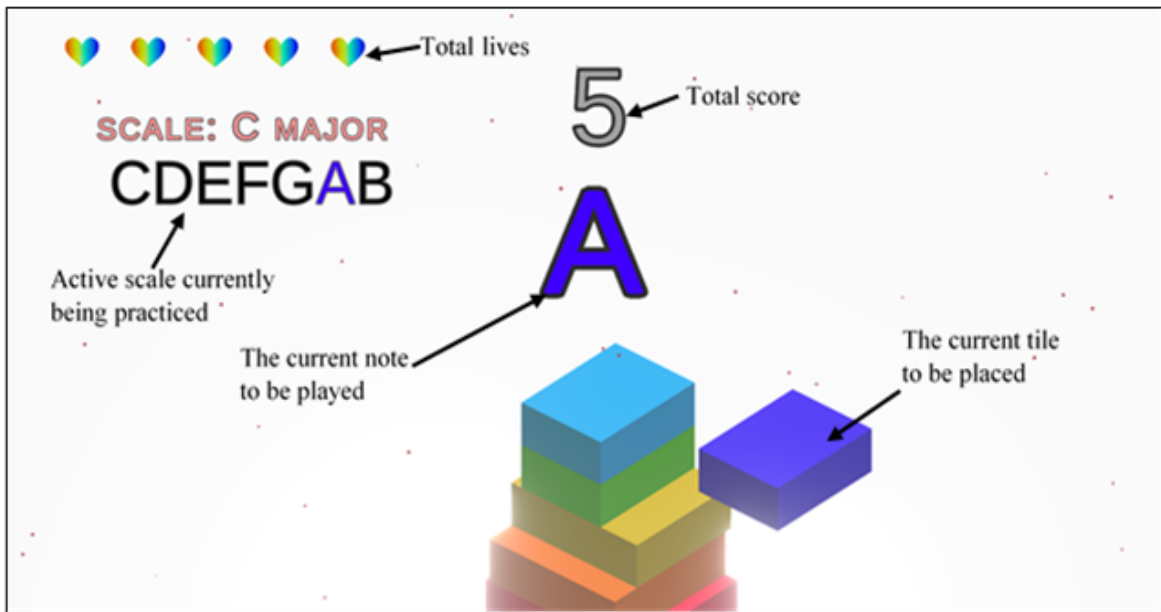
Based around the ideas derived from a similar mobile game, Ketchapp by Ketchapp Games. The core loop in this game revolves around playing corresponding notes shown on screen or playing through a scale in order to place moving tiles on top of one another to create a 'tower'; the higher the tower, the higher the score. The core loop is simplistic but it is because of this that players want to return; players feel as though they could score higher next time and because it is easy enough to try again, they will. If the user plays at the right time (either

by using rhythm, using a metronome, or by visuals) then the tile will match perfectly on top of the previous one, if three perfect tiles in a row are placed then the size of the next tile increases slightly in size; making it easier to place, which can lead to higher scores or can help a player who has fallen behind. As with all the prototypes, notes can either be coloured to reflect the colours of the keyboard or in black and white (to reflect a more traditional approach).

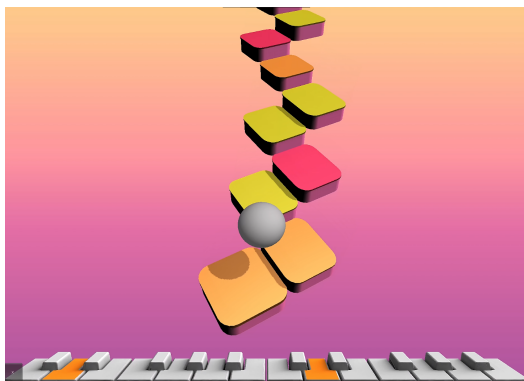
Feedback is offered in two forms; visually, the player will see a glow if they place a perfect tile or, if they do not place it perfectly, whatever part of the placed tile that missed the previous one will then be cut off, resulting in the next tile placement being a smaller target. The second form of feedback is auditory; a perfect placement results in a satisfying bell sound which increases in pitch on each consecutive perfect placement, whereas a non-perfect placement results in a snapping sound and resets the pitch back to default. Finally, playing an incorrect note does not place the tile but removes a life (with three lives available in total) and if all lives are lost then it is game over.

Intended Learning Objectives

Due to the nature of the core mechanic and the use of existing game design paradigms, the learning objective was relatively simple but there is room for extending this. At a basic level, the game helps players to learn scales, improves their overall sense of rhythm and helps to learn specific finger techniques whilst improving overall hand dexterity. Additionally, players who are beginning their learning journey could use it to learn simple concepts such as the familiarity of notation, if this view mode is selected, rather than showing note letters.



(a) Annotated Screenshot of Note Stack



(b) 'Note Tower', a version of Note Stack implemented into the LUMI application



(c) Note Stack being played, the colour of the tower reflects the colours of the scale practiced

Fig. 4.6 Mini Game Three: Note Stack

Crossy Notes

This prototype is based on an existing game, noa or, the modern take on this, noa. The objective is to cross endless roads and avoid obstacles as far as possible without being hit. The game consists of endless obstacles such as rivers, cars and props. and players must time their movements to cross each lane without being hit by a car. The camera constantly moves forward and if the player takes too long to move and fall outside of the camera's view frustum then this will result in game over. Feedback is offered by rewarding the player with score on each successful forward direction and additional points can be acquired by playing chords scattered throughout the game. In this version, players must move forward by playing an

ascending scale (the option to move backwards is also offered by playing the previous note in the scale).

This was the first game to make use of more than two octaves, by joining two LUMI keyboards together (which the hardware allows). The size of the keyboard increases to forty-eight keys; keys on the lower side are used to play chords and move left/right whilst higher notes are used to play through the scale and move the player forward. Playing an incorrect note results in the screen flashing red and an off-putting sound being produced; no score is affected as this was deemed too punishing for beginners.

Intended Learning Objectives

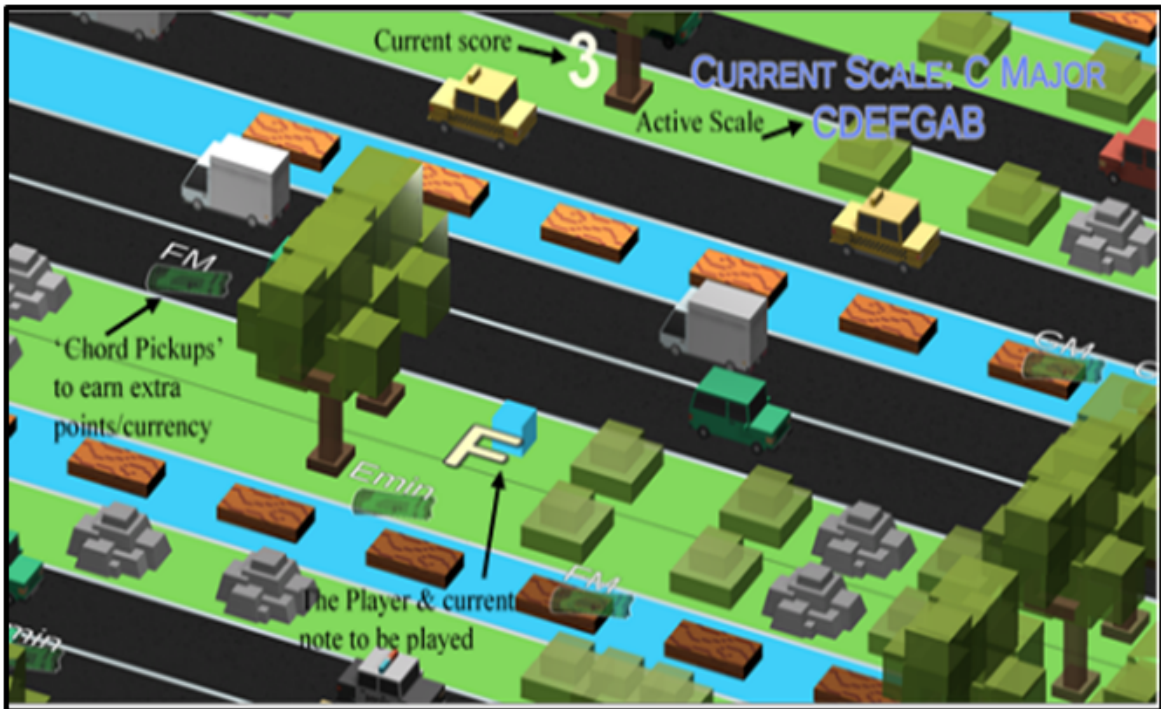
This prototype is not a typical learning game and as such its dedicated learning objectives are up for somewhat of a debate. The core of the game revolves around playing repeating scales which change over time (i.e. players input which scales they want to learn and these change over time). However, the nature of the mechanics and the idea of the game lend themselves to a broader range of learning objectives which have yet to be defined. One core concept is rhythm, which was later implemented; if players move forward in time to a certain tempo then they should be able to cross the road without being hit. The game helps practice rote areas of instrument learning; playing through scales as well as helping learners familiarize themselves with two hands at the keyboard.

Extensions of the Game

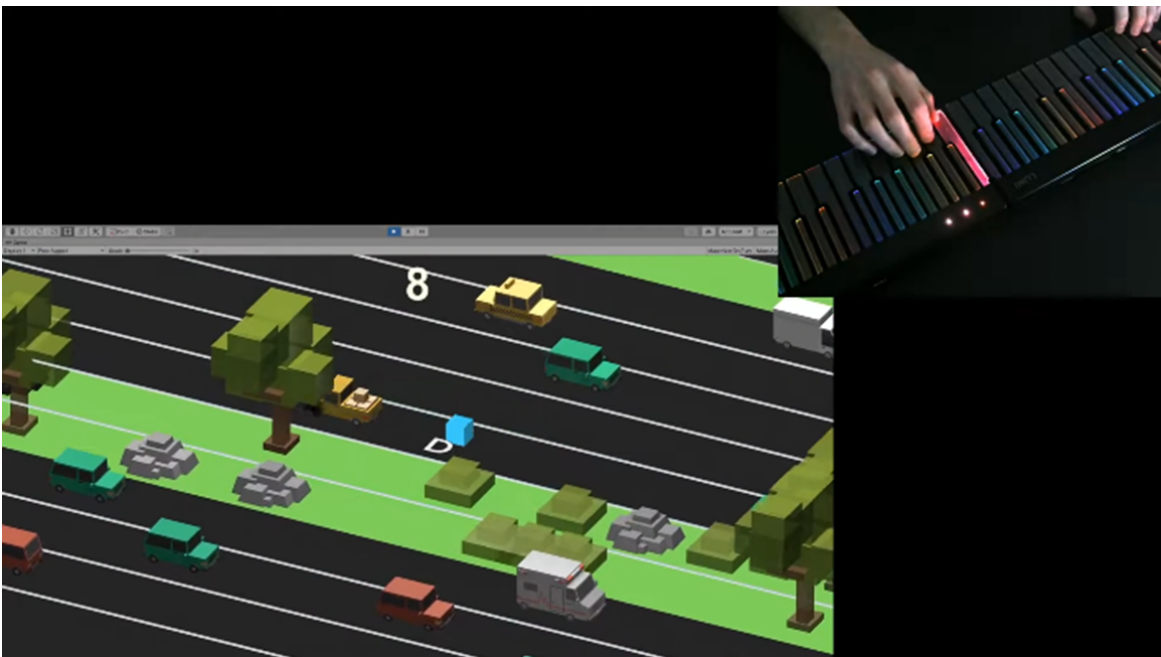
The game increases in difficulty the further the player travels. Difficulty is measured by a few facets; the scale itself (the mode of scale or starting from a sharp/flat key), the rate at which cars spawn and the average speed of cars. This means that eventually the player will loose and the incentive to play again is based around a need to beat their previous score or their personal best. Future directions that were considered include implementing 'levels' in which players must reach a goal rather than seeing how far they can go and this should help provide the player a greater feeling of accomplishment (completing a level consistently as opposed to constantly trying to beat their high score). Finally, additional learning objectives were required to be set and defined through user testing and development.

4.3 Testing the Mini Games

The first step in assessing the suite of mini games was running an initial small-scale study. The study would allow participants to speak freely about their prior learning experiences to



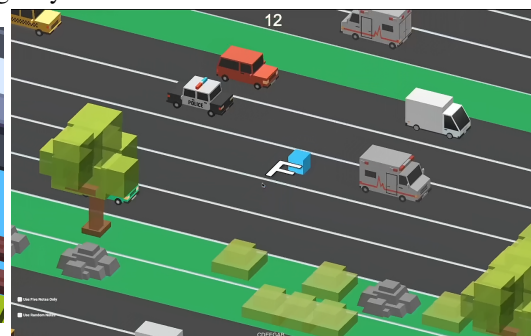
(a) Annotated Screenshot of Crossy Notes



(b) Crossy Notes Being Played with the LUMI



(c) 'Crossy Road' The Inspiration for this game



(d) Crossy Notes played during a study

Fig. 4.7 Mini Game Four: Crossy Notes

get a deeper understanding of the research's key issues. The sample was mostly reflective of the research's target population but was also extended to intermediate and advanced users as it was of concern of what current beginners were frustrated by but the common themes that other learners had faced in their early stages of learning. This is the first lesson other developers and researchers to consider: ensuring that their process is an iterative cycle of development and testing, with a key focus on testing more than actual development (as is apparent in the mini games - they were not overly developed which avoided wasting time developing assets which would eventually be forgotten about).

The study's goals was multi-faceted and the nature of the interviews was semi-structured as the research was still pin pointing specific areas of frustration and where video games would be most beneficial. The goal to improve the user experience and determine how educational a specific gamified experience can be. Specifically, the key questions of the study were:

- Why do beginner learners drop off/give up? Reasons for this had been established using secondary data and personal insights, but it was the decided that this would be explored and confirmed through the use of primary data
- Are the games developed focusing on the right areas and which game was the most ideal solution for the key issues, i.e., do they have the right scope?
- Were the games deemed enjoyable, within consideration to usability, time spent playing, difficulty, observed engagement, design and educational value?
- Regarding enjoyment, educational value and motivation, how can one measure these criteria empirically and furthermore, what lessons can be taken from the initial study to improve future ones?

4.3.1 Participants

Participants were recruited (N = 10) using opportunity sampling through mailing lists and also ones familiar to the researchers. Participants were mostly beginner musicians (or at least beginners in reading music), over the age of 18, a mix range of genders and, for the most part, had at least some experience playing video games.

Table 4.1 Study One Participant Demographics

Demographic Information	Age Group		
	18-24	25-34	35-44
N (Count)	1	5	4
Gender (count)	1M(100%)	3M(60%)	4M(100%)
Use Applications To Learn Keyboard (count)	1Y(100%)	3Y(60%)	2Y(50%)
Video Game Player (count)	2Y(50%)	3Y(60%)	2Y(50%)

4.3.2 Experimental Design

Before commencing with the play session, introductory questions were presented to gather insights into each participant's background. Overall participant information had been disclosed prior.

This study employed a structured experimental design to observe and assess learning outcomes through controlled play sessions with both gamified practice tools and training games. The choice of an experimental design was motivated by the need to establish clear cause-effect relationships between gameplay experiences and learning outcomes in music education. This setup allows for consistent data collection across participants, reducing variability and enhancing reliability in assessing the impact of these tools on music learning and retention.

In considering alternatives, data collection through analytics dashboards was considered as a means to gather data from a larger participant pool in a less controlled environment (which would later be revisited). An analytics dashboard approach would have allowed for real-time tracking of quantitative metrics such as engagement duration, interaction frequency, and learning progression across a diverse group of users. Additionally, retention metrics—such as returning user frequency and longitudinal progression—could be tracked and analysed, yielding valuable insights into the sustained effectiveness of these mini games. However, this study ultimately favoured an experimental design in a controlled environment to facilitate precise and comprehensive data analysis, given the study's focus on early-stage validation of game efficacy. Future iterations of our studies and games integrated game-based analytics to broaden the scope of data collection and enhance the generalisability of findings. In this case, we opted for precision and due to lack of resources were not able to implement such analytics at this stage (but this was a consideration that was built upon within studies during the latter part of the research).

The second stage of the study was the play session, in which each participant played each game (discussed prior) for five minutes. The games were categorised into gamified practice

tools (Note Flash and Note Typer) and training games (Note Stack and Crossy Notes). This categorisation helped in exploring distinctions between gamified practice and traditional video games, and to examine the point at which a learning experience becomes a gaming experience. The sole researcher observed each participant in real-time and via desktop live streams (in which notes were made and then cross sectioned using the video evidence). Each game was played using the LUMI keyboard, and games were ordered from least game-like (closer to brain training apps) to more game-like (similar to casual mobile games) to evaluate the shift in learning to gaming experience. After each game, participants were asked related questions in line with the study aims, with a final set of questions posed after all tasks were completed. Feedback was encouraged to ensure a thorough capture of participant opinions. This feedback was cross reviewed with the observational data and in-situ notes to ensure that participants feedback correlated correctly with the observational data.

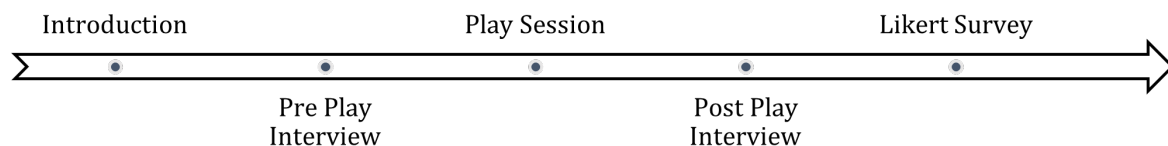


Fig. 4.8 Timeline of the Study Procedure

A comprehensive list of questions and the complete study protocol is available in the appendix.

Hardware Considerations and Setup

As the games developed were to be integrated into or alongside the LUMI learning application, the main hardware for this project, and the controller of each game, was the LUMI and as a consequence, games developed fit within the colour schemes of the keyboard – using aforementioned theories of cognitivism (Zinn et al. 2015) to reinforce learning through the use of colour.

The LUMI was placed in front of a MacBook Pro, along with an external webcam which recorded the participants hands during the session – this was to see how they used their hands and what impact playing a game would have on form (whether or not these games could be useful for improving executive functioning skills (West 2015a). Although participants were observed first hand, the MacBooks camera was used to record the participants reactions to each game, whether or not they were observed as confused, frustrated, happy etc. The screen was recorded during their play sessions to observe points of confusion and frustration as well as areas of high engagement – these recordings were made available to the whole research

team and were consulted during data analysis. Finally, the interviews were recorded using the microphone attached to the external webcam, later transcribing the interview data for analysis.

Future Proofing Studies with Game Analytics

In addition to the qualitative and observational data gathered, future studies would later benefit from crowd-sourced data collection and in-game analytics dashboards. Such data would allow the collection of quantitative metrics such as:

- **Engagement Metrics:** Tracking the time spent on each mini game, frequency of interactions, and in-game actions to assess player retention and attention span.
- **Learning Metrics:** Capturing performance data such as the accuracy of notes played, response times, and progression rates to provide objective measures of learning efficacy.
- **Retention Data:** Aggregating data on how often participants return to the game over time, giving insight into long-term engagement and skill retention.

An analytics-driven approach would later allow for broader data collection beyond the study's immediate setting, opening avenues for large-scale, cross-demographic analysis to gauge how learning retention and engagement vary among diverse participant groups. Analytics data could also illustrate the longitudinal impact of these tools, helping to identify learning patterns, skill acquisition rates, and the longevity of knowledge gained through gamified learning. As mentioned prior, this was not the case for this study due to the nature of the study and the restrictions of time and resources to implement such analytical capturing. Not only this but such an analytical was merely considered at this stage and we opted for precision in our study rather than attempting to gather large quantities of data. As the research matured so did the approach to gathering data and the analysis of such data.

Acclimatisation and Bias Considerations

To ensure a comprehensive and unbiased assessment of our mini games, we meticulously designed the learning experience for novice musicians. We implemented a progressive difficulty curve, commencing with straightforward tasks and gradually increasing complexity to mitigate learner overwhelm. Intuitive controls and explicit feedback were prioritised to minimise frustration and optimise engagement. Each game incorporated a concise introductory page or level where players could acclimatise to the game's mechanics and gameplay. Prior to any questioning or game interaction, a dedicated session was allocated for participants to

familiarise themselves with the games. During this session, participants were encouraged to offer feedback, though it was emphasised that this informal discussion period was intended to enhance comfort and comprehension of each game's rules and mechanics.

To ensure objectivity and reliability, we adhered to standardised procedures throughout the study, ensuring consistency across participants. We collected both subjective feedback and objective data, such as time spent playing and game performance metrics, to gain a comprehensive understanding of the games' effectiveness.

To ensure that our findings were applicable to a wide range of learners, we recruited a diverse group of participants with varying levels of musical experience, ages, and backgrounds. This allowed us to identify patterns and trends that were not limited to a specific demographic.

By carefully considering these factors, we were able to create a supportive and informative study environment that allowed us to obtain valuable insights into the effectiveness of our mini games in supporting music learning.

Ethical Approval and Covid-19

Ethical approval was received in line with the University's policy as well as any precautions relating to Covid-19 . Multiple precautions were taken for safety, adhering to the Government's policies and regulations. Participants were introduced to the researchers from a distance outside the premises before ensuring they were wearing a mask upon entry. Upon entry, all participants and researchers sanitised their hands and whilst conducting the study remained at least a foot apart in distance. Participants sat down at the desk where the study would commence and were required to handle the laptop interactions (i.e., opening each gamified solution) as to avoid any close contact with researchers and to avoid cross contamination of touch points. Finally, after each participant was finalised, the testing station was thoroughly sanitised before allowing the next participant to commence.

4.4 Results

Data was collected through multiple methods: recordings of both the participant and the recorded gameplay, observations conducted in real time and answers provided by each participant were written down in shorthand form and recorded during the interview process. As previously mentioned, the participants were varied in musical skill, from those who had musical degrees to casual musicians; only one participant had never participated in learning an instrument. The analytical approach needed to be flexible to respond to the differences

within the data collection methods utilised, thematic analysis (Nowell et al. 2017) provided this flexibility and was deemed the most appropriate method.

4.4.1 Music Education Insights

One of the first questions posed to participants revolved around their methods of learning, specifically asking, ‘How would you go about learning to play keyboard/piano?’. This was a useful question as it helped determine where exactly the prototype practice games would fit into an existing learners journey. Over half of the participants had used a teacher with a series of books (the most traditional and popular method for serious learners). Others had learned from their friends and families who were musicians whilst, surprisingly, only 2 participants had used learning applications, and their experience with them was quite limited. This helped to determine that most serious learners already have a method of learning the fundamentals and define their own unique learning journeys; what they required the most was a method of practicing skills which were applicable to the application of their learning and would help expediate the learning, rather than a method which tries to replace their whole journey.

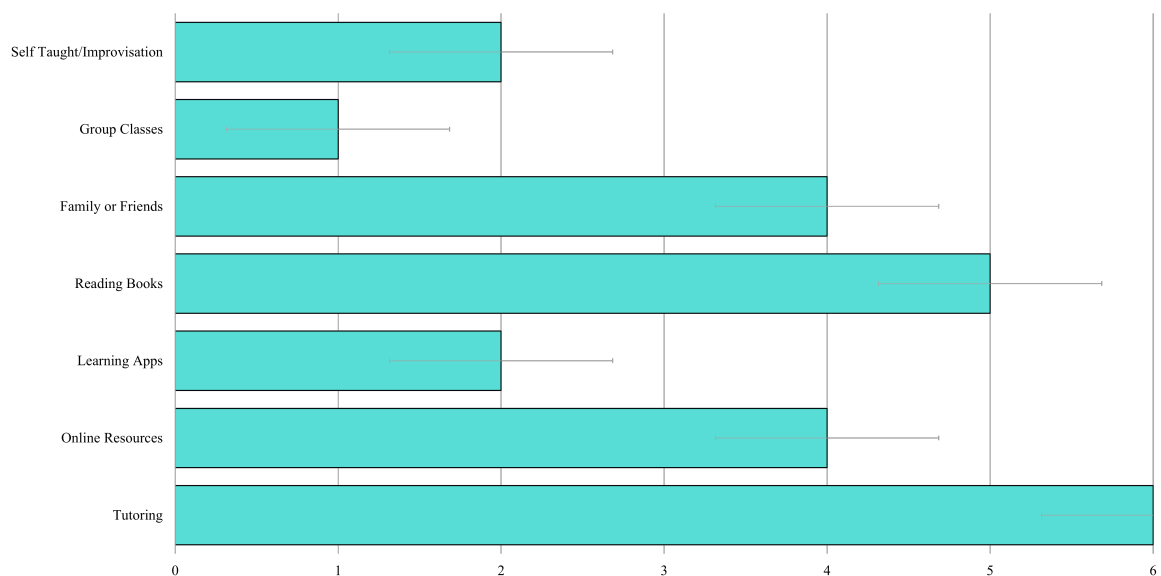


Fig. 4.9 Bar Graph Outlining Methods of Learning for All Users

Overall, it was found that most participants had at least some exposure to music education during the early stages of their lives, typically being made to attend lessons by their parental figures or were involved with music as their family backgrounds were musical. Those that had less experience or no experience at all, did not have this level of exposure or experience to music. Whilst they were avid music listeners, they had no connection to playing or

understanding, highlighting that for adults to have this type of exposure would require rote learning or at least a substantial amount of time committed to playing and practicing. The absolute beginners and lapsed consistently mentioned the lack of inspiration they had to practice on a regular basis and the frustration of trying to accomplish a task but struggling due to the lack of skills. It was clear that casual learners wanted to express themselves but never could and when seeking new methods of learning they were still hit with a wall which required consistent and tedious practice to climb.

It was established that the reason most of the participants eventually dropped out of learning music at some point was that they found no personal connection to it (the fact they were forced led them to associate negative feelings with playing). Tedious practices also led to negative connotations around playing and, finally, most of the participants wanted enjoyment out of playing; they never really saw the application of what they learnt and found typical ways of practising a bit bland and meaningless. The participants who had experience teaching, also claimed that it was difficult to get their students to practice on a regular basis and show up to lessons consistently. Whilst they thought the use of gamified learning applications could be useful, they worried that this method of teaching would lead to poor technique without the use of an experienced player to critique them. However, what the teachers could benefit from is a gamified method of practicing specific skills which could also grade their participants accurately regarding that specific skill. They claimed that there were specific areas of learning which would always be deemed as tedious such as finger exercises, practising reading or writing musical notation and learning patterns such as chord progressions and scales. They would prefer a suite of practice tools to work alongside their teaching rather than a replacement for the entire teaching philosophy.

4.4.2 Feedback on Games

To provide insight into how participants perceived each game, and how this can be improved upon, participants' responses to each game were analysed. Each participant was observed whilst playing the game, specifically looking at whether they were using the correct technique, were encountering frustration in specific areas, how engaged they were and how easy the system was to use. In addition to this, specific questions were asked relating to the Scope of Game, Design, Usability and Enjoyment/Engagement; this set of criteria was defined specifically for this research in line with the main aim of the project. This procedure was followed for each game before asking questions relating to the whole experience. Through analysis specific sub-themes were defined relating to the primary themes; whilst most sub-themes were shared throughout each game, specific critiques were also found for each prototype game. Below is a list of each of these themes and sub-themes. This is then

followed by an in-depth analysis of the data regarding each theme, for each game. Finally, a general overview of the games is provided.

Scope of Games

Three sub-themes emerged when reading through the transcripts in regard to the scope of the games (referring to the application regarding a specific educational objective). The application itself, improvements that can be made to ensure that it teaches the right content, and how the game could/would be used in conjunction with the participant's typical learning. Responses provided regarding the games' educational value and how well this was rated (using a Likert scale approach of 1-5 in terms of rating, with 1 being the least educational) were analysed.

Design

Three sub-themes emerged when analysing the data regarding design (the aesthetic elements). These themes were SFX and VFX, how the game 'felt' (regarding overall themes, mechanics etc.) and, finally, music related (this is different from sound effects and pertains only to how music was used in each game). It is important to note that the games were in early stages of development, so efforts made relating to design were mostly focused on the use of colours, specific sounds etc., rather than the quality of the design.

Usability

Usability refers to the overall user experience of the application and how easy or difficult it is for a user to understand the concept of the game, navigate menus and whether the game is too hard or too easy. Two sub-themes became apparent when analysing the data: difficulty and complexity (was the game too hard/too easy, was the concept too complex to understand etc.) and frustrations (what gave the participants frustration relating to how the game is played and/or the user experience is handled).

Enjoyment/Engagement

It was important to understand two concepts regarding the enjoyment of each game: was the game actually fun and are there trends in both what was observed and within the answers in order to provide criteria to improve upon. The second concept was interactivity (or engagement), referring to how interactive each game was, and this was mostly derived from observation; was the participant too distracted to answer questions and, did they want to

continue playing outside of the time limit? Through the use of Likert scales (1-5) participants also rated how much fun they had (with a rating of 1 being the least fun) and how likely it is they would want to play again, given the opportunity.

Note Flash

Below is an analysis of the first prototype game, Note Flash in which the results are discussed based on the pre-defined categories of scope, design, usability and engagement.

Scope of Game

All participants agreed that the idea of the game would be useful at the beginner stages as well as later stages. For example, the more experienced participants commented that the 'Chords etc. are good as it adds difficulty'. Observing the participants play also showed that they were using the right fingers to play each note and gradually stopped looking at the keys, showing confidence at the instrument. One participant stated, '[the game] forces you to learn note positions without looking at the keys'. What participants wanted was more challenge and this was typically in the form of rhythm or audiation skills. Participants wanted clearer sounds when playing the keys to determine the sound quality of it. It was apparent that participants were worried they would be reliant on colour and the application to something more organic, such as playing a song, could be missing.

Design

Participants had specific comments regarding design and mechanics. Most commented on the 'floating dust' (the particle effects) being a good thing, '. . . floating dust is also nice as it adds atmosphere', but a few participants stated that it distracted from the game and wanted to focus on the mechanic rather than how it looked. Regarding sound effects, almost all participants commented on the sounds played when answering a correct question (it was a satisfying bell sound) but they wanted to hear the actual note (a sound that actually reflected the actual note). Participants also commented on the sound and effects when playing an incorrect note, saying it was too abrupt and caused discomfort, 'the wrong sound is too harsh'. Finally, most participants wanted to know what the correct answer was if they got it wrong, otherwise they felt they would not improve/progress.

Usability

Most participants agreed that the game was the right difficulty and enjoyed that it started easier and gradually got more difficult. A few participants stated that the game was too quick to begin with, ‘... the timer is too tough on the first go and should start slower’. The concept of the timer and the core mechanic were easy to understand but, it could be argued, perhaps a little mundane., Adding additional layers of music such as rhythm should help address this issue. Most participants agreed that it was an easy concept to understand but navigating menus and actually starting the game was slightly confusing; ‘UI needs improvement’. Although the idea of agency is a common theme within games, a couple of participants mentioned that the sense of agency when attempting to learn something new can be frustrating and lead to feelings of anxiousness. Finally, the idea of allowing participants to choose their learning objective might not be ideal; participants seemed to want a clear path of progress to follow.

Enjoyment/Engagement

One participant noted that the game has ‘An addictive attitude’, in which they would want to come back and play again because of how easy it was to jump into and felt as though it had challenged their knowledge. What was deemed enjoyable about the experience was the challenge itself. When more experienced participants found the Chord Mode setting, they immediately became more interested and when they gave incorrect answers this did not deter them but in fact encouraged them to try again to beat their previous score and ensure they get the right answers next time.

Note Typer

Below is an analysis of the second prototype game, Note Typer in which the results are discussed based on the pre-defined categories of scope, design, usability and engagement.

Scope of Game

All participants agreed that this game had substantial application and could be used for further complex techniques. They agreed that the game would be great for practicing rhythm and fingering exercises; ‘A good learning tool; lots of application’. However, what participants requested was that they wished there was more structure and to sound as though they were actually playing a melody or being forced to play in time more, ‘Everything moves at different rates unlike sheet music that doesn’t move.’ When experienced musicians were introduced to

the 'phrase mode' they found this much more challenging and agreed that it could be useful for practicing basic rhythm control, correct fingering and reinforcing sight-reading. When participants played the 'two hand mode' they all struggled to look at both sides of the screen, opting to clear one side before clearing the other, indicating that this game is not an ideal candidate for practicing two hand technique. Participants could see this game being used as exercises to be employed in conjunction with their own learning methods, 'Good to start with/warm up exercises'.

Design

Most participants enjoyed the design of the game, commenting, 'Very much like other arcade games' and 'retro'. They all found the error noise a bit 'jarring' and almost all participants said that the notes 'exploding' was 'satisfying' but also detrimental to playing well, 'Explosions cover the notes too much', requesting that they are smaller or slightly more transparent. Most enjoyed the 'panic' when playing and trying to ensure that the notes do not fall below the screen; the idea of building up levels and consecutive right answers led to participants being more cautious and getting less incorrect answers. The most important aspect of this to note was the 'disconnection between sound of notes and the soundtrack'. Participants wanted to feel as though they were playing along with the soundtrack and the idea of playing notes as quick as possible resulted in the sound being 'clunky'. Finally, because this game was infinite (i.e. play until you fail) participants began to get tired of the backing track, 'I got sick of the same tune over and over again'.

Usability

Whilst the concept was easy enough to grasp, participants stated that they wanted a bit more of a challenge. The concept of notes falling was familiar with most participants, 'Used to falling of notes; akin to YouTube vids etc.', which made the game easy to approach. Frustrations stemmed from the fact that notes would be covered up by the visuals (the explosions) and this hindered how well participants could play and occasionally resulted in unfair game overs. Whilst the navigation of the game was deemed straightforward, as participants could see in real time what the different options meant (i.e., visual representation of options), they felt as though some explanation or acclimatisation was required.

Enjoyment/Engagement

All participants clearly showed states of 'flow' when observed and would struggle to comment when playing, being too distracted to do so. Participants claimed that the single note mode

was somewhat dull but found joy in getting multiple notes in a row correct and found playing out phrases the most satisfying and enjoying. The idea of notes ‘exploding’ when getting the right answer made participants more engaged with the game, ‘[Note Typer] is much more interactive!’ one participant commented when discussing this (in comparison to typical practice).

Note Stack

Below is an analysis of the third prototype game, Note Stack in which the results are discussed based on the pre-defined categories of scope, design, usability and engagement.

Scope of Game

Participants were split on the purposes of this game, some felt as though it could be a great way to practice scales, ‘Great way to learn scales as it is all laid out!’, whilst others did not associate this with the practice of scales and felt it was more about muscle memory. A number of participants (mostly those that had some experience) claimed that the practicing of scales typically includes playing up and down the scale whereas, in this game, one only plays up the scale (indefinitely). All participants commented on the fact that the audio did not match the visuals and when trying to place ‘perfect tiles’ on the beat (on the click of the metronome) they struggled as it was not quite right. Participants also felt as though showing the actual scale on the keyboard (i.e. highlighting the keys that belong to the scale) and showing the scale on an on-screen keyboard with correct finger placements would be more beneficial than just seeing it spelled out on screen.

Design

The main concern from the playthrough, from both observation and remarks from interviews, was that the visual of the shifting tiles did not match the actual rhythm of the metronome or backing track. This led to participants placing tiles incorrectly and having to account for this delay between sound and visual. Besides this, most participants enjoyed the design style, ‘the idea of chopping tiles when placing a non-perfect piece is equally satisfying and annoying’ and whilst the colours were ‘nice’, participants wanted the tiles to reflect the note they played (e.g., red tile for the note ‘C’). Whilst participants reported enjoying the simple and calming nature of the backing soundtrack, others commented on wanting to have more impact when playing each note; reflecting that the backing track should match what is being practiced.

Usability

Once participants had understood the concept, which almost all did due to the simple mechanic, they found the game quite easy. The overall speed/difficulty of the game did not increase gradually (to try and keep participants playing to a set tempo), but participants struggled to focus on too many concepts at the same time. Observing the playthroughs it was apparent that keeping in time whilst playing out a tonal pattern (the scale) was already challenging for some. In addition to this, participants also needed look at the screen to place tiles. This led to frustration when trying to look at too many places all at once, as one participant reports, ‘Annoying about focusing on the screen whilst trying to play’ whilst another notes, ‘[it was] disconcerting when you get a tile placement wrong’. A positive response stems from how easy the menu was to use; participants could see the result of changing options on the screen in real- time.

Enjoyment/Engagement

Participants reported that it was easy to use and had an ‘addictive quality’ but eventually the concept ‘would get boring’ because it is simply repeating the same mechanic. Participants wanted additional features such as going up and down rather than constantly going up and more focus on the performance of a learner, ‘... more like score attack about how I performed’. Finally, most participants stated that they would prefer previous games as they offer both fun and some educational value right away.

Crossy Notes

Below is an analysis of the fourth prototype game, Crossy Notes in which the results are discussed based on the pre-defined categories of scope, design, usability and engagement.

Scope of Game

One of the recurring themes regarding the scope of this game was that it needed to be broader, ‘[Crossy Notes] lends itself to a broader range of objectives’ as well as the game being more about ‘fluid movement’, which reflects playing keyboard. Although participants could use two hands, most found themselves finding this difficult as, ‘Left and right controls make it more of a game but less of a music game because hands are in weird positions’. However, most participants agreed that this would be a fun way to practice concepts such as scales or notes on a staff; a good number of participants commented that the roads/lanes look like a staff so were confused when the game did not play as they figured it would, ‘Could be

confusing as it looks like a staff'. Participants also wanted the sound of the player 'jump' to be the actual notes they played to help reinforce audiation skills, 'useful to hear the notes properly, game sounds are nice but use piano!'

Design

In terms of sound effects, participants reported that they enjoyed the 'arcade' sounds, such as the cars beeping and the jump sound of the character. As this game is based on an existing theme, participants were happy to accept this and welcomed the idea of such themes; most participants commented that this would be ideal for children but would prefer to see something a bit more abstract was it to be aimed at their age range. As this was based on existing games, participants also wanted to see more design regarding the character, 'Better to have a frog than a cube!' Participants also reported that there was much happening on the screen; the original game is a simple mechanic of one press and this game is more complex than this, so, attempting to marry these two concepts may have led to unnecessary confusion and a lack of educational impact.

Usability

Observing participants, it was apparent that the aim of this game was difficult to grasp. The concept of crossing roads and avoiding hazards was simple but when combining this with having to play a note, participants became confused, especially due to the fact the game looks similar to a musical staff. In addition to this, the speed of the game was too quick to begin with and participants did not want this to speed up over time; 'start slower!' one participant commented. One of the biggest frustrations revolved around when and how participants failed; when getting hit by an oncoming car or playing the wrong note ended the game. Participants struggled to actually acknowledge this and tried to carry on playing. What was clear from this game was that the keyboard was seen as more of a toy, '[the keyboard] is like a game controller, you do not really look at it when playing!'. Comments such as this help to reiterate the direction the research must go in next. The lack of options was deemed a positive aspect as participants could jump straight in.

Enjoyment/Engagement

Nearly all participants found this game enjoyable to some extent, as it received the highest Likert score rating for enjoyment, indicating that this game was deemed fun though, confusing in regard to the actual learning objective. Participants commented that this was 'more of a game' and that 'the music was fun and enjoyable', and 'the most addictive'. Participants also

mentioned the idea of using levels rather than an infinite-based mode, i.e., the idea of having something to work towards was more motivating than trying to beat a high score each time.

Favourable Games

As mentioned, part of the post play interviews asked participants to give Likert scores regarding each game's educational value and enjoyment. Whilst this is quite a subjective method of assessment, enjoyment was defined by asking participants how much fun they had in comparison to playing a typical video game or whatever their typical recreational activities were. Educational value was defined as how useful it would be for each participant when using the tools in conjunction with their own learning methods and whether or not they would seriously consider the practice of these skills beneficial to their playing. Not surprisingly, the games which focused on existing video games were deemed the most entertaining but lacked the educational aspect and vice versa for the games which resembled more of a learning exercise. Whilst the margins were rather slim, it was evident that the boundaries needed to be pushed further whilst also focus on assessment methods which were not so subjective and could be replicated by other researchers, i.e., there was a need for more empirical methodologies and to ensure the methodologies could be highly reliable and validated.

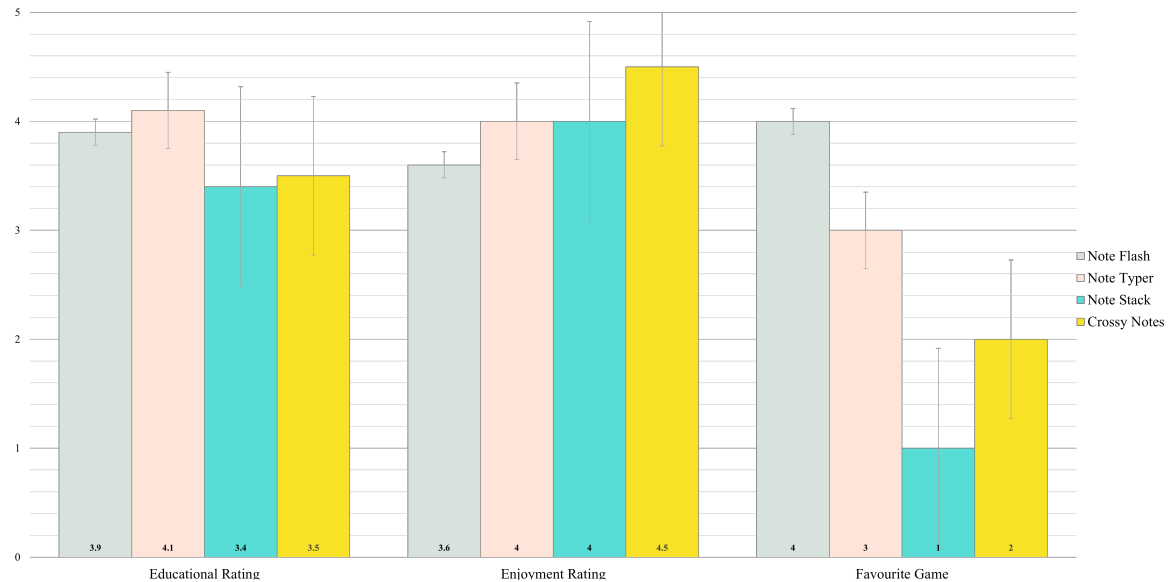


Fig. 4.10 Educational, enjoyment and favourite game Likert scores for each game that was featured in the study

Each participant was also asked what their favourite game would be and if they could offer insights and reasons as to why they chose a specific game. The two most popular games were Note Flash and Note Typer. Reasons provided relate heavily to how beneficial they are

to improving musical skills as well as being ‘simple and effective’. Both Note Stack and Crossy Notes received at least a vote for the favourite game question, but most participants stated that this was because they looked most like a game and would only use them if the scope was defined, and the mechanics had been refined. Once again, participants wanted the solutions to resemble games more so but needed them to be just as educationally valuable as their typical practice.

4.4.3 General Data Overview

There were some overlapping themes and changes which could be applied to all prototypes and considered when developing additional concepts. This includes:

- Showing an on-screen keyboard to demonstrate scales, notes etc.
- Feedback the correct answer when a user plays an incorrect one in order to encourage progression and improve overall effectiveness of the education
- Each game requires some form of acclimatisation if there is to be no researcher interventions, simply adding a tutorial is useful but further developments should try to implement lessons throughout and balance the difficulty based on performance of the individual player
- Menus and UI need to be simplified in terms of options and how obvious each option change is

Finally, participants were asked to rate how likely it was that they would recommend the game to a budding learner, all participants scored either 4 or 5 out of 5. When asked to rate how likely they would be to use the tools themselves, all participants said that they would be very likely to with some participants stating that it would be great for purposes outside the typical lessons, ‘A good use would be for travel’. Finally, all agreed that focusing on the practice of these specific skills would encourage them to play more and find more enjoyment in doing so.

4.4.4 Discussion of Results

This section explores the results from the pilot study, tying in the takeaways from Chapters 2 and 3. The contributions of this chapter aims to show how gamified learning and music education are rooted in addressing the key gaps in outlined prior by demonstrating how game-based learning can improve traditional instruction and practice. Additionally, the

consequences for our implementations in music education are discussed, as well as the study's limitations and what this suggested for future methodologies.

Establishing Research Position and Contribution to the Field

The findings of this pilot study confirm and extend existing knowledge on the issues of music education and gamified learning. Research has shown that consistent practise, especially in the first few months of learning, is difficult for many learners because their motivation is fragile at that point. The study's interviews repeated this reinforcement with participants frequently saying the lack of engaging tools to practise foundational skills was frustrating and resulted in disengaged attitude towards learning. An often cited point in the literature as foundational skills for beginner musicians are reading notation, rhythm control, dexterity of the hand and fingers, and the ability to audiate (sense and make sense of) a piece in one's head. However, the participants' consistently observed that they lacked a method by which to improve these skills efficiently or enjoyably, and thus require tools that blend structured learning with exciting experiences.

The more experience musicians and instructors echoed these statements, adding that since these tools could supply students' with the same, targeted practice, it could potentially help them as well. Overall, they expressed optimism about the idea of using mini games to align teaching goals and said that they thought such tools might improve learners' consistency in engagement and lengthen their musical journey beyond initial forays.

However, prototypes associated with the study showed how even in a formative way, gamified tools could help to address these issue. One of the best demonstrating facilities for simple mechanisms is in games like Note Flash and Note Typer. But the results also identified some of the limitations of the design. Participants were able to recognise the concept of a musical staff but found no explicit correspondence between the games and a musical staff. This provides us critical feedback as to how we need to further ground future designs in conventional musical notation so that the games have real world purpose.

Another critical gap identified was the lack of rhythm and tonal elements in the games. Participants highlighted the absence of musicality in the prototypes, emphasising the need for rhythm-based challenges and melodic patterns to create a more authentic and educational experience. This aligns with gaps noted in the background review, where existing tools often failed to integrate meaningful musical content into their design. Incorporating these elements would not only enhance engagement but also provide a deeper connection between gameplay and the skills learners aim to develop.

Despite these limitations, the study provided important insights into how gamified approaches could transform music education. While it remains uncertain whether such games

can directly improve specific skills, the findings suggest that their engaging nature makes them a valuable supplement to traditional learning methods. The study also highlighted the need for a more focused approach to game design, narrowing the educational scope of future prototypes to allow for more precise evaluation and skill development (something that was missing from the research in literature at the time of reviewing it).

Limitations and Implications for Future Research

This study was conducted at an early stage of our research, with several limitations that shaped the scope and reliability of its findings. The use of qualitative methods was hampered by the fact that they are both invaluable in capturing participants' perceptions but lacking in rigour and replicability if we are to make broader generalisation. This mirrors a larger problem in gamified learning research in which subjective evaluations tend to dominate empirical and objective assessments (as we found when reviewing the methodology of other approaches adopted in this domain).

With regards to breadth, as with its educational objectives, the pilot study also had its challenges. The prototypes risked losing effectiveness in any single area of music learning, like sight reading and rhythm, trying to address several at once. In order to limit participants' playtime, we restricted playtime to five minutes per game, denying us a means to assess long-term engagement, or skill acquisition. The need for the game to complete in this short duration, would have been a result of the limited content in the prototypes but at the same time the implication for more robust and extensive game design was highlighted.

The validation of the qualitative instruments used was also another limitation. Some of the findings were difficult to ensure reliability of without grounding the questions in established frameworks for measuring constructs and here I would like to talk about engagement as an example. The open ended nature of the study compounded this challenge, while the study was useful for exploring purposes, rendering results difficult to divine as to games' impact. This quest to understand the educational impact and implications on a learners habits was a tricky one and reflected what we had found in prior research reviews; where no single process or pattern was adopted and typically left more questions than answers.

We would consider ensuring that future research place more precise and more replicable methods to address these limitations. Such design, for instance, might entail narrowing the educational objectives of games, for instance applying such design to teaching players how to sight read or telling time easily, to be designed to support simpler evaluation. Furthermore, their playtime should also be extended and loosely defined to let the users free play the games to understand their patterns of natural engagement without direct factors.

Additionally, combining the qualitative insights generated through mixed methods approaches with quantitative metrics could further contribute to understanding of the effectiveness of the games. Metrics such as playtime, accuracy, and progression, combined with physiological measures like heart rate or eye-tracking, could offer a richer and more objective perspective on engagement and learning outcomes. Standardised tools for measuring constructs like flow and difficulty curves could also enhance the study's validity and reliability, allowing for more rigorous comparisons across different prototypes and studies. These approaches in our methods would later be implemented, building upon the weaknesses that were observed when consulting previous literature and examples. We wanted to tackle this problem pragmatically and empirically rather than by looking at it anecdotally (as is often the case in this domain).

Recommendations for Game Development

The pilot study revealed that the simplest games often yielded the most positive feedback, suggesting that intuitive, accessible mechanics are key to maintaining learner engagement. However, the findings also highlighted the need for deeper integration of music-specific elements to enhance the educational value of the games. As we found with previous research, the experiences that were received most positively had layers of gamification and game theory embedded into their core gameplay. Games such as those by Raymakers (Raymaekers et al. 2014) and specific XR experiences (Hackl and Anthes 2017) were great at engaging the learners but lacked the educational value.

More efforts needed to be made on future iterations to embed rhythmic challenges and melodic patterns to bring in more of an authentic learning experience. Adding sound effects that correspond with actual musical notes and chords would strengthen the connections of gameplay to musical skills, namely audiation. In addition, game mechanics must be more closely mirroring music education, such as adaptive difficulty, immediate feedback as well as a progression of skill, to form a structured yet engaging learning journey.

Another critical recommendation is to make the educational focus of each game narrower. Developers can focus on particular skills, like sight reading or rhythm, to create more personal, more potent learning experiences. On the other hand, this also eases better measurement of the impact of the games so researchers can make more specific judgement on game's effectiveness.

Retrospective Potential for Statistical Analysis

Although this study was based on qualitative research, the findings of this study indicate the potential of including statistical analysis in future research. Metric quantitative data, such as playtime, performance and participant engagement could offer a more objective, more nuanced understanding of the good and bad points of those games. The generalisability of the findings would be better enhanced through statistical analysis in which researchers will be able to generalise the impact of the games on music education. As we established throughout our review of existing solutions, the evaluation of such experiences and tools are often overlooked and a observing or simple comment approach through unstructured interviews is adopted; trying to stray from this we wanted to approach this in the most empirical way possible so our findings would have greater and longer lasting implications.

Future studies that take a mixed methods approach would help uncover patterns and trends hidden in purely qualitative data. For instance, monitoring of a participant's accuracy or response time could be used as direct evidence of skill improvement or monitoring of voluntary play in sessions outside of prescribed play could serve as proxy measures of sustained engagement. Traditionally, gamified learning tools such as these would be pretty weak arguments in support of the gamified learning tools as viable supplements to traditional music instruction, but such data would provide convincing evidence that gamified learning tools are effective supplements to traditional music instruction.

In addition, the statistical analysis could form standardised frameworks for the evaluation of the educational impact of mini-games. With this, we would be able to go past subjective opinions and make our understanding of how these tools can be applied in music learning more empirical. Quantitative measures could then be used in longitudinal studies to monitor how gamified learning affects the long term development of specific skills which would provide insights into whether or not this learning could in fact be a transformative path for music education.

4.5 Chapter Conclusion

This chapter explored the individual mini-games that comprised our initial suite, used in the first pilot study. Through qualitative analysis techniques, we determined that our approach was unique and positively received by both teachers and students. Our research contributed to the broader understanding of how game-based learning can be effectively applied to musical education.

The need to objectively assess the pedagogical value and engagement of these games in real-world settings became a crucial finding. As a result, we decided to focus our future

research on a specific skill area: reading musical notation. The subsequent chapter outlines the rationale for choosing this skill and discusses the relevant games and their development.

The development of this mini-game suite represented a significant methodological contribution, demonstrating an iterative approach to educational game design. By capturing feedback from current beginners and potential instructors, we refined our understanding of how gamification can be effectively applied to music learning. The findings from this chapter not only guided the direction of our doctoral research but also laid the groundwork for more comprehensive game development in later stages.

The final concept, "The Crypt of Notation" emerged from this iterative process, leading to a remote, longitudinal study conducted in the final year of the doctorate. By incorporating quantitative measures and conducting a more rigorous longitudinal study, we aimed to provide a comprehensive and objective assessment of the mini-games' effectiveness in promoting music learning.

Ultimately, our research at this stage aimed to establish a stronger evidence base and contribute to the development of game-based learning tools that can make musical education more engaging, accessible, and effective for musicians of all ages and skill levels.

Chapter 5

Reading Musical Notation Games

5.1 Chapter Introduction

Thus far, there were two key issues which were derived from the initial study and first set of games. Firstly, the games were not so much games but various takes on trainers found on marketplaces or in literature and were replacing simple existing mechanics with a simple learning objective, such as, tapping to a beat (they were not quite learning-based games). Secondly, each game was focusing on improving a different set of skills in which there was no way to determine if the game was improving that specific skill, especially using qualitative methodologies which lacked objectivity. The initial goal that had been laid out was to build a set of games to help practice specific skills, building a foundation for beginners to ensure that learning to play a piece of music was more attainable and demanded less cognitive load (i.e., associate practice with less frustration and increase the likelihood of continuing to learn to play). However, there was no framework to follow when designing these games nor did every skill have a robust method of assessment which could help ensure real-world application and focus on the transferability of that skill to other areas of playing or learning keyboard. Whilst a review of methods for assessing musical capabilities or aptitude as a whole had been conducted, mostly consulting the domain of psychology (Law and Zentner 2012, Zentner and Strauss 2017), these forms of assessment were more interested in general musicality rather than the specifics of learning an instrument or measuring a specific skill.

Therefore, the direction was to focus on acquiring or improving a specific skill in which a framework of design, development and assessment would be built that could later be applied to any other area of skill or school of learning. Using this framework, the future idea was to develop a suite of games which would then be used in a longitudinal study against a control group that uses traditional forms of practice, helping to determine whether or not

this game-based style of practice would have serious applications to learning and build skills which were transferrable to playing a piece of music.

In the pursuit to develop games for a specific skillset, the fundamental components of learning to play of piece music were reviewed, where some aspects were derived from the definition of musicianship provided by West (2015a), but were also fairly logical. These components were rhythm (i.e., ensuring one can play to a set tempo and that their music flows correctly); executive skills which heavily revolved around using correct hand positions and fingering techniques to ensure that parts of a piece which were made up of faster notes or complex arrangements were able to be played fluidly and avoid injuring oneself; audiation which would help learners recognise if they were playing incorrectly by ear and to build further muscle memory between visual (notation), physical (the keys themselves) and sound. The final component, which was chosen to develop further solutions for, was reading musical notation (which later was defined specifically as the relationship between a physical key and a visual position on a musical staff). Whilst one could learn to play a song through audiation alone, for most adults who have a lack of experience, this is tricky. Although practising executive functioning skills, such as specific techniques to navigate the keys fluidly, is fundamental to playing a piece of music at the keyboard, it is irrelevant if one cannot read the music they see in front of them. Rhythm was inherently more enjoyable to practice than the other skills, highlighted by the fact that there is a huge industry for rhythm games alone; building practice games for this skillset was deemed redundant and our contribution would only be in the form of assessment in which there is already a large number of contributions. Finally, all of the skills except for reading musical notation, could be incorporated into a game and considered additional mechanics. For example, Note Typer was later extended to be played with rhythm in which additional points were rewarded for playing on the beat as well generating specific phrases to be played to improve hand and finger dexterity. The next round of development revolved around creating new solutions, and improving the current prototypes that were taken forward from study one, with this particular skillset in mind.

In this chapter the various games that were designed and developed for the specific purpose of improving a learners ability to read basic music notation are described. These prototype practice games fit into specific categories: basic trainers, gamified trainers, arcade style training and finally, concepts which portray video games rather than typical trainers found in the marketplace or literature ('training games'). Through the process of iterative development, 6 solutions were developed which fit into the above categories. This chapter also outlines the second study which was conducted to assess the novelty of the solutions, pursuing a more quantitative and replicable approach to assessing both engagement and usability – using questionnaires which have previously been validated within this area of

research. Finally, as the participants for this study reflected the target population more accurately than the first study, further insights were gained into both learning and gaming habits – strengthening the argument regarding both the problem statement and the consequent solutions already developed. These prototypes and models of assessment helped solidify the idea that a practice solution should focus on one core skill whilst also incorporating other areas of music and skill which have transferability and application to real-world learning.

5.2 Notation Reading Games

Two games were developed further from the first round of prototypes: Note Flash and Note Typer. During this round of development, there was a decision to categorise each game into specific groups which have already mentioned - each group is described below in more detail as well as each game that was developed for that group. These categories were to help further determine the balance between an experience which is more of a video game and an experience which is a simple practice tool; categorising each game would help reveal which group was most appealing to specific learners/users and allow the development of games within that specific category (an attempt at organising concepts rather than developing individual solutions which had no real direction). For this phase of development, internal testing was mostly used before running a second study, which is detailed later in this chapter (see section 5.3). Below is a discussion of the key additional developments made at this stage; improving upon the limitations of the previous processes and taking into account the more generic lessons that were discovered in the previous study. Further details about the specific categories that were defined and each game that was developed for each category are then explored. If it was an existing solution then the discussion regards the additions developed and how the game was expanded regarding the design. For all developed solutions the key lessons that were taken into account based on previous insights are explained, as well as various inspirations that aided the design process and an overview of how the solutions are played with their various intricacies.

General Improvements

The same process was followed as the previous development cycle except with the focus on internal testing and validation rather than external. The focus on internal testing was followed for a number of reasons: it was cost effective; it was already established that there was a place for these novel methods of practice and there was high amounts of similarities between the first study feedback and the feedback received internally. The second study was

based on the six key games but the use of internal testing help to narrow in on these games, to help focus on specific designs and smooth out mechanics.

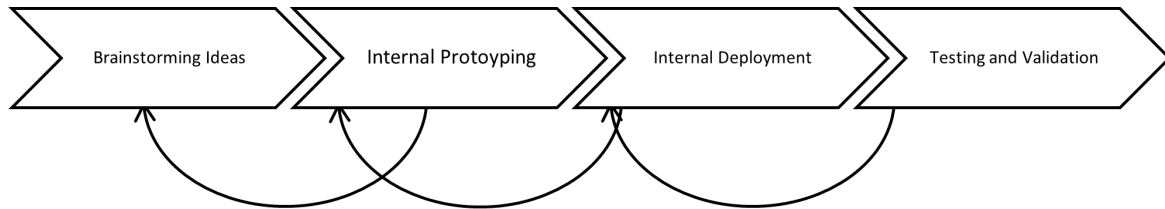


Fig. 5.1 Development pipeline for the second set of games, focusing on mostly internal testing and validation

Concerning the programming and the ‘backend’ of the prototypes, there was some refinement as well as some overall additions that were implemented based on the feedback gained. As much of the feedback revolved around including more music and rich sound effects the developments began to investigate the most efficient and effective way of implementing this. Initially music was sourced from open-source libraries and used samples of sounds which were played when playing specific keys. Typically, a sample that was chosen at a certain pitch (e.g., C5 would be the same pitch as ‘middle C’) then shifted the pitch depending on which key was pressed using a simple power algorithm (see below for further information). There were a few issues with this implementation: the songs found did not include their BPM making it tricky to build rhythmic elements, finding the exact sound effects proved tricky and the pitch shifting led to inconsistencies regarding the length of notes played (as increasing/decreasing pitch would naturally change the speed of the sounds). These issues were overcome with the incorporation of an in-house synthesiser into the project - using the Audiohelm plugin for Unity (Audio Helm for Unity, 2014). With this plugin, it was possible to load patches into Unity and play specific samples which had already been created (rather than creating new ones by manipulating pitch).

$$F = c * 1.05946^n$$

(a) Calculating the frequency of each note would require taking a base frequency, typically the lowest note possible, and multiplying it using the above equation; where c equals the base frequency and n is the number of semitones

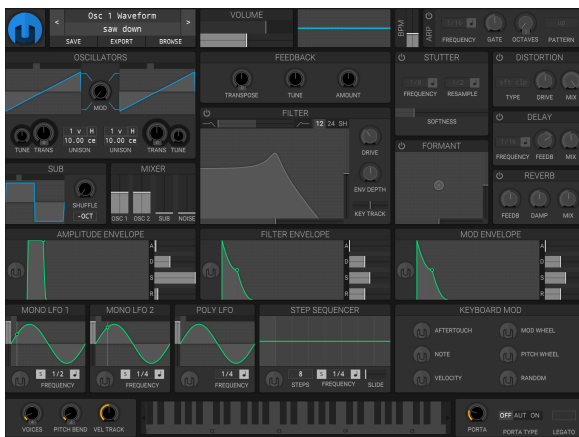
$$F = 1.05946^{12} == 2$$

(b) As demonstrated, if one sets the power to 12, the value equates to 2 (i.e., raising the pitch by a whole octave)

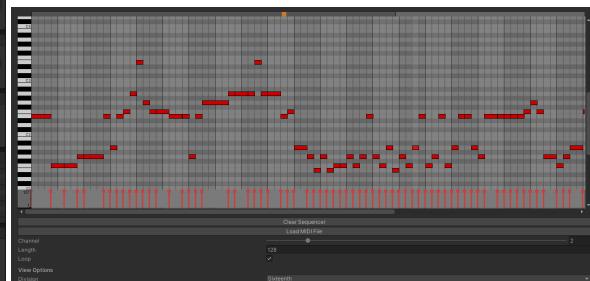
Fig. 5.2 Manipulating pitch by multiplying frequencies

The issue of rich music was solved by creating a simple but effective generative music system. The system worked by selecting a random note from a set of notes which could

be chosen by the user, in which there was a minimum and maximum number of octaves that the note could be chosen from (e.g., a user would input ‘middle c’ with a minimum and maximum number of octaves set to one and the system could pick a ‘c’ note from an octave above or below the ‘middle c’). There was another variable defined as ‘density’, that essentially defined how spread the selected notes could be – the higher the density, the more spread out the notes generated would be and vice versa. The plugin included a sequencer, where one could set the length of the generated song (typically in factors of 8) and the division of the length (again, typically in factors of 8) telling the sequencer how often to play each note (e.g., if it was a length of 16 and a division of 16 then a note would be played every beat without rests for 16 beats). Using the sequencer, one could generate a series of notes based on the length and this would be outputted to a specific audio channel. Later each game implemented multiple generators which would play bass notes as well as lead notes – setting the specific BPM for the sequencers to play to using a simple audio clock. Finally, specific drum patterns were created which would be chosen at random when generating the music and would add a steady drum beat. Combining multiple generators and a drum beat led to satisfying music with an obvious tempo, helping to play to the beat and improve basic rhythmic skills.



(a) Audio Helm's standalone patch creator



(b) Audio Helm's sequencer seen in Unity

Fig. 5.3 Audio Helm

Another major contribution to the development of the prototype games was ensuring that the music and metronome in which users would play to would maintain consistency, as it was found that the first set of games would often fall out of time and this would frustrate the players/learners. To overcome this required moving the components which tracked sound or tempo outside of Unity's update method, a method that updates every ‘frame’ which can vary significantly for each device (a high-powered computer will have a much higher frame

rate than a mobile device, for example). This meant that each game could not rely on Unity for maintaining consistency of tempo for the games as it would eventually fall behind or become too fast. Therefore, these settings were based on more precise measurements using the Unity's Audio settings – this implementation was derived from an online guide (Tattersall 2019). First, beats per second were calculated by dividing the provided BPM by 60 (i.e., a minute). Then, using the time that audio settings could provide, (Audiosettings.dsptime) which would measure time independently of any other methods within Unity, the beat per second variable would constantly check (using enumeration) if the audio time would go over this variable - if it did then another beat per second would be added to the same variable and checked again, constantly repeating this. Using this implementation, actions were executed or determined if the player was playing on time every time the time went over. This was extremely accurate and led to almost no inconsistencies which was great for syncing visuals over extended periods of time. However, because it was so accurate, it was quite tricky to actually 'play on the beat'. Therefore another variable called 'difficulty threshold' implemented, which would be a small fraction of time either side of the beat to allow for easier playing. This would later be used to add various scores to how accurate players would hit the keys on the beat (defining this as 'early', 'perfect' or 'late' depending on when the note was played).

Basic Practice Tools

The first category of practice solutions begins with the most basic premise learning based game and was used as the baseline comparison for the other games. These solutions are replications of simple practice tools found in the marketplace and focus on function with a lack of gamification or game design. During study one, the results indicated a positive response to simple practice tools as they offered a simple but effective approach to practicing a specific skill without the distractions of gamification. Essentially, the idea was to determine if learners preferred a simplistic approach to practice as it was inherently easy to understand and effective or would they prefer something which resembled more of a game; this category helped create a baseline of comparison to answer this question and to compare against more gamified approaches. This category features two solutions: Note Trainer and Note Flash, which are described below.

Note Trainer

Note Trainer is a tool which helps learners build familiarity of notes to physical keys and later to musical notation. This game is based on Note Flash, except with as little gamification

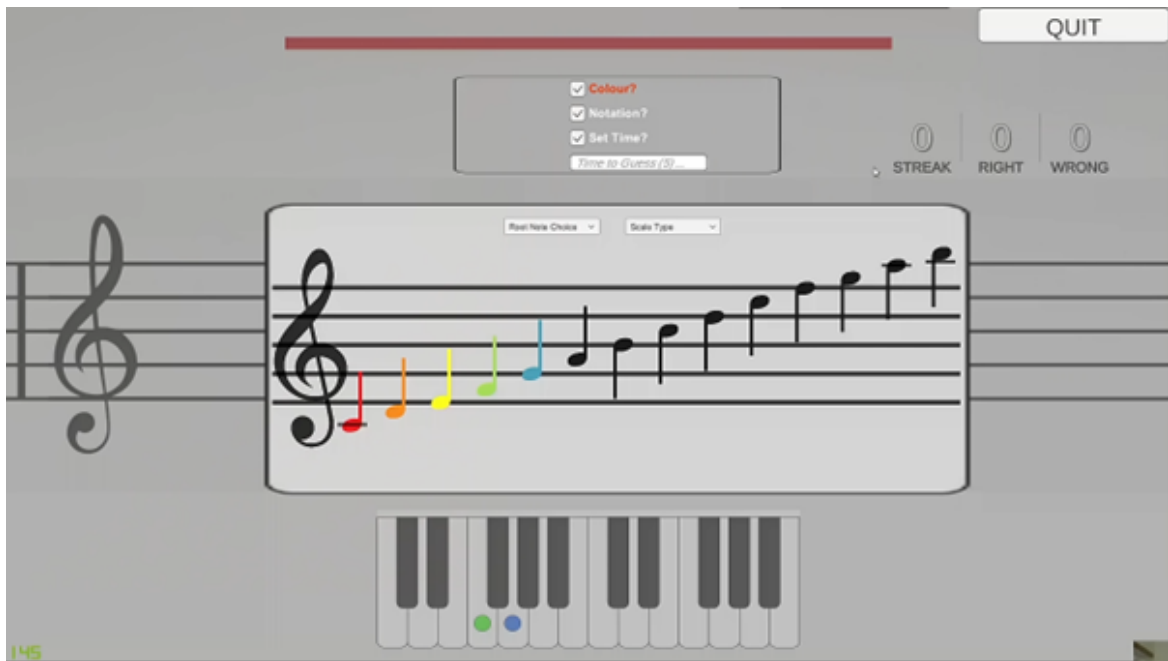
as possible and focused on the functionality of the tool more than the experience of the player (i.e., the opposite of gamification). Similar applications online were reviewed for inspiration, and it was found that they all followed a similar pattern of choosing notes to practice then being shown these notes (with the exception of some implementations (noa 2012, AB 2020, KORTX 2017) which built a series of levels for players to follow and were typically aimed at children). Players could either choose specific notes or pick a particular scale in which notes would be randomly selected from. Players could also choose if they wanted to be shown the letter representations of the notes (useful for absolute beginners) or if they wanted to be shown notation. All of these representations could also be shown with or without colour (which was useful when playing in conjunction with the LUMI keyboard as the colours would match one another). There were three modes available: infinite mode where players would keep guessing correctly and get a game over if they get an incorrect note (how many notes in a row could they get); timer mode where players had to guess as many correct notes as possible in a specific period of time; clock mode where players had a small window of time to correctly guess and if it was correct then more time would be added onto the clock which would get increasingly more quick, eventually too fast to correctly guess. These modes with the addition of score (showing total correct, incorrect and correct guesses in a row – the streak) were the only main aspects of gamification. As the game was inherently simple there was no tutorial except for showing an on-screen keyboard which would highlight the correct key after a number of incorrect guesses.

Inspirations and Insights

This game was heavily inspired by Note Flash and incorporated lessons from the initial study: an on-screen keyboard was implemented, the sounds were accurate representations of the note played and if they player continually gave incorrect guesses, they would be shown the correct guess on the on-screen keyboard.

Note Flash

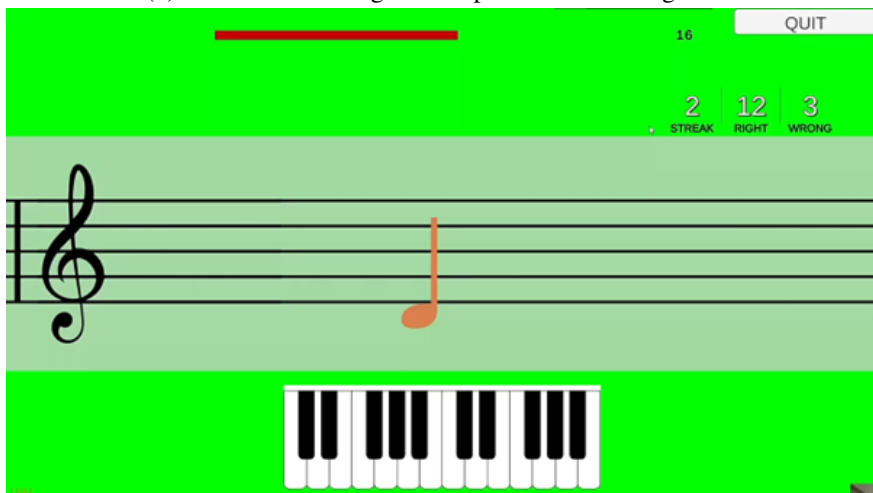
The development of Note Flash continued on from the first phase of development as it was one of the prototypes that was rated highest in all categories. Taking on board the feedback from the study regarding the desire of rhythmic elements and UI, an on-screen keyboard was implemented and a new mode which showed smaller notational cues in a circle. Players had to play the correct key when the ‘tempo bar’ crossed over the corresponding notation, in an attempt to incorporate rhythm (see screenshots for more details). An extension prototype was developed in pursuit of adding rhythmic elements to Note Flash, where notation is revealed



(a) Note Trainer menu: this setup menu was implemented for every game at this stage



(b) Note Trainer being used to practice note recognition



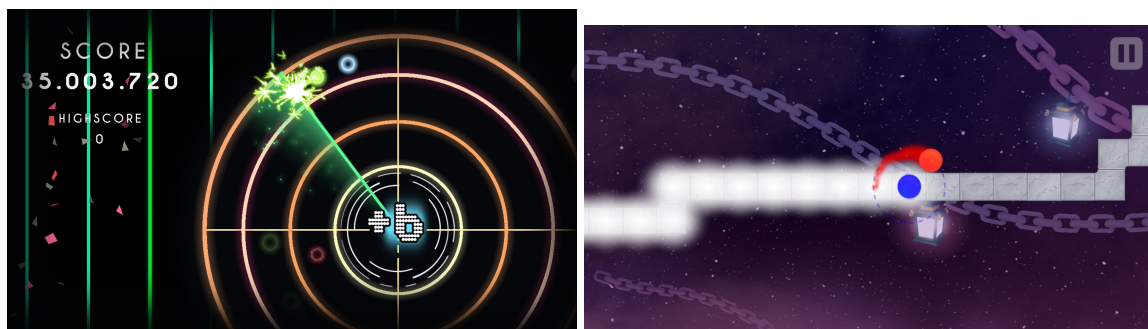
(c) Note Trainer used with notation and 'timer mode'

Fig. 5.4 Note Trainer screen shots

on a horizontal axis and a ‘rhythm bar’ moves from left to right – players must play the correct corresponding key to the tempo to score; the use the circle representation of rhythm appeared to reflect the concepts of rhythm more logically and allow fluid repetitions.

Inspirations and Insights

Whilst inspirations have already been discussed in the previous chapter, a review of more games for inspirations into incorporating rhythmic elements into Note Flash was conducted. This review was specifically concerned with rhythm games and found that using some form of visual for the ‘tempo’ was useful as relying on audio alone proved quite tricky. This idea of visualizing rhythm with the audio proved to be both a valid aid and a satisfying mechanic. Whilst most games create their own tracks and specific beats, it found it most efficient and pedagogically valuable to base the rhythm on simple but recognisable time signatures (which would add transferability to a learners practice). Finally, another common design in rhythm games was to increase the tempo over time (typically using the ‘ascending arcs’ design (Holleman 2019)) but it was found that doing so would distract learners and lead to frustration when the action was overwhelming.



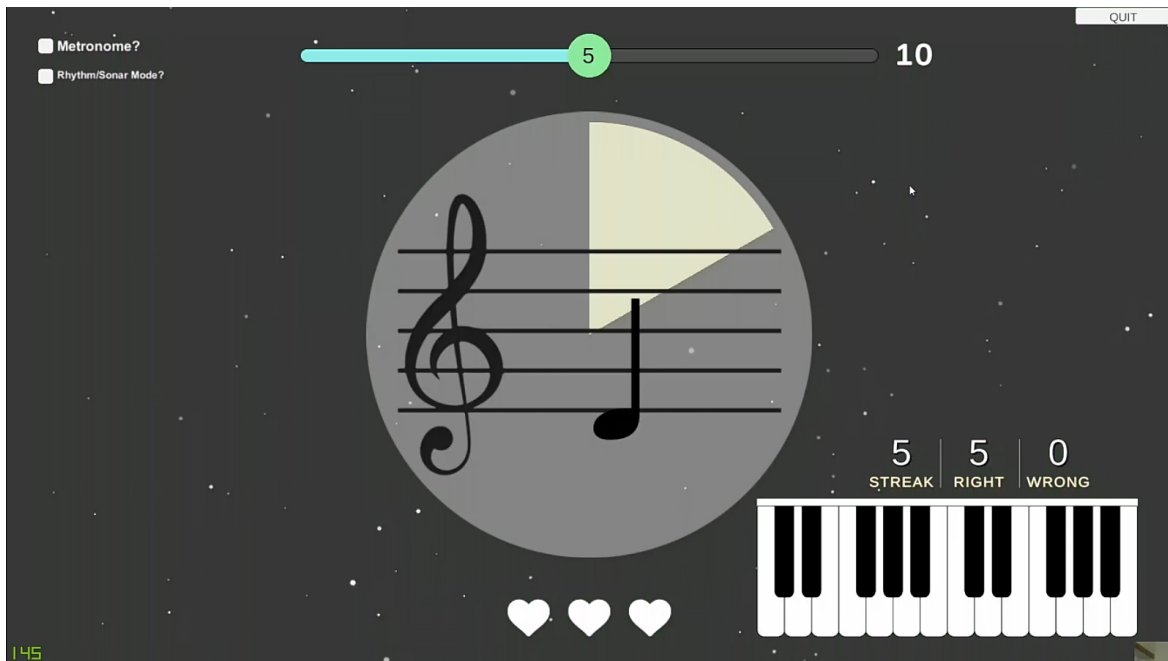
(a) Zero, a rhythm game in which the design replicates a ‘sonar’ graph

(b) 7th Beat Games a unique style rhythm game

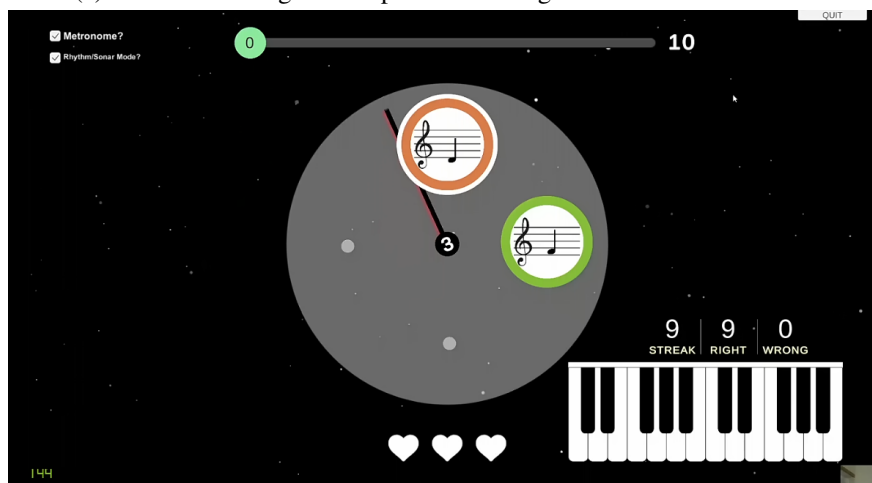
Fig. 5.6 Various Inspirations for Note Flash

Gamified Practice Tools

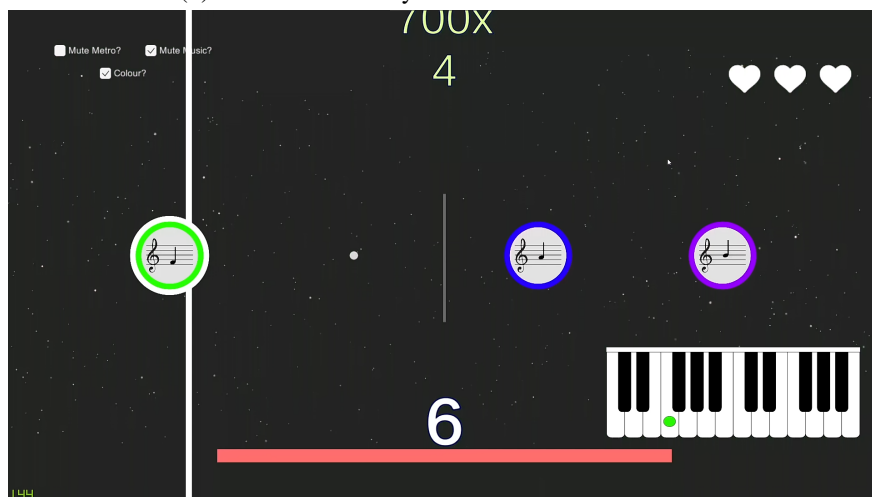
Whilst the basic trainers helped provide a baseline for comparison, the research also explored possibilities of gamifying them further and what effect this may have on engagement and pedagogical value. Several prototypes were developed in an attempt to gamify a basic version of Note Flash/Trainer. The end result was inspired by noa, UFA and based on Note Typer, which adopted a sci-fi style theme. Whilst there were other concepts developed for this category, which are shown below, only Notes Invaders was used in the study as it was the



(a) Note Flash being used to practice reading notation in 'level mode'



(b) 'Note Sonar' a rhythm variation of Note Flash



(c) 'Note Line', another variation of Note Flash using rhythm

Fig. 5.5 Note Flash and Variations

most positively received during internal testing. In the below section Notes Invaders is described and whilst also briefly mentioning the smaller concepts that were developed and the other games that helped inspire this category.

Notes Invaders

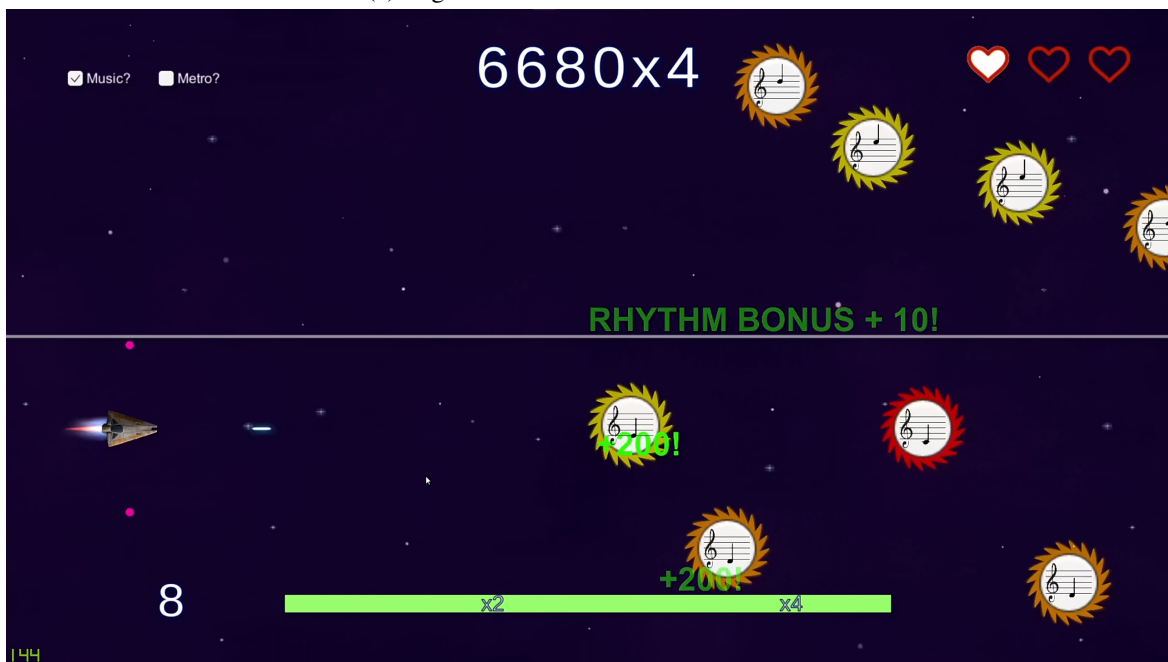
The original Note Typer game had notation/notes falling from the top to the bottom of the screen, however it was realised that to reflect a musical staff more logically it made sense for the notes to move from right to left (to reflect reading sheet music). The option to play with two hands persisted by splitting the screen horizontally and allowed lower notes (i.e., bass notes) to be played on the bottom side of the screen with the left hand and vice versa for treble notes. This was the first game that made use of generative music, which created a simple yet satisfying and bass driven chiptune style track from the notes that the learner was practising in their current session. The combination of the track matching the same notes as the learners were playing with a strong sense of rhythm made the game feel musical but still quite jarring (as the notes were random rather than a coherent and melodic pattern). To overcome this, notes were generated with set patterns which helped increase finger dexterity and build muscle memory whilst also adding additional juice (Hicks et al. 2019) and musical depth to the game. Later, the design of the game chosen opted for a sci-fi theme. The choice for this design was inspired by the main inspiration noa as well as the arcade classic, Space Invaders (hence the name of this game). The notes were designed as ‘hazards’ which would flash to the beat and explode when their correct note was played (adding additional layers of ‘juice’). The hazards would spawn in waves and if a hazard hit the player ship, a life would be lost (with a total of three lives to lose). Each wave the hazards would increase in quantity and speed. An error bar and a multiplier bar was also developed. The error bar would fill with each incorrect note played, resulting in a life lost once fully complete or would reset on a correct note - this ensured players could not ‘spam’ the keyboard to win every time. The multiplier bar would fill on consistent correct notes – the higher a streak, the higher multiplication of score (again, borrowing ideas from game design (Schell 2008)).

Inspirations and Insights

The game was based on a previously developed game, Note Typer as well as extending further by conducting a more in-depth review of the games mentioned above. The game also borrowed ideas from an online practice game which used a ‘Star Wars’ as the theme (Colin 2016), which helped to decide on the sci-fi theme, albeit, without being specific to the ‘Star Wars’ franchise. One of the main takeaways from the previous study was that the



(a) In game screen shot of Notes Invaders



(b) Notes Invaders being played with two hand mode: using higher and lower treble notes

Fig. 5.7 Notes Invaders and Variations

‘hazards’ (the notation) moved at different speeds and were appearing at different rates. Tying this in with the need for a musicality, the notation spawn to the tempo/BPM of the backing music whilst ensuring that the notation move consistently to the music also. Difficulty could be raised by either increasing the BPM or the length of the notes to reach the player (for example, rather than quarter notes, one could use eighth notes which doubles the speed). Whilst the previous study determined that the exploding notes were an exciting addition, they were too bulky and would cover the oncoming notation too much. Therefore, the design of the explosions were changed so they were less intrusive and dissipated faster. A final change was related to the design of the ‘phrases’. Initially phrases spawned as one object - in the new version only single notation is shown but are spawned in patterns – this reflected the feedback from the initial study in which participants enjoyed the patterns but found them difficult to read.

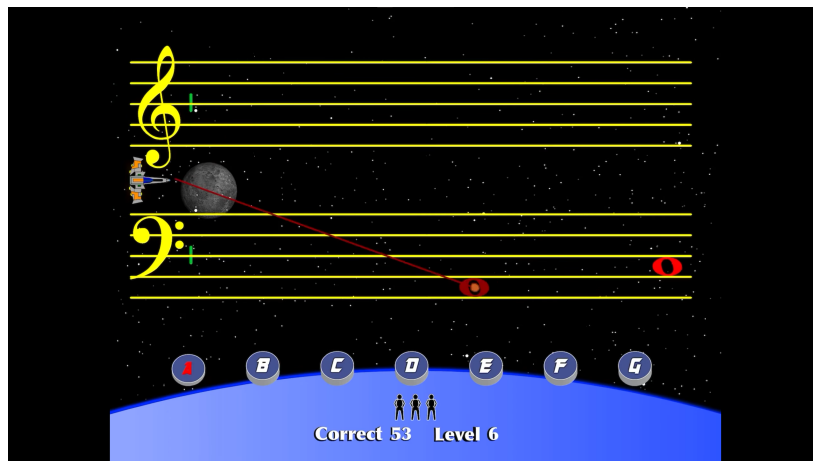


Fig. 5.8 (Colin 2016), a notation reading practice game based on Star Wars themes

Arcade Practice

This category was an attempt to bridge the gap between video game experience and a practice tool by creating ‘old-school’ style games which would offer meaningful practice. A key takeaway from the first study was that most participants were familiar with the visual representation of a musical staff and could recognise it even if they were complete beginners, furthermore, they naturally associated the musical staff with learning and playing music. When reviewing rhythm games, it became apparent that a lot of them were based on ‘lines of beats’ in which the objective was to hit oncoming objects to the time on a specific line. It only logical to try and mimic this but use the lines of a musical staff as the main basis of design. Ideas were borrowed from other games (BitFinity 2016, QubicGames 2020) where one would glide down a line on the and shift up and down to different lines to avoid incoming

hazards or collect items. Multiple concepts of games were developed that were based on staff and found that it was significant step forward to becoming a game, albeit in a simpler fashion which was akin to games to found in arcades – hence the name of the category. Whilst this category only features one game, Staff Arcade, this game is made up of smaller mini games (which is derived from the games reviewed previously which use this mini game format). Below is an outline the overall process of making the arcade and the five mini games that are featured in the arcade.

Staff Arcade

Staff Arcade is a collection of smaller mini games all based on the musical staff. The original idea was to take a previous prototype, Note Shooter, where players ‘shoot’ objects down lanes which correspond to notes of a scale, and apply it to the musical staff. This translation appeared highly logical and was in line with the feedback received during study one: participants wanted higher transferability of each game to real world applications (i.e., a reflection of what playing and learning would look like). Essentially, the premise rather simple: put the player on a specific position of the staff and allow them to move from one position to another by playing corresponding notes (basing the design on a strong core loop (Korek 2019)). There were two mechanics that allowed this movement: one was a teleport mode where the player could press any key and move instantly to that location and ‘adjacent mode’, in which the player had to play the note adjacent to the current one they were on to move up or down (for example, if they were on a ‘c’, they could either play ‘e’ or ‘d’). Later, scales were implemented forcing the player to only play notes which were part of a scale and could include sharps and flats, for more experienced learners. All mini games made use of the generative music system as well as the rhythm components, spawning notes to a specific tempo and ensuring they move smoothly to the backing track. In all mini games, the player object (represented as a whole note) would have two dots which would move back and forth and represented the visual of rhythm. As with all of the games, if the player correctly scored with rhythm they would earn extra points. With some of the staff mini games, there was an option to ‘force rhythm’ where players were required to play on the beat rather than just being offered additional points. The game also featured a lives system, typically allowing five lives lost besides from two of the mini games, which are mentioned below. Five mini games were developed as a part of the arcade:

Staff Shooter was the first mini game developed and involved firing at incoming ‘hazards’ which would be spawned on specific positions on the musical staff. They were two design options that were developed: one would ‘explode’ notes when correctly guessed

and the other would ‘colour’ notes; notes would spawn white and if they were correctly guessed their colour would change to that of the colour of the key on the LUMI. If a note ‘hazard’ reached the left-hand side of the staff before being played, this would result in a life lost. As with Notes Invaders, if they player had earned a streak this would result in a multiplication of score. Also borrowing from Notes Invaders, notes would be spawned in particular patterns to increase musicality and help improve hand and finger dexterity

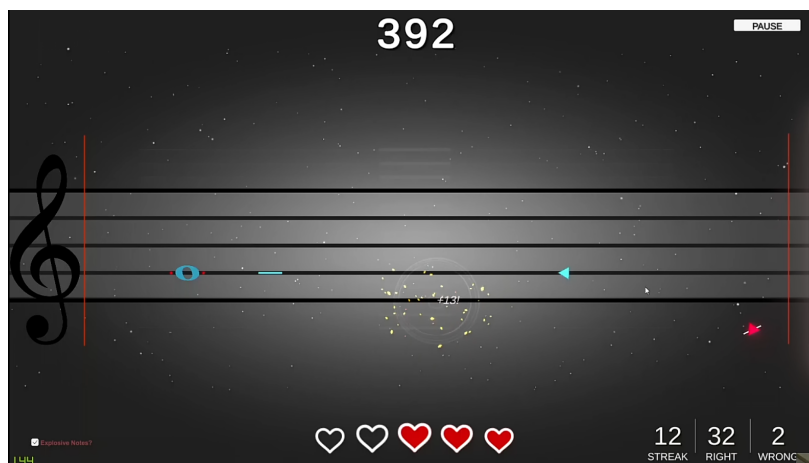


Fig. 5.9 Screenshot of Staff Shooter

Staff Dodger was essentially the opposite of Shooter where players would avoid or ‘dodge’ incoming notes by changing their position on the staff. Bonus notes were spawned to increase the agency of the game – by collecting these notes and narrowly avoiding incoming hazards, the players would earn additional score. If the player was struck by an incoming note, they would lose a life. This game was particularly engaging when combined with ‘adjacent mode’ as players had to plan their moves wisely

Staff Catcher was the friendliest of the games and involved ‘catching’ the incoming notes. A life would be lost if a note was missed and hit the left-hand side of the staff. This game was elevated by ‘adjacent mode’ and also made use of musical patterns – the notes would move to the tempo of the backing music and players would collect each note on the beat. As opposed to having to try and play on the beat, this game ensured that the notes were played on the beat every time they were ‘caught’ which led to a great sense of musicality

Crossy Staff was developed from the original game ‘Crossy Notes’. Essentially, a series of notes could be entered to practice and players were required to play the pattern in an

ascending and descending manner, whilst avoiding incoming note hazards (typically using major scales as the note series). This game was great for building particular finger techniques, such as the ‘thumb under’ technique as well as reiterating particular scales or musical phrases – all of which required a basic understanding of reading musical notation. This game offered only three lives as internal testing sessions typically lasted too long and became a bit mundane; by decreasing lives and increasing the exponential increase of difficulty, a good balance of satisfaction and frustration – helping players to find a state of ‘flow’ (Engeser 2012)

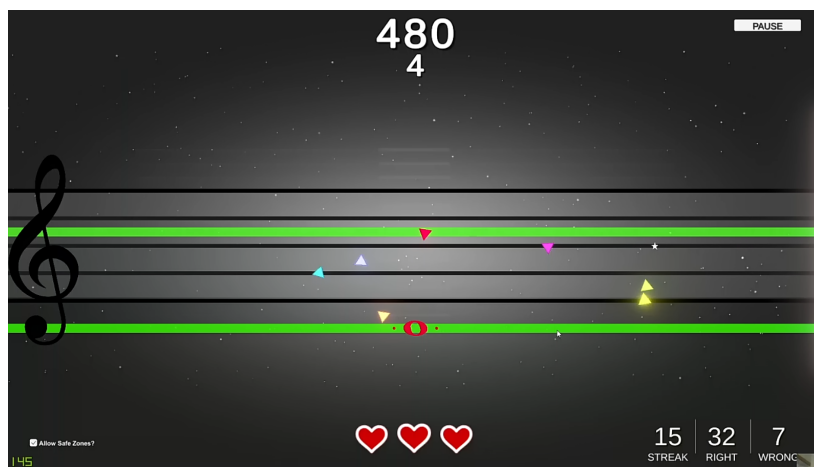


Fig. 5.10 Screenshot of Crossy Staff

Shifter and Shapes was the final mini game developed and focused on improving finger movements whilst also building stronger hand positions. In ‘shifter’ mode, players would pick a series of notes they wished to practice and a ‘blocker’ would begin to move from right to left; the ‘blocker’ was made up of a series of red blocks in which one was green – it was up to the player to ‘shift’ to the green block position or lose a life. This game mode was played exclusively with ‘adjacent mode’ as teleporting made it a bit too easy. The other mode, ‘shapes’, was similar in nature but used multiple green ‘blocks’ which required the player to hold down multiple notes to fit through the ‘blocker’, requiring particular hand shapes which would improve hand dexterity, typically used to play chords

Inspirations and Insights

Some of these concepts were based on existing solutions previously developed. For example, taking Note Shooter and applying it to the musical staff, and Crossy mode was a take on the original prototype, Crossy Notes. However, the idea of placing these games on the musical

staff was both based on feedback from the first study but also on existing games that were reviewed.



(a) BitFinity, a musical runner game based on the musical staff
(b) 7th Beat Games, a game which requires precise rhythm

Fig. 5.11 Inspirations for Staff Arcade

The additions of live systems, music and rhythm as well as more intricate design ensured that this category games was a step forward from the previous concepts. Finally, rhythm games were consulted (7th Beat Games 2021, QubicGames 2020) heavily for the development of the arcade. These games were all similar in mechanic, where players were required to hit objects at certain positions to a set beat. Combining the feedback from study one with the gamified training tools and the rhythm games led to Staff Arcade, which was believed to be a novel concept in this area of both practice and video games.

Practice Games

The final category of games is where the research finally began to break through into concepts which represented video games more than gamified practice tools. For this category, inspirations were based on popular games in the marketplace, considering multiple genres that would help build a foundation to broaden the existing solutions. Looking to RPG and action style games whilst also reviewing games which had taken the idea of rote learning, primarily typing games; games such as noa and MorbidWare, which had been around for some time and were immensely popular. Newer games such as Cactus added more depth and complexity to the simple core loop of typing words by implementing levelling systems, unlockable skills and player customisation. Looking to rhythm games, similar patterns emerged. Whilst rhythm game were inherently simple, there were other games such as Crypt of the Necrodancer that had extended the genre by combining other genres, such as RPG and roguelikes. Being inspired by video games without a serious application helped define a unique edge when it came to development. The core loop was always rather simple but

the additions of narrative, levelling, currency systems and other classic video game tropes helped to enhance these experiences and create novel practice solutions. Whilst there were multiple ideas for this category, it was decided that a game within the RPG genre would be developed. The choice of the RPG genre relied on the fact that it was recognised by gamers and non-gamers, the design was interchangeable to meet specific player types and the array of mechanics and features was almost infinite – it provided a platform. Finally, this style of game could also benefit from merging with another genre, roguelikes. This combination of genres allowed content to be procedurally generated and offer a lot of replay ability; thus reducing the need to develop very specific content and allowing developments to focus what was most important.

There were four main concepts designed and considered for development: a turn-based top-down game, an FPS style game, a platform game and an RPG game. Each design was based on existing solutions, for example, the FPS style game was derived from a typing game, noa and the top-down game was derived from Games. Whilst each game would be unique and help to develop novel solutions, the decision was to only take the RPG game forward.

Music Graveyard

Music Graveyard is an RPG-style game which focuses on a main character, Maalik – the cat guardian of purgatory, who is trying to dispel the evil found in a fictional graveyard by ‘playing funky beats’ and bring peace once again to the afterlife. Players progress through a series of levels by destroying specific objects (crates, pots etc.), defeat enemies and resolve basic puzzles by using their knowledge of reading musical notation.

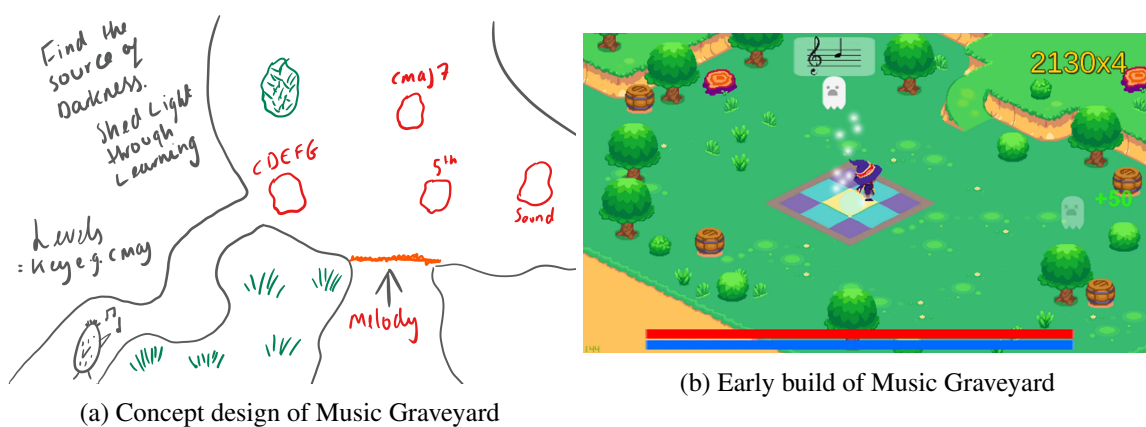


Fig. 5.12 Music Graveyard Early Concepts

The core loop is essentially to learn the notes throughout the level, gain skills, powerups and attributes which will then help you defeat the final boss/scene. Players should be

reinforced in this regard by wanting to find the secrets, coins and powerup, not just because it is satisfying, but because it will help them beat the level (Colby 2019). The core loop and secondary ones are reinforced by rhythm and players should want to play in time earn extra score/XP. Obvious and typical traits are found throughout the game – follow a series of patterns to unlock something, place a block on a button, scenes of agency where players must navigate difficult paths with speed. Players can switch from ‘move mode’ to ‘read mode’ – in ‘read mode’ they can see all areas of interaction with notation. As this game was rather extensive to develop, a useful tool that was used was the MoSCoW development framework (Spiru et al. 2019) to ensure that time was not wasted on over designing specific mechanics or complex designs.

Inspirations and Insights

As mentioned above, there were many games were used for inspiration to develop this game. However, there were a few key games that were used to base a lot of the design and mechanics on. Notably, this was Cactus which is a very similar concept, albeit this version is played with a MIDI keyboard and incorporates music in a more involved manner. Other particular action and RPG style games were reviewed, including Games, Multimedia, Wishes Ultd.) to help define a clear narrative and inspire the theme of the game. Finally, two roguelike rhythm games were used Crypt of the Necrodancer, Nintendo to help design the theme and also implement rhythm into the game. These two games were key inspirations where ideas of narrative, health system, currency and various puzzle mechanics were borrowed and applied in their own fashion to this game.



(a) Cactus

(b) Crypt of the Necrodancer

Fig. 5.13 Inspirations for Music Graveyard

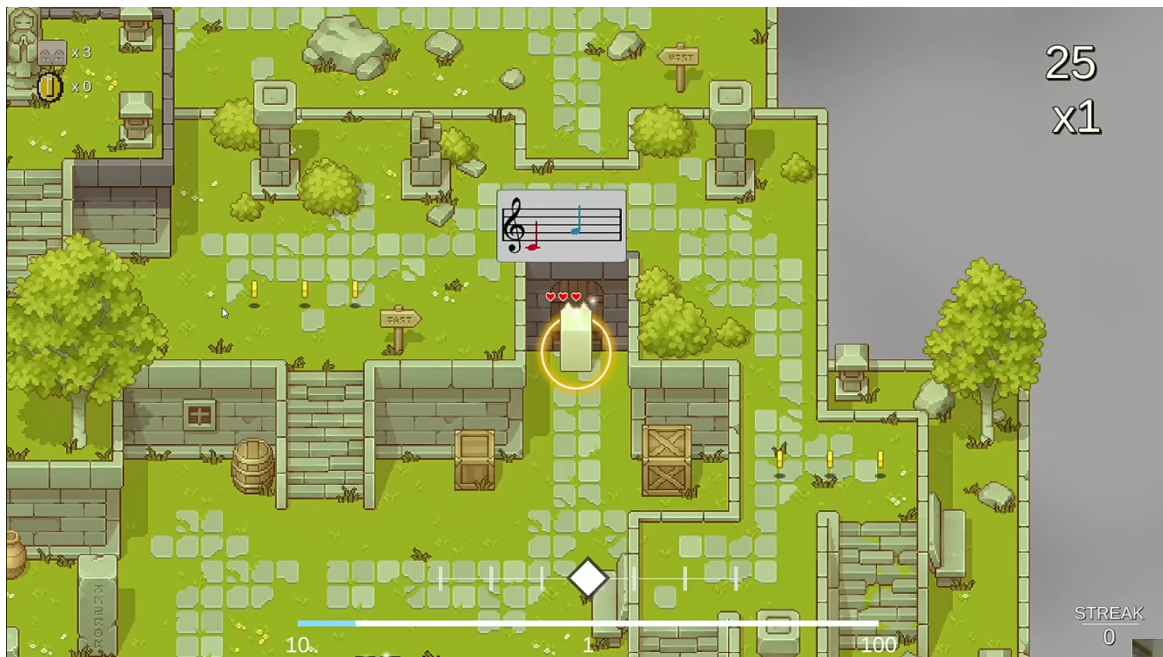


Fig. 5.14 Newer development of Music Graveyard

5.2.1 Designing for Beginner and Advanced Music Learners

When developing our games, it became clear that we must consider the varying needs and skill levels of learners (as such games and styles of learning are not just applicable to novices but extend way beyond this scope). The games described above showcase different approaches that can be tailored to suit both beginners and advanced learners.

We provide details of how these games address user base differences and some principles for designing across skill levels:

Scalable Difficulty

Many of the games incorporated scalable difficulty, which was essential for accommodating different skill levels. For example, games like Note Trainer and Note Flash offered basic modes where beginners can start with simple note recognition, often including letter representations of notes and colour-coding to match physical keys. As learners progress, these same games can increase in difficulty by removing letter representations, focusing solely on musical notation, and increasing the tempo or complexity of the patterns presented.

Skill-Specific Focus

Different games focused on various aspects of music learning, which was beneficial for learners at different stages. For example, games like Note Trainer focus on basic note recognition and familiarisation with the keyboard layout, while Staff Arcade and Music Graveyard incorporate more complex elements like rhythm, scales, and chord shapes, which are more suitable for advanced players. This design principle of modular game components allows not just players with varied experience but also opens up the play sessions depending on what individual learners need to focus on the most; it was important to try and consider a holistic approach (as outlined as important in the initial literature review and preliminary studies).

Feedback and Guidance

The level of feedback and guidance provided should vary based on the learner's experience. This includes how much acclimatisation to provide and how often tips and tutorials are offered to each player. Such settings should be highly customisable and unique per individual; not only did our games allow skipping of information but the amount of feedback and information was adjustable. Additionally, games had options and additional information that was available through menus - not overwhelming new users but also providing them with the information they may need was an important balance. For beginners, games like Note Flash provide immediate feedback and visual aids, such as highlighting correct keys on an on-screen keyboard. More complex games like Staff Arcade may offer less direct guidance, challenging players to rely more on their developed skills. This helps to reiterate that engagement is a process of acclimatisation, challenge followed by lower stress moments which help to reiterate key ideas and not overwhelm players.

Game Mechanics and Complexity

The complexity of game mechanics can significantly impact a learner's experience. For beginners, simple games with straightforward mechanics, like those found in Note Trainer and Note Flash, provide a solid foundation without overwhelming them. As learners progress, more complex games like Staff Arcade and Music Graveyard can introduce additional layers of complexity, such as multiple game modes, RPG elements, and intricate gameplay mechanics. This not only keeps experienced players engaged but also allows them to apply their knowledge in new and challenging ways. By designing core gameplay mechanics that are accessible to beginners but can be expanded for advanced learners, game-based learning

tools that were developed at this stage of the research can cater to a wider range of skill levels and ensure that the learning experience remains both enjoyable and effective.

Balancing Challenge and Engagement

Game-based learning offers a dynamic and engaging approach to music education. By tailoring game mechanics and difficulty levels to suit different skill levels, players can create a personalised learning experience which applies to beginners and advanced learners alike.

Key design principles include scalable difficulty, allowing games to adjust their challenges based on player performance. Our games also focused on specific aspects of music learning, providing learners with targeted practice. The level of feedback and guidance varied based on the learner's experience, offering more support for beginners while challenging advanced learners. Music theory concepts were gradually introduced through the games, making learning more enjoyable and effective.

Game mechanics and complexity was also adjustable to suit different skill levels. Simple mechanics were suitable for beginners, while more complex mechanics help to challenge advanced learners. Customisation and user choice allow learners to personalise their experience, making the learning process more engaging. Maintaining the right level of challenge is crucial for both beginner and advanced learners. By implementing these principles in our games, we hoped to cater to a wide range of learners; not just in regard to their individual skill or competency but their wants and personal aspirations.

5.3 Assessing Notation Reading Games

The six games were used in a new study, building upon the limitations previously discovered: most notably using existing questionnaires to measure the aspects of usability and engagement which would lead to higher reliability and validity. The play time for each game was increased and were less strict which would help make observations into which game is more engaging purely by comparing total time played and overall reception. Each game had various mechanics and design choices, and through this study specific could be narrow in and deemed the most appropriate for the target population. The study would help to narrow in on one or two concepts which would later make use of the highest rated and most generalisable mechanical and design principles. This assessment would help establish how far one could gamify practice, using the finalised developed games within studies that reflect real-world application and measure pedagogical aspects in a standardised and objective manner. Finally, whilst participants did share similarities in their gaming preferences and habits, there was conflicting opinions of preferences which naturally arose through this process. Through this

study it became apparent which genres of game could be most applicable to a wider audience and it was important to define the target population further, resulting in a niche but loyal audience which would be easier to retain for longer periods of time.

5.3.1 Intended Outcomes and Questions

- Ensure methods that assess both usability and engagement were robust, valid and could lead to high reliability that could be used in future studies
- Ensure the educational aspect of the prototypes are clear, accurate and meaningful, identifying any additional facets of the main issue
- Ensure user experience, overall usability and difficulty is suitable (i.e. not too difficult or too easy and can be played without researcher interventions)
- Narrow down specific mechanics and designs in each concept such as levels (and progression) vs. infinite, the use of music, important UI decisions etc. (a full list is available outlining each key decision for each prototype)
- Use suitable observations and insights to narrow down to one or two game concepts

5.3.2 Participants

The initial sample comprised of 17 participants (5 females) aged 25-64 (with the majority of participants aging from 25-34 (70%)). In total, 8 participants (47%) were musicians who had at least 5 or more years of experience, 10 participants owned a key based instrument which was mostly a MIDI keyboard and 9 owned either another or second instrument (this was typically a guitar but with some more niche instruments including a flute, cornet and cello). Out of those that were not experienced musicians (i.e., less than five years of experience), there were some lapsed (N=3) who had typically played music as a child and had not attempted to learn since. The rest were novices who were either absolute beginners (i.e., no experience whatsoever) or beginners who had been playing for less than a year. The novices had a desire to play keyboard or piano – mostly stating that they wanted to play their favourite pieces rather than become producers or composers. As the initial invitation was seeking aspiring musicians (particularly pertaining to key based instruments) who were already interested in video games, all participants, except for one, were avid video gamers.

The majority of participants played video games at least once a day and would play for over an hour, however, all of them stated that they used to play a lot more but struggled to find time for consistent and longer sessions as their responsibilities became overwhelming as

Table 5.1 Study Two Participant Demographics

Demographic Information	Age Group		
	25-34	35-44	55-64
N (Count)	12	3	2
Gender (count)	3F(25%)	0F	1F(50%)
Use Applications To Learn Keyboard (count)	4Y(33%)	0Y	1Y(50%)
Video Game Player (count)	11Y(92%)	3Y(100%)	2Y(100%)

they grew older. Participants were also asked why they played video games and the results were remarkably similar. They were playing for reasons of escapism, immersion, stress relief and enjoyment; they were seeking ways to unwind after a long day, as they were raised with video games from childhood, it was natural for them to use them in this capacity.

Regarding each participants methods of learning, there was some variation and most participants stated they had used multiple methods. The majority of the experienced musicians had used a teacher at some stage in their learning or had enrolled in music during school, typically being pressured by parental figures to do so. Intriguingly, the lapsed had stated that they were pressured to learn and this led to them dropping out - those that had carried on even though they were pressured claimed they had found a niche area of music which they were passionate about (for example, switching from classical to jazz pieces). The second most common form of learning was reading music books and self-learning. The majority of participants stated that they had used learning applications but did not find them particularly useful and preferred either YouTube videos or dedicated practice tools. When asking what their typical method of practice would look like, the novices would attempt to play simple songs or parts of pieces they enjoyed as well practicing scales, reading notation and using examples from books or friends. All novices stated that it was a struggle to consistently practice and would often miss sessions they had planned due to time constraints or because they simply wanted to pursue less demanding recreational activities. All of the participants were excited by this novel solution to mundane practice and would relish such a method of practice if they had the chance.

5.3.3 Study Procedure

Participants were recruited via email using existing mailing lists of the placement company which were made up of previous user testers for various hardware and software, most recently, the LUMI. The study was conducted in the company's main offices – most of the previous users were locally based and those that had signed up were aware of the commute to the office.

To ensure that enough participants were recruited, an incentive in the form of a £20 Amazon gift voucher was used in advertisements. The initial date of the study continuously changed due to the Covid-19 epidemic that prevented working in closed spaces and interacting with those outside of small groups of friends or family. After delaying the study for around two months, the rules and regulations had changed, giving the ability to run the testing, provided specific safety regulations (see chapter 4, Covid-19 policy for details) were adhered to.

Once participants had signed any required forms and were comfortable with their safety and information being shared with the internal research team, they were asked introductory questions that gave background information regarding music experience and gaming habits of each participant. Participants were sat down in front of a screen (in this case, a laptop running Windows 10) before the play session. Each participant was guided through the process of the study and they were required to setup each game whilst being offered minimal or no instructional help (only if they requested it) – it was important to measure usability of each solution and ensure they could be used outside of a controlled setting. All users were allocated ten minutes to play each solution and were instructed that they do not have to play for the full ten minutes or can go over the time limit (this open-ended approach provided valuable insights into how engaging each game is). Real-time observations were conducted throughout and participants were asked questions regarding the preference of certain mechanics and design choices during gameplay, as well specific questions after each solution had been played. Their responses, and their play style using the keyboard, were recorded via a webcam recording and Contributors was used to record the screen.

A major challenge in assessing the effectiveness of novel games for fostering musical skill acquisition is determining their 'enjoyment' or engagement and understanding the motivational dynamics of each developed game. This was reflected in the limitations of our initial study, which relied on simple and open-ended questions about 'enjoyment' from the participants' perspective. To address this, we implemented a comprehensive data collection and analysis approach, including pre- and post-game assessments, in-game performance tracking, qualitative data gathering, and comparison with a control group.

Through a review of literature for robust assessment methods, we identified the Player Experience of Need Satisfaction (PENS) questionnaire (Rigby and Ryan 2007) as a popular and effective tool for evaluating such abstract concepts. The PENS is an easy-to-administer questionnaire that focuses on the underlying motivational aspects driving players' actions. These aspects are framed as basic psychological needs: competence (the idea of challenge), autonomy (the desire for choice), and relatedness (connecting socially).

For our study, we primarily focused on the competency aspects of PENS, as the prototypes' small scale naturally limited choices (autonomy) and social interactions (relatedness).

However, we did include questions about the potential addition of social aspects and their impact on engagement. The PENS questionnaire was administered after each game was played, using Likert-style questions related to each category.

To complement the PENS assessment, we conducted pre- and post-game standardised musical aptitude tests to measure participants' ability to recognise pitch, rhythm, and melody. We also assessed their understanding of basic music theory concepts. Detailed in-game performance data was tracked, including time spent playing, levels completed, accuracy rates, scores achieved, and progression through difficulty levels. Error analysis was performed to identify specific areas of struggle and inform game improvements.

Semi-structured interviews, post-study surveys, and focus groups were conducted to gather qualitative data on participants' subjective experiences and perceptions of their musical skill development. This approach allowed us to gain insights into the games' effectiveness and their impact on musical learning. A control group of participants who did not play our games was included to provide a baseline for comparison. Statistical tests were used to compare the performance of the experimental group (game players) to the control group. The collected data was analysed to assess improvements in musical aptitude, the correlation between game performance and musical skills, and qualitative insights from participants.

We compared pre- and post-test scores on musical aptitude tests to determine if participants' musical abilities had improved. We examined the relationship between participants' performance in the games and their improvement in musical skills as measured by the aptitude tests and music theory knowledge. Thematic analysis of interview and survey data was conducted to identify common themes and patterns related to participants' experiences and perceptions of their musical learning.

The PENS questionnaire proved to be a viable tool in measuring enjoyment of each game, and our research had already shown that it would be more accurate in determining engagement and retention when compared to simple questions related to enjoyment (which were previously used in study one).

To further strengthen our research, we planned to conduct longitudinal studies to track the long-term impact of our games (this has been expounded on in later chapters). We also planned to collaborate with music educators or experts to validate their effectiveness in promoting musical skills (as such individuals were already working at the placement company). As this study relied on opportunity sampling, a diverse range of learners was recruited in which the range of education experiences varied (most were amateurs and some were more experienced). As a result, we not only gained insight into the experiences from a novice perspective but understood how each game could have helped those who were experienced gain specific skills quicker and in a more enjoyable way.

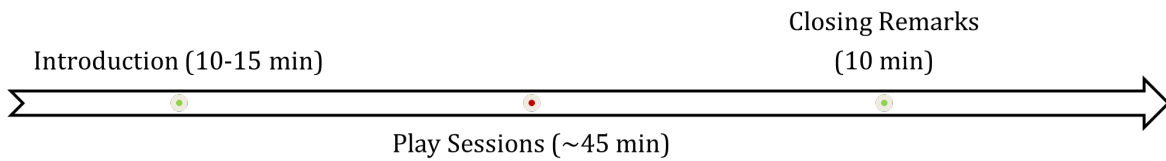


Fig. 5.15 Timeline of the study procedure

Please see the appendix for the specific questions that were asked during the study as well as key points of observation and the specifics of each mechanic and design choice posed.

5.4 Results

The study aimed to evaluate the effectiveness of game-based learning tools for music education. Five games were developed and tested with participants, who completed Likert scale surveys and semi-structured interviews. The results showed that the games had a positive impact on both educational value and competency, with significant differences observed among the games. Specifically, Notes Invaders and Staff Arcade were found to be particularly effective in improving both educational value and competency. The thematic analysis revealed that participants appreciated the pedagogical aspects of the games and found them engaging and enjoyable. Overall, the study suggests that game-based learning can be a valuable tool for music education, providing a fun and effective way to learn musical notation.

The comparisons of average competence, usability and educational Likert scores for each game is shown below in Figure 5.16. A one-way ANOVA was performed to compare each average Likert score of the five games. The ANOVA revealed that there was a statistically significant difference in mean score for each Likert score; (competence = $F(4,355) = [3.69]$, $p = 0.006$); (usability = $F(4,85) = [11.27]$, $p < 0.005$); (educational = $F(4,175) = [2.51]$, $p = 0.043$). A Bonferroni POST HOC test for multiple comparisons found that the mean value of the competency Likert scores was significantly different between Note Flash and Notes Invaders ($p=0.003$) as well as between Note Flash and Music Graveyard ($p=0.003$); there were also near significant differences between Note Flash and Staff Arcade, and Note Trainer when compared with Music Graveyard, Staff Arcade and Notes Invaders. Another Bonferroni POST HOC test for multiple comparisons found that the mean value of the usability Likert scores was significantly different between Note Trainer when compared with Note Flash ($p=0.009$), Staff Arcade ($p<0.005$) and Music Graveyard ($p<0.005$), whilst also finding that there was a significant difference between Note Flash and Notes Invaders ($p<0.005$); finally finding a significant difference between Notes Invaders when compared with Staff Arcade ($p<0.005$).

and Music Graveyard ($p < 0.005$). A final Bonferroni test for multiple comparisons revealed that the Educational Likert scores was significantly different between Note Trainer and Note Flash ($p = 0.002$), whilst also showing a near significant difference between Note Trainer and Music Graveyard as well as Note Flash and Staff Arcade.

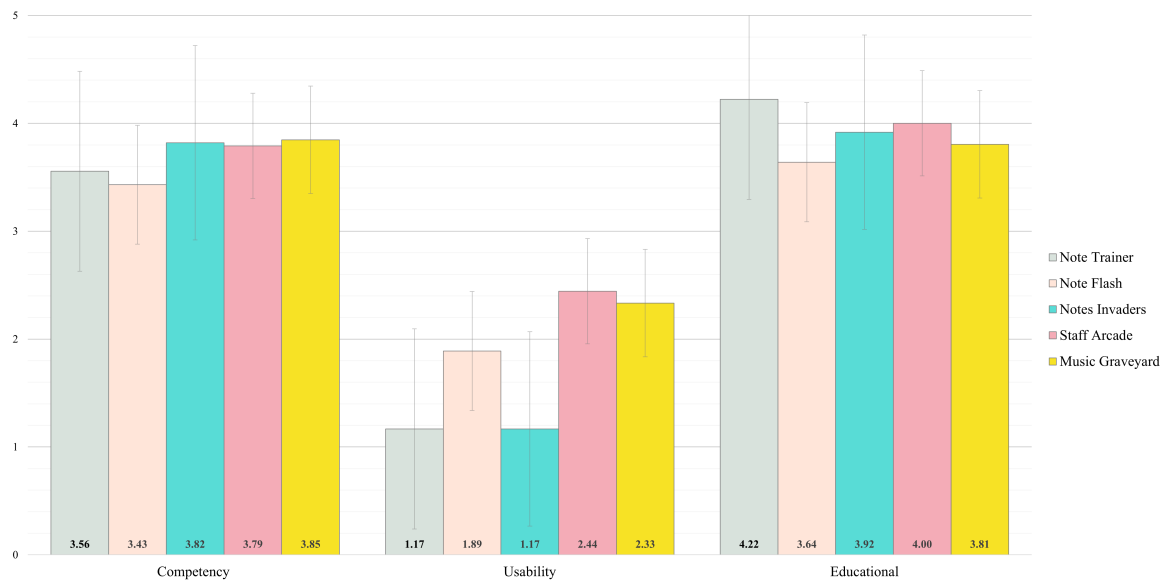


Fig. 5.16 Likert scores for each game in study two

5.4.1 Educational and Competency Likert Score Correlation

It was important to understand whether or not increasing the amount of gamification or if the practice solutions that were closer to the video game end of the spectrum would still yield educational value – and whether increasing the amount gamification or content regarding game design attributes would lower the educational value overall. Therefore, correlational tests between the Likert scores regarding competency and educational value conducted - which is visually represented in in Figure 5.20. A Pearson correlation coefficient was computed to assess the linear relationship between the Likert scores for each game. There was a medium positive correlation between the two scores for Notes Invaders, $r(70) = 0.37$, $p = 0.001$ and Staff Arcade, $r(70) = 0.52$, $p < 0.005$. Finally, there was a weak negative correlation between the two scores for Music Graveyard, $r(70) = -0.002$, $p < 0.005$. For Note Trainer and Note Flash, there was no significant correlation found.

5.4.2 Qualitative Results

As part of the procedure involved conducting semi-structured interviews as well as asking the Likert style questions, transcripts of each interview were manually transcribed and a thematic analysis of the data was conducted. Through the analysis of each interview, the aim was to provide evidence to the deductions whilst also finding recurring themes relating specifically to each game and the experience of it, general changes which apply to all games and the overall study itself (regarding improving for next time). In order to manage, organise and analyse the data, the management software system, Lumivero, was used along with triangulation and a common seven step process (see appendix for details) to define overarching themes and consequent smaller sub themes. The ‘parent themes’ were ‘Design’ (any aesthetic related information), ‘Mechanics’ (relating to changes of gameplay or specific mechanics), ‘Education’ (any mention of the pedagogy for each game), ‘Hardware’ (any comments relating to the LUMI keys or the general study setup), ‘Engagement’ (any information regarding enjoyment, states of flow and continued use), and finally ‘Usability’ (referring to the onboarding, general ease of use and overall user experience). Further subthemes were defined relating to the above parent themes which helped gain insight into the why the above Likert scores were given by each participant.

A recurring theme related to the use of colour being distracting and that most participants stated it was a distraction rather than useful – opting to use the mode without colour. Other themes related to finding the balance of difficulty as most comments related to the games either being too difficult or too easy; the idea of increasing difficulty over time was received positively but could hinder the pedagogical value. A common design theme was the use of the on-screen keyboard, many participants claimed it was useful but wanted it to be larger and only show if it was needed - rather than being on screen all the time. Finally, it was clear that participants understood and found the pedagogical aspects of each game understandable and meaningful – specific themes related to the additional educational aspects of specific games (for example, the use of patterns and rhythm helping to build finger dexterity in Notes Invaders). The full thematic analysis is made available in the appendix.

General Mechanic and Design Choices

Using thematic analysis and reviewing answers to specific questions regarding the mechanic and design choices, overall choices and changes which could be applied to all games were found. These included:

- The preference of ‘infinite mode’ rather than ‘level mode’ as the main form of gameplay (whilst also ensuring there was a choice for both)

- Including juice wherever possible (choosing explosions over simple colour animations as well as adding further design to games which already had layers of design, for example, adding more refined artwork to Staff Arcade)
- Not forcing players to play to rhythm but encouraging them to do through additional ‘juice’ and score or rewards
- Overall, participants enjoyed all facets of every game and would prefer to see the implementation of all choices with the choice to decide which they prefer (which is what was expected due to the variation of player types and learner ability)

Specific Game Choices

Questions were also asked relating to specific mechanics on each game to try and understand what increases engagement and to gain insight into what each game should be focusing on, in regard to both design and mechanics. The choices per game included:

- Note Trainer and Note Flash both offered ‘infinite mode’, ‘level mode’ or ‘survival mode’ and the choice for ‘survival mode’ gained the most votes; participants preferred to challenge themselves in short bursts for practice
- In regard to the variations of Note Flash, most participants preferred the original version but also wanted to earn additional points for playing on rhythm (but did not want to be forced to, as the other variations required)
- For Notes Invaders, participants preferred a progression of increasing waves in which they could save their progress (breaking these waves into ‘levels’) as opposed to repeatedly trying to get further than their last attempts
- For all instances where ‘adjacent mode’ could be used in Staff Arcade, all participants preferred to not use this and would opt to use ‘teleport mode’ as it was easier and observations demonstrated it offered more enjoyability

5.4.3 Favourable Games

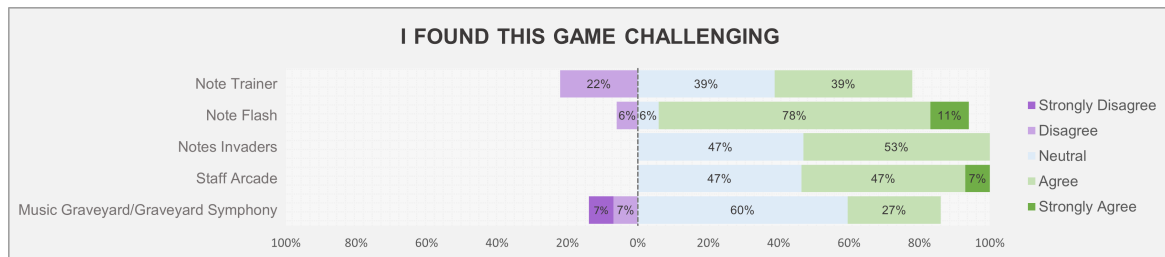
As with the previous study, and to determine which game would be taken forward in this research, questions were asked to which game was the most favourable of the session. Music Graveyard had an overwhelming response (with over half the participants voting for it), Staff Arcade came in second with four votes and both Note Trainer and Note Flash received at least one vote each. The observations of gameplay showed a similar reaction for each group, with

Notes Invaders being an exception (which could be argued is due to the design). However, the reception of Music Graveyard was different from the rest. Participants showed signs of heightened interest and each one played over the ten minutes of play, asking if the game was available elsewhere to play test (where with all other games, participants typically played the set ten minutes or less – with the basic practice tools being played the least).

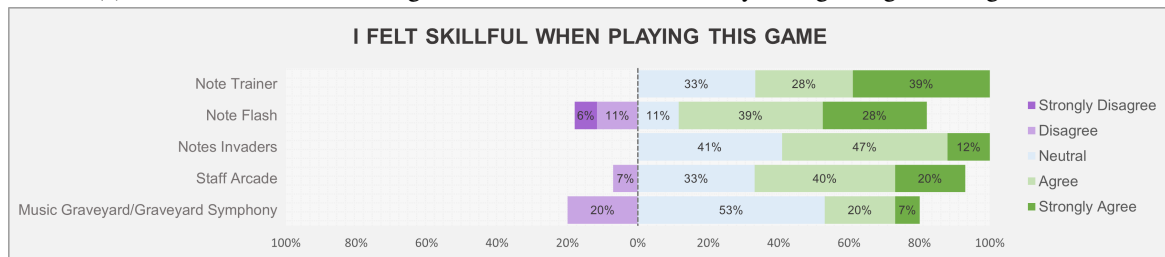
5.5 Discussion

The differences in competency between each game category were to be expected and this is overall positive. The results show that the Basic Practice Tool category (Note Trainer and Flash) was rated the lowest for competency and this is also reflected in the observational and interview data; most participants would complete the play session early and were not particularly animated when providing answers to each game (stating they had used similar tools). The lack of a significant difference between scores in regard to Notes Invaders, Staff Arcade and Music Graveyard is somewhat expected, especially because the highest rated game was Music Graveyard, the solution that resembled a video game most closely. However, it is believed that ratings may have been higher and the difference potentially significant between all games and Music Graveyard if the questions posed were fully understood and Music Graveyard was designed to be more challenging. Whilst participants rated ‘satisfaction’ and the likelihood to return or recommend Music Graveyard the highest, they rated the idea of challenge and the application of a particular skill low (all four criteria were used to generate the score of competency). The games’ learning content was purposely designed to be simple as it believed that the concept was already somewhat complex and did not want to overwhelm participants. In reality, all participants understood the concept with ease and as such were not challenged enough which also meant they were not applying their musical skills in an in-depth manner – leading to a lower competency score.

The difference between usability for Note Trainer and Note Flash was also expected. Note Trainer was very basic and did not offer additional variations, whereas Note Flash also included the rhythm variations. These variations led to confusion amongst some participants and led to lower scores for ease of use. This also applies to all other games and the greater differences in usability score as the solutions became more gamified, was expected; the interview and observational data helped us implement more robust tutorials and simpler UI to ensure that each game’s concept was easier to grasp and the user experience was more intuitive. An unexpected result was the difference of educational score between Note Trainer and Note Flash (as the expectation was for them to be similar) but this also reflects the variations of Note Flash being complex and leading to lower educational scores. The



(a) Stacked bar charts showing lower scores for Music Graveyard regarding Challenge scores



(b) Stacked bar charts showing lower scores for Music Graveyard regarding Skill scores

Fig. 5.17 Stacked bar charts of Skill and Challenge scores for all games

differences between the Arcade category and Basic Training Tool category, was somewhat expected as the comments received were that Staff Arcade was an enjoyable game but the various mini games felt more game-like and less pedagogical (as well as being too complex to be a meaningful practice tool). The difference in educational score between the basic trainers and the training game was expected but it is believed this difference would have been less so if the educational content of Music Graveyard increased (as stipulated above, this was not the case reduce complexity of the game).

The lack of correlation between competency and educational score for both Note Trainer and Note Flash was not surprising as they were designed with a lack of gamification and for the purpose of practice. The positive correlation that was found in Notes Invaders and Staff Arcade was interesting as it points to the conclusion that adding more gamification would actually increase educational value. This result indicates mostly that increasing challenge and required skill, would lead to higher amounts of educational value as the more skill required, the more meaningful and applicable practice would be; this would naturally lead to higher amounts of challenge. The very weak negative correlation observed in Music Graveyard, combined with the low usability score, indicates that the game was not robust enough in regard to onboarding and consistent tutorials which must be paid attention to; the higher amounts of gamification or elements of game design needs to be coupled with attention to detail regarding instructing learners on how to play and understand the game at every stage.

5.5.1 Scalability of the Developed Games

The scalability of the games developed in this study is an important point of discussion as their broader application in music education must be considered. We cannot simply state that each game was impactful in helping skill acquisition or improvement but must offer insights into how this can be applied to other areas of learning and indeed how this can be used in the future of a music student's education. Each game presents unique opportunities for expansion and adaptation which are outlined below; whilst certain features are already implemented, we discuss future implications and applications of each game respectfully.

Music Graveyard

Music Graveyard, the most well-received game, offers significant scalability potential. Its design allows for the implementation of varied difficulty levels, making it adaptable for learners across different skill levels. The game's core mechanics could be modified to accommodate various instruments beyond the keyboard, broadening its user base. Furthermore, the game framework could be expanded to include additional musical skills such as rhythm training and chord recognition, enhancing its educational scope.

Notes Invaders and Staff Arcade

These games, while less complex, show promise for scalability through their mini-game structure. Staff Arcade, in particular, could be expanded to cover a wider range of musical concepts. Implementing adaptive difficulty and multiplayer features could further enhance their educational value and engagement potential.

Note Trainer and Note Flash

Despite their simpler design, these tools offer scalability through content customisation. Allowing for user-input of custom note sets or rhythms could significantly increase their utility. Integration of these basic tools into more complex games as practice modules could also enhance their scalability within a broader educational framework. Such mini-games are featured styles of games on the mobile devices (as previously discussed) and lend themselves to having longevity and thus applicable to other areas of learning beyond musical instruments.

General Scalability Considerations

Overall scalability of these games could be improved through cross-platform development, enhancing accessibility across devices. Localisation efforts could expand their global reach,

while incorporating learning analytics could enable more personalised learning experiences (meta analysis of telemetric data continues to be an important point to investigate to understand the impact of game-based learning in this domain). A modular design approach would facilitate easier updates and additions, ensuring the games remain relevant and adaptable to evolving educational needs.

By addressing these scalability aspects, the games developed in this study have the potential to serve a diverse range of music students, adapt to various educational contexts, and provide comprehensive music learning experiences. This scalability not only enhances the current research's value but also opens avenues for future development in music education technology.

Scalability for Other Musical Skills or Instruments

The study primarily focused on reading musical notation for keyboard learners. However, it's important to consider the potential scalability of these game-based learning approaches to other musical skills and instruments, an aspect not initially covered earlier in our research.

The core mechanics of games like Music Graveyard show promise for adaptation to various instruments beyond the keyboard. With appropriate changes to visual representations of notes (such as using guitar tabs or even other forms of note representation), these games could serve learners of string, wind, or percussion instruments. This adaptability extends beyond just note reading; the games could be reconfigured to teach other fundamental musical skills like rhythm, harmony, or ear training, broadening their educational scope (fundamentals that were covered in our initial review of literature).

To enhance their versatility, future iterations of these games could incorporate customisable difficulty settings. This feature would allow the games to cater to a wide range of skill levels and learning paces across different instruments and musical abilities. Furthermore, exploring multiplayer modes where different instruments interact could promote ensemble skills, adding another dimension to the learning experience. Such examples are already popular in the game industry, such as Rock Band ¹ and Band Hero ².

The potential for integrating more comprehensive music theory elements into the games presents an opportunity to create valuable tools for broader music education. This could involve developing a series of games that progress from basic skills to more advanced concepts, providing a structured learning path applicable across various musical disciplines.

From a technical standpoint, scaling to other instruments may require developing new input methods or integrating with different types of musical hardware. Additionally, adapting

¹<https://www.harmonixmusic.com/games/rock-band>

²<https://www.nintendo.com/en-gb/Games/Wii/Band-Hero-280572.html>

the games to include various musical genres and cultural styles could significantly broaden their appeal and educational reach.

5.5.2 Study Limitations

Whilst the study had improved upon previous limitations of the initial study by focusing on a specific area of skill (reading notation), focusing on specific mechanics or design choices, using peer reviewed methods of assessment regarding engagement, not limiting the play time per session and improving overall observational and interview techniques, some important aspects were still neglected and would need to ensure they were improved for future studies. These limitations include:

- The reliability and validity of the testing methodology was not considered. Although the assessment of engagement was based on prior literature, it is deemed a limitation that this and the other methods of assessment were not validated nor was their reliability taken into account
- Whilst PENS was used for assessing engagement, the implementation was limited. The full PENS was not taken into account (only considering competency and overlooking both relatedness and autonomy). Whilst this was intentional, it was found that these questions would have been useful and not added any more complexity to the study
- Although PENS was used, albeit in a limited capacity, other methods of assessing notions of engagement or enjoyability were not reviewed - this was mostly measured using observations which lacked standardisation
- The study still used open ended and subjective measures of educational value for all games whilst also not considering how each game improves the specific skill of reading musical notation
- The study was lab-based and did not reflect real world applications; whilst it offered a lot of control, this methodology can never be a true representation of real-world practice or learning
- The study had also measured usability with personal forms of measurement but neglected to consider other methodologies found in literature or the market place

5.5.3 Future Implications

One of the main outcomes of this study was to choose specific mechanics and designs whilst also narrowing down the developed prototype games to one or two concepts. All the data indicates that the game which was received most positively was Music Graveyard, which was expected. Going forward, this game was developed further, taking on board feedback regarding onboarding, simpler controls and coherent, consistent tutorials throughout (which should lead to a more pedagogically valuable concept). The choice boiled down to combining aspects of Notes Invaders and Staff Arcade into one sole game or going ahead with Music Graveyard. Whilst ideally both would have been taken forward, there was limitations of both resources and time. What finalised the decision on Music Graveyard was the observations and overall feedback. As mentioned, participants were incredibly animated when playing the game and found it incredibly novel (a theme amongst participants of all age groups and skill levels). The final goal was to test the game in real world applications, improve assessments of engagement and usability by reviewing literature, and begin to determine how one can measure the improvement of the skill of reading musical notation in an objective and standardised manner – determining the application this would have in the real world.

Going forward, Music Graveyard was improved based on the feedback, ensuring that the hardware is not restricted to the LUMI keys and a review of literature is conducted, giving way to more robust methods of assessing engagement, usability and pedagogical value (specifically measuring the improvement of a specific skill and its application). How this can be reflected in real world scenarios is consulted by running a pilot study which is used as a basis for a longitudinal study conducted remotely in learners homes. The goal was to determine how effective this novel method of practice can be for beginner adult keyboard learners and whether or not this would eventually lead to longevity of learning or reduce the high rates of early drop out exhibited by these learners.

5.6 Chapter Conclusion

This chapter discusses the second round of development which begun to focus on games which have a specific purpose: improving a beginners ability to read musical notation. The categorisation of each game into specific groups help determine how gamified each practice game could be and defined considerations to what is required to be implemented to ensure that pedagogical is maintained whilst the amount of game design attributes are increased. Through a second study, it was realised that the most game-like solution could be used if particular attention is paid to onboarding and tutorials which should ensure that the main game, Music Graveyard, can be deemed a viable learning tool when compared to typical

practice methods. However, there were some major limitations of the study, notably this was lack of validity and reliability whilst also neglecting to measure usability and engagement in a robust manner. In the next chapter, the development of Music Graveyard is discussed and it's use in a pilot study which is used as a basis for the final longitudinal study. The pilot study helps to remedy the limitations of the second study and bring together the missing pieces; helping to ensure that the game has real world application and meaningful transferability to learning and playing keyboard.

Chapter 6

Note Reader Adventure: A Learning-Based Game

6.1 Chapter Introduction

The research journey through previous chapters revealed a clear evolution in our understanding of game-based musical learning. What began as an exploratory investigation into practice tools has gradually crystallised into a more focused and methodologically rigorous approach. Our initial work uncovered the broad challenges faced by beginner musicians, particularly around maintaining consistent practice routines. Through subsequent prototyping and testing, we narrowed our focus to specific games centred on musical notation (i.e., matching positions on a musical staff to physical keys on a keyboard), with our most recent findings suggesting that highly gamified approaches show particular promise (specifically, game-based learning rather than just gamification of learning).

However, this journey has also highlighted crucial gaps in our methodology that need to be addressed before we can make definitive claims about effectiveness. While our earlier studies provided valuable insights into game design and user engagement, they lacked the standardised assessment methods and real-world validation necessary to draw robust conclusions about pedagogical value. This realisation has led to an important pivot in our research strategy.

Originally, we had envisioned developing and testing a comprehensive suite of games through longitudinal studies. However, the insights gained from our previous work suggest that a more focused approach would be more valuable at this stage. Rather than immediately proceeding with multiple games, we recognised the need to first validate our core methodology through a carefully designed pilot study of a single, refined game concept. This

strategic decision allows us to establish reliable assessment methods and test our fundamental hypothesis about the relationship between engagement and skill improvement before scaling to larger implementations.

The pilot study described in this chapter serves as a crucial bridge between our earlier exploratory work and future larger-scale implementation. It specifically addresses the limitations identified in previous chapters while building upon our accumulated understanding of effective game design for musical learning. Through this study, we aim to validate methods for assessing engagement, usability, and pedagogical value within real-world settings. Crucially, we seek to determine whether our gamified approach can demonstrably improve notation reading skills using reliable quantitative methods.

This chapter details the further refinements made to our selected game based on previous findings and new literature, followed by a comprehensive discussion of the pilot study's methodology and results. We explore how engaging and usable the game proved to be, compare its effectiveness against traditional practice tools, and gather qualitative insights to inform future iterations. This focused investigation provides the methodological foundation necessary before expanding to larger-scale studies, ensuring that our approach is both robust and reliable.

Our underlying hypothesis remains straightforward yet significant: increased engagement with practice leads to improved skill development. While previous work (outlined in earlier chapters) suggests that video game approaches yield higher engagement, we now need to conclusively demonstrate that our developed game can effectively improve notation reading skills. This pilot study represents a critical step in validating both our methodological approach and our fundamental assumptions about game-based musical learning.

6.2 Note Reader Adventure

The second round of development began for the RPG style game, currently titled 'Music Graveyard'. The title was still a work in progress for this round of development and assessment, therefore the game was titled to be as descriptive as possible, resulting in: 'Note Reader Adventure. Specifically, the games' genre was defined as rhythm adventure RPG with some parts of a roguelike instilled. Essentially, the game had adventure elements (exploring, narrative and placing the main character as the hero) as well as RPG elements (levelling systems, currency collection and shops) with aspects of roguelikes (dungeon crawling and a typical fantasy design). As mentioned, the choice for this style of game allowed a lot of content and complexity to be added without the over designing the graphical elements or intricate mechanics. Not only this, but these genres are particularly popular at the current

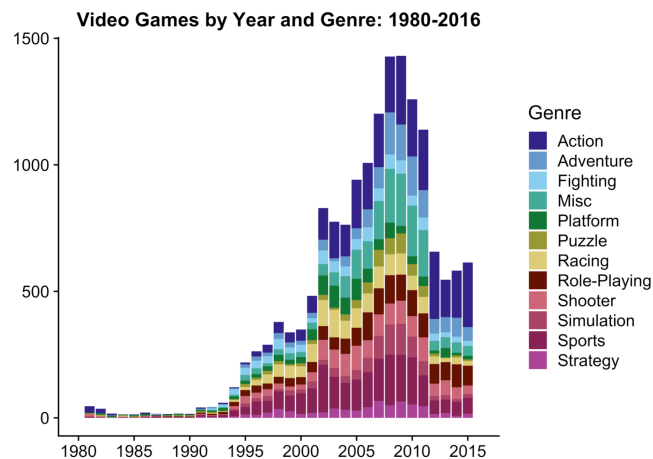


Fig. 6.1 Bar chart highlighting total number of games developed per year from 1980-2015

time of writing and are familiar to the majority gamers and non-gamers alike; the game would be recognised as a game without needing to stipulate how it is played or what the common drivers and core loops are. As previously argued, there was a desire to develop an arcade style game but this would require hand creating all levels which would lead to a lot of debugging and tweaking to find the balance of each level; with a game that borrows from roguelikes, one could procedurally generate content which allows time to be focused on the elements which matter most. Finally, whilst development of such a game would require a lot of time, the foundation of the game had already been created and developing additional content would be less demanding than starting completely from scratch.

6.2.1 Insights From Previous Study

Many of the insights and lessons learned from the previous study were considered in the further development of the RPG style game. The preference of playing games in an ‘infinite’ capacity as opposed to levelling resulted in additional developments to the arena mode whilst later creating multiple levels using procedurally generated content (this also was based on the feedback that users wanted as much choice as possible). The game would offer additional points for rhythm but players could choose whether they wanted to be ‘forced’ to play to rhythm (as feedback showed this was too demanding for beginner learners or novice gamers). Where possible, additional ‘juice’ (Hicks et al. 2019) was added in the form of visual effects (VFX) and rich sound effects (SFX) – all sounds would revolve around a common theme and relate to specific keys to help build audiation skills. Notation shown would either be single notation which was easy to read or make use of patterns that would add musical depth and

help to increase specific techniques with the fingers. Finally, the on-screen keyboard was still provided but it was hidden behind a menu, which allowed players to show it all the time or refer to it when additional help was required.

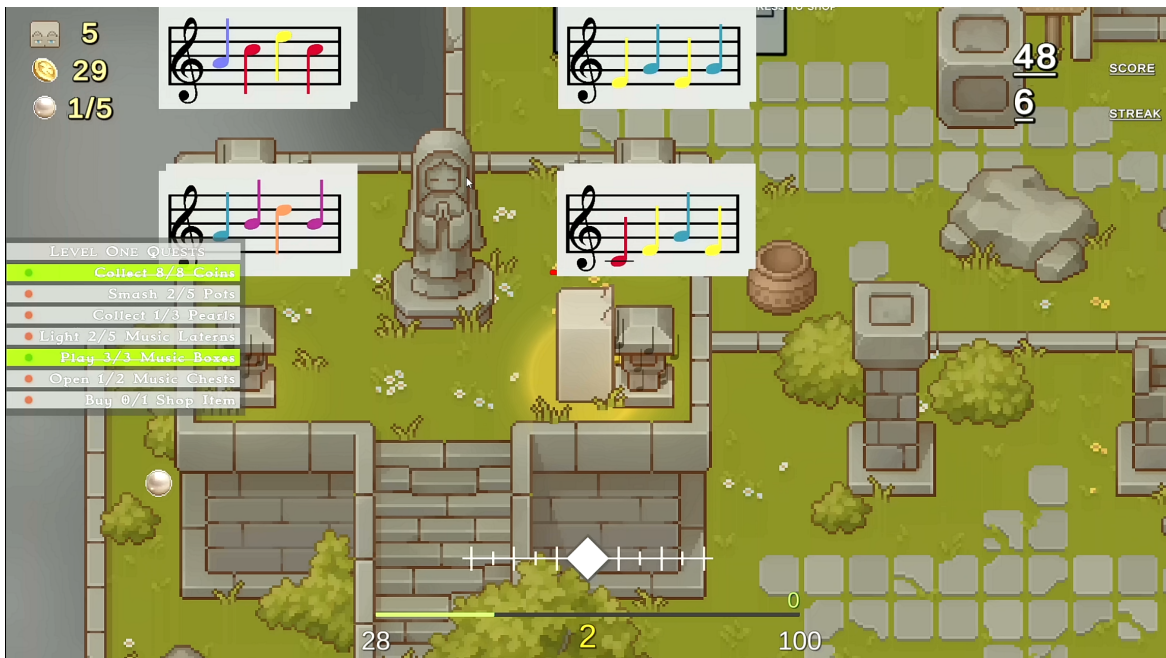
6.2.2 Game Description and Pedagogical Nature

Previously, a multitude of games were used as inspirations for the development of this game. During this stage of development there was a particular focus on a few specific games in which mechanics and design choices were borrowed and modified to fit within this game's scope. Specifically, *Crypt of the Necrodancer* (and the adventure style DLC game, Nintendo) were reviewed continuously throughout development and specific mechanics were borrowed such as, health and lives systems, collection of coins and the ability to purchase powerups and the main aspects of how rhythm was used, including the visual design of the tempo on screen. Another game that was used heavily was, *Cactus* as the game had a unique control system designed to improve touch typing skills at a typing keyboard. Ideas such as the quest system and levelling up the character were inspired by this game and the design was consulted throughout further development of the RPG game. Finally, whilst the design and general gameplay was rather different, *Multimedia* provided some inspiration for this game.

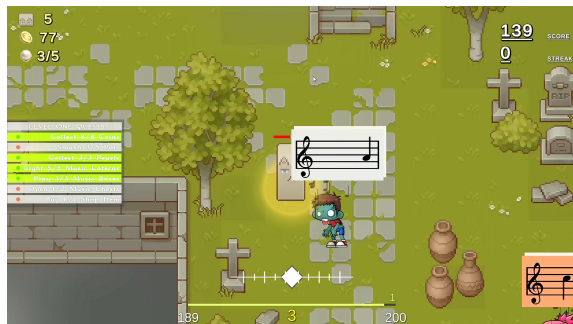
The simple but satisfying quest line and in-game puzzles helped to add more depth to the game and ensure that the narrative was closely integrated with the design of the game. This allowed players to feel like the hero of their own stories, rather than just following a linear plot. By embedding the educational content within an engaging storyline and RPG-style progression, it made the learning process feel more natural and immersive for the players. The narrative provided context and motivation for the gameplay, helping players feel invested in mastering the musical skills. This narrative-driven approach was important for maintaining player interest and making the educational content feel less like pure drill-and-practice. The integration of narrative and gameplay elements would later be realised as a key factor in the success and accessibility of this game-based learning approach to music education.

The general concept of the game and the overarching core drivers and loops have previously been discussed, what follows below is a description of how the game is played and a more in-depth description of the specific game elements.

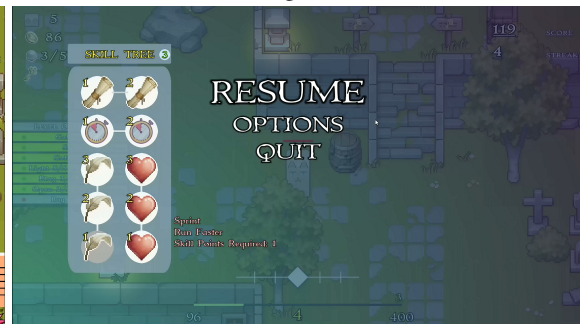
Players control the main character using a MIDI keyboard with a total of 48 keys: the lower side of the keyboard is used to control the character movement and the higher side of the keyboard is used to carry out certain actions, such as switching from play mode (in which players can see notation) to move mode (in which the keyboard is used to move the character and interact with the world, a crucial part of the game). The control scheme encourages players to place their fingers on the keys in certain ways, which reflects typical early-stage



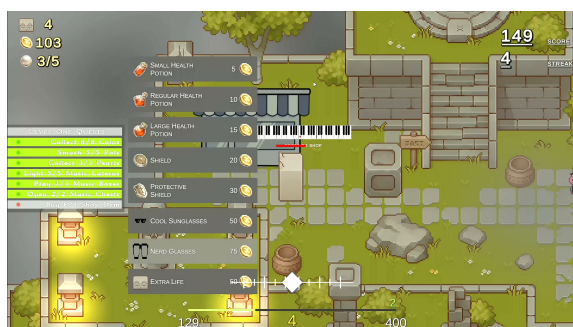
(a) Screenshot of Note Reader Adventure with notation being shown



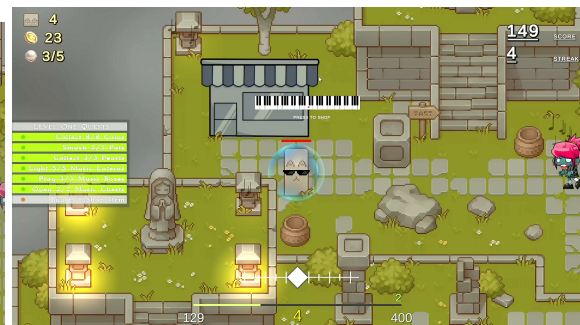
(b) Note Reader Adventure zombie enemy



(c) Note Reader Adventure skill menu



(d) Note Reader Adventure in game shop



(e) Example of Note Reader Adventure purchased cosmetic: sunglasses

Fig. 6.2 Note Reader Adventure Screenshots

hand positions found within teaching (for example, the five-finger position (Furuya et al. 2011)). For the most part, players must complete each level by playing all the notation found (in which patterns of notes are used to improve finger and hand dexterity, implementing basic finger exercises found in typical learning), though more depth is added to the game to ensure that it was not just a typical trainer with a different guise. So, not only are players required to play the musical notation, but they must solve simple puzzles, navigate through tricky mazes, defeat enemies in unique ways, collect additional items and coins which can be spent in shops in order to improve the character's abilities and style (i.e. powerups and cosmetic items).

Whilst most of these additional game design concepts integrate with the learning, for example the puzzle elements focus on placing notes in a correct ascending order, it was intentional that certain game design concepts to be a distraction from the learning to help ensure that players felt like they were playing a traditional video game, rather than a practice tool. The notation that players are required read varies over the course of the game, starting with the basic notes and eventually adding more notes to the gameplay; learning books (Palmer et al. 2005) and applications were consulted to build a unique progression of reading notation, focusing on landmark notes and building from this. Notation is viewed either as single notation cues (i.e., one note on either treble or bass clef) or as a pattern (typically made up of 2 double notes or 4 quarter notes); some objects require multiple patterns in which notational cues are 'stacked' atop one another – once the player reads the first pattern the second one is revealed.

The game is of course centred around music and incorporates rhythm as a core element of its design and mechanics. Drawing inspiration from existing music games, rhythm is integrated throughout the game to encourage players to hit notes on the beat, enhancing both satisfaction and rhythmic skills—key skills in the game. The gameplay includes a visual and audio metronome, along with a backing track with a clear tempo. Various elements, such as flashing visuals on a "dance floor," enemies moving in time, and animations synced to the beat, reinforce this rhythm. Additionally, players build up a streak by moving or interacting in time with the beat, increasing their score multiplier with each consecutive hit; missing the beat, however, breaks the streak, a gamification approach akin to the "sunk cost prison."

As an RPG-style game, level progression and skill unlocks play a significant role. Players earn experience points (XP) by performing positive actions, such as playing correct notes or solving puzzles. Upon levelling up, they can spend skill points on abilities that make gameplay more enjoyable or manageable, like slowing down enemies when playing the correct note, gaining extra health, or maintaining their streak multiplier for longer durations.

Sound design is rich and purposeful, featuring satisfying note hits, rhythmic feedback, and celebratory chimes upon level completion. These audio cues reward accuracy, reinforce rhythmic engagement, and offer a sense of accomplishment. The energetic, dynamic sound design aligns with the game's visuals to create an immersive experience. Dynamic audio further enhances immersion by adjusting music intensity and sound effects in response to player actions and game environment changes. Spatial audio techniques are utilized to create a 3D soundscape, positioning sound effects to add depth and directionality.

In addition to enhancing immersion, sound design improves usability through clear audio feedback, confirming actions, indicating successful inputs, and warning of potential threats. Directional audio cues help guide players toward objectives and away from hazards, making the game more intuitive. The sound design is integral to creating a dynamic and immersive atmosphere, ensuring that the game feels "alive" and that players feel deeply integrated into its musical framework. This approach motivates players not only to progress within the game but also to strive for rhythmic accuracy and musical cohesion, fostering a desire to perform well in order to enhance the auditory experience.

6.3 The Pilot Study

This pilot study was used to ensure that the various assessment methods were validated and were measuring what was intended, ensuring that the game could be played without any intervention or game-breaking bugs and that the game would offer equal pedagogical value to a typical form of reading musical notation practice. Specifically, a pre and post-test with intervention experiment approach was adopted (i.e. a pre-skill test, an intervention which is either a practice game or tool, followed by a post-test in which pre-to-post test scores were compared to). The study explored how each solution was perceived by participants in regard to educational value, usability and engagement through Likert style questions and observations; the aim was to find that the game group rated, at least, the engaging component higher than the practice tool. Below is details of the study protocol in which the specific methods that were conducted to measure the aspects of engagement, usability and pedagogical value (i.e., the ability to improve the skill of reading musical notation) are discussed. The following outcomes of the study are as follows:

- Ensure the methods of assessment regarding engagement and usability are valid, reliable and measure what they intend to
- Validate the method of assessing the games' ability to improve the skill of reading musical notation, in comparison to a typical method of practice; ensure that the game

does improve the skill of reading musical notation just as well if not more so than the comparison practice tool

- Ensure the prototype game can be played without intervention outside of lab-based environments
- Ensure the prototype game has no major bugs or areas of confusion (i.e., ensure that it can be played without issue outside of lab-based environments)

Regarding the ‘experimental phase’ of the study, i.e., the comparison of skill acquisition and application regarding the prototype game and typical practice tool, the expected hypotheses are stated:

Hypothesis H₀ (Null Hypothesis): There is no statistically significant difference in the improvement of musical notation reading skills between the game group and the market standard group, as measured by:

1. Difference in total time and total errors on the flash card test (pre vs. post)
2. Difference in average time and average errors on the flash card test (pre vs. post)
3. Difference in score for each SASR exercise (pre vs. post)
4. Difference in total SASR score (pre vs. post)

Hypothesis H₁ (Alternative Hypothesis): There is a statistically significant difference in the improvement of musical notation reading skills between the game group and the market standard group, as measured by the same metrics listed in the Null Hypothesis, with the market standard group (tool group) demonstrating greater improvement compared to the game group.

6.3.1 Participants

The sample consisted of 18 participants (6 females) aged 18-64 in which an equal variance of age groups was observed (besides from the age group of 55-64, where there were only 2 participants). The majority of the participants were amateur musicians who lacked any experience reading musical notation besides from two participants who had at least 5 years’ experience playing the keyboard and were competent in reading music. There were only 2 participants who did not play games on a regular basis whilst the majority of participants played either at least an hour or two a day or whenever they could within a period of a week.

Table 6.1 Pilot Study Participant Demographics

Demographic Information	Age Group			
	18-24	25-34	35-44	55-64
N (Count)	6 (34%)	5 (27%)	5 (27%)	2 (12%)
Gender (count)	4M (66%)	3M (60%)	4M (80%)	1M (50%)
Experience Reading Music (out of ten; mean)	2.2	2	3.8	2.5
Gaming Habits mean)	1-2 Hours Per Day	2-3 Times Per Week	2-3 Times Per Week	Once a Week

Whilst the aim was to recruit mostly amateur musicians who played video games regularly, it was important to capture a varied audience to ensure that the usability of the developed prototype game was understood by a wide range of learners outside of controlled environments whilst the varied experience of learners would help to validate each skill test.

6.3.2 Protocol

Following the study's introductory phase, participants underwent two assessments to evaluate their musical notation reading skills. The initial assessment aimed to gauge skill acquisition, specifically participants' ability to match positions on a musical staff to physical keys on a keyboard. This test utilised a custom-designed flash card approach comprising of thirty random notation flash card cues. Participants were encouraged to take as much time as needed and make as many mistakes as necessary to arrive at the correct answers.

The Standard Assessment of Sight Reading (SASR) was selected as the primary tool for evaluating sight-reading skills because it provides a reliable, adaptive assessment that aligns well with the goal of measuring skill acquisition through repetition and practice, a key component of rote learning. The SASR test's adaptive nature allows it to dynamically adjust to each participant's skill level by presenting progressively challenging exercises based on performance accuracy, making it particularly suitable for tracking skill development across varied levels of proficiency.

The SASR, an extension of the online practice tool Piano Marvel ¹, was applied in a real-world context for this study. In the SASR test, participants had a brief 20-second window to familiarise themselves with a monophonic motif before attempting to play the notes displayed on the staff at the correct tempo, accompanied by either a metronome or a simple musical backing. Each assessment consisted of three exercises, with the SASR tool generating both individual and overall scores based on participants' accuracy in pitch and rhythm. Participants who scored lower on each piece were given progressively easier follow-up pieces, while higher-performing participants faced more challenging selections,

¹<https://pianomarvel.com/>

thus accommodating individual skill variations and promoting gradual, skill-appropriate progression.

Alternative assessment methods were considered, such as the Advanced Measures of Music Audiation (AMMA) (Gordon 1991), a standardised test that evaluates general music aptitude and audiation skills, including melodic and rhythmic reading. However, the AMMA primarily measures a broad range of musical abilities, such as tonal and rhythmic memory, rather than specifically focusing on sight-reading proficiency. While AMMA offers a comprehensive view of musical ability, its broader scope is less suited for evaluating targeted skill improvements in sight-reading, which is central to our research (Valerio et al. 2014).

Another option was the Watkins-Farnum Performance Scale (WFPS) (Moura et al. 2024), which assesses sight-reading skills through a series of graded musical passages. Though the WFPS provides a consistent evaluation of sight-reading skills, it lacks the adaptability found in the SASR. This adaptability is essential to reflect the lessons gained in a game-based learning environment, where students benefit from a tailored, gradually increasing difficulty level based on individual progress. Not only this, the test were developed for big band instruments more so than keyboard (and piano) so tailoring this further could lead to less efficacy during the test and analysis of consequent results.

At one point, we considered using experienced music teachers specialising in piano or keyboard to assess participants' skill levels before and after the intervention period. However, we ultimately decided against this approach due to several factors, primarily resource limitations, as engaging such professionals would require additional fees. Additionally, this assessment method has been widely employed in previous research (Hackl and Anthes 2017), and the recurring issue of human variability posed a further challenge. Individual assessments would vary depending on the examiner's judgment, requiring multiple evaluators to corroborate each assessment to obtain an average score. This approach would demand more resources while also potentially reducing the study's reliability and future replicability. To address these limitations, we sought quantitative assessment methods to ensure consistent, replicable, and resource-efficient measurements, ultimately leading to our selection of the SASR test.

By choosing SASR over these other methods, we ensured the assessment was both skill-level appropriate and adaptive, capturing participants' real-time progress in sight-reading as fostered through game-based learning exercises.

Participants were randomly assigned to either the game or practice tool group (since the sample was representative of the population in terms of demographics), practising for a standardised fifteen-minute duration. This time-frame was selected based on existing literature and practical considerations regarding participants' given time (as most participants

were taking time out of their working day to participate). Both groups were exposed to identical educational content and provided with instructions on tool usage, with assistance available upon request.

The sole researcher, who had prior experience in video game studies and had collaborated with professional musicians but lacked formal training, conducted observations for each group. These observations were entirely passive. The researcher, positioned at a short distance, documented participants' experiences solely through observation sheets. These sheets listed pre-defined behaviors to watch for, such as time spent on specific tasks, navigation patterns within the experience, and instances of confusion or frustration. Additionally, the documentation adhered to typical observation protocols, recording objective details without interpretation or judgment. To further validate these observational notes, screen recordings captured participants' interactions throughout the entire session. These recordings began precisely when each practice session commenced and stopped upon completion. It's important to note that audio recordings differed – they ran for the full duration of the entire session, encompassing both the practice period and any pre- or post-session discussions.

Following the intervention period, participants immediately underwent the same tests as the pre-intervention assessments. They were then presented with Likert-style questions, rated on a scale of 1 to 5, to gauge their perceptions of educational value, usability, and engagement for both the game and practice tool. Educational potential and usability were evaluated through a concise set of 1 or 2 questions, while overall engagement was assessed using a modified version of the Player Experience of Need Satisfaction (PENS) questionnaire, tailored to align with the research's specific requirements.

The Comparison Practice Tool

A third-party practice tool was used (Leafo 2023) for comparison in order to avoid bias. The tool consists of a staff (which participants can choose from treble, alto, bass or grand) and a series of notes which can be chosen by the user are displayed (the notes which are spawned based on the users' choice follow no melodic pattern and are a purely random series). The one action users can carry out is playing the first note seen on the staff (the note they play can be visualized on the staff to help orient themselves if they are unfamiliar with the note they have to play) and three scores are collected: total correct, total incorrect and the current streak (i.e. how many they have got correct in a row).

The tool has no elements of gamification or features of game design beside the score. This simple but effective practice tool was ideal as it would make for fair and logical comparisons. In contrast to the game, there is a lack of musicality in that there is no background music nor

rhythmic aspects, the user interface is somewhat convoluted and there is a lack of guidance, but most importantly, the key difference is the lack of game design and gamification.

6.4 Results

The data can be categorised into two groups: performance and perception (opinion-based). Performance data includes the results of skills tests, enabling both within and between group comparisons. On the other hand, perception data encompasses Likert-scale responses, group comparisons, observational data, and participant feedback regarding score-related reasoning.

Table 6.2 The outcomes of Shapiro-Wilk test for data collected

Data	W	<i>p</i>
Pre total time	.783	<.001
Post total time	.764	<.001
Pre total error	.829	.004
Post total error	.894	.045
SASR Total pre score	.941	.297
SASR Total post score	.965	.705
SASR 1 pre score	.883	.029
SASR 1 post score	.769	<.001
SASR 2 pre score	.869	.017

We employed statistical tests using SPSS (a combination of t-tests and Wilcoxon Signed Rank tests as not all data was parametric) in order to assess potential significant differences between the pre-defined criteria in our study. Normality of data distribution was assessed using the Shapiro-Wilk test for all criteria. Only the pre and post total scores for the SASR ($p = 0.297$ and 0.705 , respectively) exhibited normal distributions.

Consequently, paired-samples t-tests were employed to analyse these two criteria. For the remaining criteria with non-normal distributions, Wilcoxon Signed Rank tests were utilised to evaluate significant differences between pre and post measurements. Following significant findings, a post hoc power analysis was conducted using G*Power to determine the power.

6.4.1 Flash Card Results

Flash card scores were evaluated based on two primary criteria: time taken and total errors made (i.e., recall time and question accuracy).

Analysis revealed a significant decrease in time spent on the test overall (pre vs. post), regardless of the learning solution used. Participants took considerably longer on the pre-test

(median = 202.32) compared to the post-test (median = 125.62). This improvement was statistically significant (Wilcoxon signed-rank test: $Z = -3.724$, $p < .01$), with a large effect size ($r = .88$) indicating substantial practical significance.

Similar trends were observed within each group. Learners using the game solution showed a significant decrease in time spent (pre vs. post) (median pre-test = 171.12, median post-test = 113.07). The Wilcoxon signed-rank test confirmed this with significant results ($Z = -2.666$, $p = .008$) and a large effect size ($r = .89$). Likewise, learners using the market standard tool displayed a significant decrease in time spent (pre vs. post) (median pre-test = 203.99, median post-test = 126.52). The Wilcoxon signed-rank test supported this finding ($Z = -2.666$, $p = .008$) with a large effect size ($r = .89$).

Interestingly, no statistically significant difference was found between the game and tool groups in terms of time spent on the post-test (Mann-Whitney U test: $U = 36$, $p = .691$).

Overall, participants made significantly fewer errors on the post-test (median = 13.50) compared to the pre-test (median = 24). This improvement was statistically significant (Wilcoxon signed-rank test: $Z = -3.048$, $p = .02$), with a large effect size ($r = .72$) thus indicating a substantial reduction in errors.

Similar trends were observed within each group. Learners using the game solution showed a significant decrease in errors (pre vs. post) (median pre-test = 30, median post-test = 17). The Wilcoxon signed-rank test confirmed this with significant results ($Z = -2.371$, $p = .018$) and a large effect size ($r = .79$).

However, for learners using the market standard tool, while the pre-test error rate (median = 14) was higher than the post-test error rate (median = 8), the decrease did not reach statistical significance (Wilcoxon signed-rank test: $Z = -1.778$, $p = .075$). Despite the lack of statistical significance, a large effect size was found ($r = .59$), suggesting a potential trend towards improvement.

6.4.2 SASR Results

Overall, participants scored significantly higher on the SASR after the test ($M = 132.11$, $SD = 12.94$) compared to before the test ($M = 123.94$, $SD = 13.90$) ($t(df) = -2.333$, $p = .032$). This improvement reflected a large effect size (Cohen's $d = -.550$).

Participants who used the game showed a significant increase in SASR scores after the test ($M = 138.33$, $SD = 13.97$) compared to before ($M = 124.33$, $SD = 10.52$) ($t(df) = -4.688$, $p < .001$). This improvement represented a large effect size (Cohen's $d = -1.563$).

Participants who used the tool exhibited a slight increase in SASR scores after the test ($M = 125.89$, $SD = 8.58$) compared to before ($M = 123.56$, $SD = 17.31$). However, this

difference was not statistically significant ($t(df) = -.396, p = .351$). The effect size remained small (Cohen's $d = -.132$).

Participants in the game condition displayed a significant improvement on the first SASR question after the test (Mdn = 100) compared to before (Mdn = 27) ($Z = -1.970, p = .049$). This change indicated a large effect size ($r = .65$) with good statistical power (.82). In contrast, the tool group did not show a significant difference in scores on the first question (Mdn = 79 vs. Mdn = 57; $Z = -.652, p = .515$).

Neither the game nor the tool condition yielded significant changes in scores for the second (game: Mdn = 92 vs. Mdn = 72; tool: Mdn = 57 vs. Mdn = 79) or third SASR questions (game: Mdn = 79 vs. Mdn = 91; tool: Mdn = 83 vs. Mdn = 51) after the test.

A Mann-Whitney U test revealed no significant difference in error improvement scores between the game and tool conditions ($U = 28.50, p = .286$). This suggests that both interventions yielded similar results regarding error reduction.

The overall findings indicate that participants improved their self-assessment of self-regulation skills after the test. However, this improvement was only statistically significant for those who used the game, demonstrating a large effect size. While the tool group showed a slight increase, it was not statistically significant and had a small effect size. Further investigation is needed to understand the differential effectiveness of these interventions on specific aspects of self-regulation captured by the individual SASR questions. The lack of significant difference between groups regarding error improvement suggests that both the game and the tool may be similarly effective in reducing errors.

Similar to the random presentation of flash card tests, SASR exercises were also randomised for each participant, with the selection of exercises 2 and 3 contingent on performance in previous exercises. To ascertain that the results derived from the data were primarily influenced by performance and not the specific exercises encountered, an analysis of exercise occurrences was conducted.

Statistical tests revealed a significant difference ($p=0.0017$) in exercise occurrences, suggesting that any conclusions drawn from the SASR scores should be approached cautiously, taking into account the influence of exercise variability.

6.4.3 Reliability and Validity of Skill Tests

The flash card test demonstrated high reliability for both recall time (Cronbach's Alpha, $\alpha = 0.938$) using the split-half method, and recall accuracy ($\alpha = 0.865$) using all items. These values exceed the minimum acceptable threshold of $\alpha > 0.7$ commonly used in educational research, indicating consistent performance across participants.

Table 6.3 Comparison of Likert Scores in Education, Competency, and Autonomy

Criteria	Group 1 Mean	Group 2 Mean	SD	t(df)	p-value
Education	4.6	3.7	0.53	3.2	≤ 0.05
Competency	3.9	3.4	0.91	8.5	≤ 0.05
Autonomy	4.2	3.5	0.99	5	0.007

In contrast, the SASR test, measuring musical notation skills application, showed low reliability ($\alpha = 0.276$) when assessing individual exercise scores. This suggests the individual exercises may not be reliable measures of musical notation application. Further investigation into the design and scoring of these exercises is warranted. However, for overall SASR scores, reliability was moderate ($\alpha = 0.671$). This discrepancy aligns with the earlier discussed score variations and is elaborated upon in the discussion section.

In order to assess the construct validity of both the flash card and SASR tests, the study examined whether participants' self-reported musical ability aligned with their test performance. Participants with higher self-reported musical proficiency (which was measured during the initial questionnaire - see table 7.1) performed better in the tests. For instance, those with more years of training or experience in reading notation performed faster in the Flash Card test and made fewer errors. Similarly, in the SASR test, more experienced participants demonstrated greater accuracy in tempo and form, with fewer mistakes. This alignment between self-reported ability and test performance suggests convergent validity for both tests.

6.4.4 Participants' Perspectives

A comparison of average Likert scores was conducted in four key areas: education, usability, competency, and autonomy for two different groups. Standard t-tests were employed to assess group differences. The decision to utilise t-tests was informed by the parametric nature of the data, confirmed through both visual data inspection and Shapiro-Wilk tests for normality. The results revealed significant differences between the two groups in education, competency, and autonomy. Notably, no significant difference was observed in usability, which aligns with the expected outcome. This finding suggests that both groups perceived the usability of the system similarly, potentially indicating a well-designed and user-friendly interface. Further investigation into the specific aspects of education, competency, and autonomy that differed significantly between the groups can provide valuable insights for targeted improvements.

Comparisons between the game and scores from a previous study by (Brett et al. 2021) using the same education, usability, and competence criteria revealed significant differences ($p < .05$) across all areas. Crucially, both studies employed the same questionnaire format,

ensuring greater comparability of the data. It is worth noting that while the criteria were the same, the current study collected data through game interaction, whereas the previous study used a more traditional questionnaire format. We employed standard t-tests for these comparisons as the data from both studies was confirmed to be normally distributed using Shapiro-Wilk tests. Notably, the gap between challenge and skill, previously rated low, had increased. Although there was no significant difference in these specific scores, it is noteworthy that the overall competency score significantly deviated from the results of the previous study.

During the practice sessions and subsequent post-tests, an important observation was related to participants' hand usage. Those playing the game naturally adopted a standard five-finger hand position due to the game's control scheme. This hand placement was crucial for quick and precise note-playing during the game, especially during enemy phases. This practice carried over to the post-test, making it less frustrating for game group participants to play the notes they saw, particularly in the application test.

Additionally, participants who played the game exhibited a more confident sense of rhythm, likely influenced by the game's strong musical and rhythmic elements. This confidence translated into their ability to perform well in the tempo-based post-sight-reading tests.

A notable difference in behaviour was also observed in how each group approached their practice sessions. The typical practice tool group showed a tendency to complete their sessions quickly, while the game group participants were engrossed in the game and often expressed a desire to finish specific levels or scenes before ending the session. Furthermore, all game group participants expressed enthusiasm for future studies, whereas the practice tool group showed less excitement about participating again.

To enhance the game further, participants' feedback, encompassing both specific and general suggestions, was gathered through standardised post-session discussions. A semi-structured interview guide ensured consistency across discussions, prompting participants to share both specific and general suggestions for game improvement. While this approach offered some structure, it is important to acknowledge that only one researcher conducted the interviews. Future research might consider employing multiple researchers or standardised online surveys to complement in-person discussions and further minimise potential bias from a single interviewer.

Responses were categorised based on similarities, which closely mirrored the patterns observed. For instance, many participants found the use of colour distracting and frequently switched to black and white mode during gameplay, validating this response. The specific changes were subsequently derived using this approach, and they include:

1. Showing the note name when a successful note was played on a notation.
2. Colours were used as a default option for the notation, but many participants preferred this option off by default.
3. The metronome was useful to keep in time, but the sound was too jarring, and the visuals were not obvious enough.
4. Participants wanted to see their score and have it tracked over time, including the number of notes played in a row and the duration of rhythm tempo.
5. The tutorial was considered too short and reading-intensive, suggesting a need for a more involved approach.
6. All participants found cosmetic items in the shop appealing and wanted to see more of them.
7. The quest system was positively received, and participants were eager to complete challenges. Efforts are needed to increase the number of challenges and ensure they can be completed over multiple levels.

6.5 Discussion and Future Considerations

Below is a discussion of the results concerning the quantitative and qualitative data of the study before a discussion of the overall perspectives of the data as a whole. Finally, limitations of the study are offered before outlining the future considerations that this study has help to define.

Quantitative Results

When observing the data regarding the flash card test results, the key takeaway was that both groups performed significantly better in the post-tests compared to the pre-tests. This result is even more significant as the time allotted for practice (15 minutes) was so small. Whilst there was no significant difference in recall time between the two groups, the difference in improvement in regard to the recall accuracy indicates that the game group improved more so than the tool group. This observed difference in scores may be due to the nature of the practice in each group. The participants who used the game were forced to place their hands in specific positions, which may have led to increased memory through repeated use of specific muscles. Additionally, the use of repeating patterns matched with a musical

accompaniment may have led to stronger associations with practice and thus helped to increase how comfortable participants felt using the keyboard, an idea also evidenced in previous primary research. Finally, unlike the practice tool, the game penalised participants for incorrect mistakes (a negative sound, screen shake and eventual loss of health), which may have reflected into their performances i.e. associating incorrect notes with negative consequences may have led to more a careful and accurate approach in the testing phase.

Whilst it is safe to infer that the data shows each participant improved from pre to post for the overall SASR scores (and that participants in the game group had a significantly higher increase than the practice tool group), this is not the case when observing the individual SASR exercises. This is due to the nature of the test, as the exercises varied depending on performance, so the up and down results from exercise to exercise is to be expected. Out of the three SASR exercises, the most important exercise is the first, as the difficulty of the exercise was similar across all participants (they all received very similar notes). The variation of scores which is observed in the next two exercises is not a negative observation but can be attributed to the nature of the test, as the exercises increased or decreased in difficulty depending on performance. Analysing the data closely, it appears that the game group does improve in regard to the overall score and in the first exercise more so than the practice tool group. Reasons for this improvement may be due to the nature of the practice solutions. Whilst observing the practice tool groups; participants used mostly one hand and a limited number of fingers - they looked less composed than the game group who were forced to use their hands in specific places on the keys. Furthermore, the game also had additional elements such as music, specific musical motifs/patterns to play and made use of phrases which require hands/fingers to be in specific places. This may have helped participants feel more comfortable using the keyboard in a performance setting.

Qualitative Results

The Likert data showed that the game was rated higher for perceived educational value, competency and autonomy. It is possible the difference in score regarding the educational rating is related to the context of the questions being asked. When asking how educational the game was, it would be expected that participants rate it highly because they did learn something and the nature of the concept implies it should not be very educational, whereas it would be the opposite for the practice tool as participants expect it to be highly educational and judge it based on this very context. The lack of difference in usability rating was expected as the game featured a starting tutorial and the practice tool was a simple concept to understand. What was apparent from the interview stage was that the game was relatively easier to use and understand as it guided participants through the game and used common

tropes found in games with which they were already familiar. Whereas, on the other hand, the tool required participants to ask more questions on understanding each option they had a choice of. The difference in autonomy was to be expected as the game features much more choice than the practice tool (different paths, choices of items etc.) as well as the desire to explore the game being rated much higher because participants wished to explore a game world much more than making static choices on a screen. Finally, the observed difference in the competency rating was expected as the game should elicit higher amounts of engagement and the observations highlighted this further; again, the initial reaction to those who had not seen the game was incredibly promising.

As mentioned above, it was important to compare the game from previous studies to ensure that feedback received had a positive impact on the iterative development cycle. It was clear from previous studies that the game was perceived as fun but was difficult to understand/use as well as lacking any educational impact, from the participants' perspective at least. The comparisons clearly show a significant improvement in the areas the game had been lacking in this regard. Whilst there was no significant improvement regarding perceived challenge or the feeling of required skill, the overall significant difference of competency shows that the changes to the game had a positive effect and future changes would also reflect this effect. Key areas of frustration (such as using the menu and a lack of tutorials) were also rectified and overall participants experiences appeared to be much smoother. Finally, the issues and bugs that were highlighted in the previous study were no longer major issues and were mostly resolved; however, there were some new issues that had appeared and fixes would be required before conducting further studies with the game.

General Discussion

Whilst there were some limitations of this study such as the lack of standardisation and limited time of practice, one can still infer from the results that the game helped to improve the acquisition of notation reading skills just as well as the practice tool, if not more so in regard to accuracy and real-world application (i.e. regarding the basic tests of sight-reading). Regardless that the questions and exercises varied for each participant, the results still demonstrated a significant improvement from pre to post for each participant and the game group had improved more so regarding recall accuracy and general scores on the SASR tests. Reasons for this are outlined above but it is important to also note that the game does not only offer a more engaging practice environment but also that observations made demonstrated the game improved overall confidence at the keyboard and improved the form of playing (how participants conducted themselves when using the keyboard was more sophisticated). Finally, the improvement from pre to post test scores is rendered more substantial by the

short practice time allotted for the study; a significant difference in score in such a limited time is a worthwhile result by itself.

Evaluating the Likert style data showed that the differences in engagement between the two groups was significant and this was expected (as a game version of practice should naturally elicit higher amounts of motivation relating to the concept of ‘fun’). This significant difference is also a result of the high score autonomy received from the game group and is expected – the game had lots of different choices and a multitude of actions that could be carried out during the session. The game and the tool were both easy to use and the expected result would be either they would be rated similarly regarding usability or that the tool would be rated as easier to use due to its simplicity; it was a satisfactory result to find that the game was as easy to understand and use compared with the practice tool. Notably, the significant difference between the two groups rating of education was surprisingly, however this can be a result of the context this question is posed and the expectations of each participant – as mentioned previously. Finally, feedback from the Likert-style questions and observational data provided valuable insights into what changes must be implemented to improve usability, understanding and engagement of the developed game.

6.5.1 Pilot Study Limitations

The key issue which persisted on both the flash card tests and the SASR exercises was lack of standardisation. This led to difficulty inferring any meaningful result from the SASR data. However, at the very least, each group had improved from pre to post regarding the overall and first exercise, which can still be considered a significant result. Another issue to consider, and perhaps one that could be regarded as a confounding factor, is the overall improvement observed is not just a result of the intervention period but also of comfort; participants felt more at ease and understood the concept of the exercises and tests in the post test and thus they improved based on this alone. This ‘practice effect’ should be carefully considered in future testing. Whilst there are some limitations of the skill tests, it is safe to assume there was an improvement from pre to post and the game may still have better potential to improve the skill of reading music more so than a typical practice tool. Whilst there was moderate reliability of the usability questions posed, there was a lack of validity in regard to using existing questionnaires found in the literature which perhaps reduce the potential of replication for future studies. This also applies to questions which were used to assess engagement of each solution. Improvements from the previous study were considered and implemented, however it is still important to revise these questions and refine them further, especially considering the reliability of the Likert scores pertaining to competence was rather low.

6.5.2 Future Considerations

Now that limitations of the testing methodology have been established, future studies will ensure these will be rectified by standardising tests and creating custom versions of sight-reading exercises. However, a key objective which has not been considered in regard to the overall research aim is how engaging and effective these solutions are in a real-world scenario and how one could empirically measure such a concept (another key issue missing from the existing solutions). This real-world practice over extended periods of time will also help to negate the practice effect that may have been observed. The intention now is to ensure that the developed prototype is more engaging over extended periods of time and this can be measured empirically through longitudinal studies, making use of telemetric data of participants gameplay; thus ensuring that video game practice yields higher amounts of engagement and therefore improves a given skill more so than typical practice. In addition to this, it is important to consider the questions which will help reveal how engaging and usable the game is by considering further research in each of these domains. Finally, feedback from the Likert-style questions provided valuable insights into what changes must be implemented to improve usability, understanding and engagement of the developed games. Towards this, the team commenced work leading to an improved game in line with the above feedback as well as initiating a longitudinal study which aims to answer the questions posed above.

6.6 Chapter Conclusion

In this chapter, the development of the RPG style game, 'Note Reader Adventure' was discussed in which specific insights and inspirations were mentioned that helped the further development of this game. This is followed by the third study, a pilot study which is used as a basis for future longitudinal experimentations. The results showed that the skill acquisition tests were appropriate in determining a learners ability to match musical notation to specific keys but the tests for the application of this skill were not quite as reliable. Future work includes the development of a custom sight-reading test to ensure standardisation and reliability of the application tests as well as using a set of notations and exercises (rather than random ones). Finally, questions pertaining to competence are revised to ensure that higher amounts of internal consistency are found and that future researchers can make meaningful decisions based upon this. Going forward, the developed game is refined and improved based on the feedback and observations before being used in a longitudinal study which is founded on the pilot study; limitations of the pilot study are considered and improved upon to ensure that this method of assessment if validated, reliable and replicable for future testing purposes.

Chapter 7

The Crypt of Notation: Real World Applications

7.1 Chapter Introduction

This research has followed a systematic progression in developing and validating game-based approaches for music education. Beginning with multiple prototype mini-games in Chapter 4, the focus was refined to specific skills like notation reading based on qualitative assessment. The work then evaluated different categories of games in Chapter 5, from basic training tools to fully gamified experiences, revealing that more game-like approaches could maintain pedagogical value while increasing engagement. Building on these findings, Chapter 6 presented a pilot study comparing our most promising prototype against traditional training methods, demonstrating the potential of game-based learning while highlighting areas needing refinement.

Among these limitations was the SASR approach used to assess reading skills. This standardised test proved difficult to reliably implement and analyse, as the randomised nature of the exercises led to inconsistent results across participants. To address this, this chapter presents a comprehensive remote study of 'The Crypt of Notation', an evolved version of the game prototype. Rather than relying on the problematic SASR framework, the assessment has been rebuilt from the ground up, featuring a restructured Flash card test with progressive question sequencing and a custom Notation Reading test designed specifically for this context.

Alongside these assessment improvements, the game itself has been refined, with an enhanced onboarding experience, implementation of deeper narrative elements, improved user experience and interface design, and resolution of technical issues identified earlier. The

study presented here represents the most rigorous evaluation yet, with participants engaging in either game-based or traditional practice over five days within a one-week period. This extended testing period allows examination not only of skill acquisition but also sustained engagement - a crucial factor identified in earlier chapters for effective music learning. With 30 participants completing the study remotely, the findings can now evaluate whether the increased engagement observed in controlled studies translates to real-world practice environments.

This chapter details the recruitment process, methodology, and results, demonstrating how the iterative research approach has led to a game-based learning tool that effectively balances engagement with pedagogical value. The findings help establish a new paradigm for music practice, while the limitations discussed provide direction for future research in game-based music education.

7.2 The Game

Once the prior pilot study had concluded and the results were analysed, the next round of development begun for the ‘Note Reader Adventure’ game. As the game had been so positively received, it was important to add personality and depth to the game, to help players build their own personal relationships with the story and characters found throughout the game. Therefore, a short narrative was created and inspired by the theme of the game as well as creating a title which would be less functional and would inspire creativity.

The final title that was decided upon was, ‘The Crypt of Notation’, which was inspired by the Crypt of the Necrodancer (2015), as players navigate crypt like levels in which notation is the core mechanic. Incorporating a narrative storyline was seen as a key way to add depth and meaning to the gameplay experience. The story for the game is shown to players during the beginning phases and various characters help to continue this story throughout the game.

The story revolves around a main hero character, Maalik, the guardian of purgatory. Maalik’s evil counterpart, Yalla, a pure evil and spiteful entity, has stolen the songs of Maalik and corrupted the afterlife of the souls that exist in Maalik’s crypts. Maalik calls upon the player to help him recover the stolen songs and battle the forces of evil that are spreading throughout purgatory. Yalla can only be defeated by recovering the songs and restoring the balance to Maalik’s crypts; it is up the player to fight against evil by playing funky beats and thus ensuring that Maalik can restore peace to the corrupted world.

Incorporating this narrative storyline was intended to make the game world and objectives feel more meaningful and relatable to players. By establishing Maalik as the protagonist that the player is helping, and Yalla as the antagonist that must be defeated, it gives the player a

clear sense of purpose and investment in progressing through the game. The story also helps to contextualise the game's core mechanics - recovering Maalik's stolen songs by correctly playing musical notation - within a cohesive and compelling fantasy setting. This builds on previous research findings that showed players felt more engaged and motivated when games had a clear narrative and overarching goals (Brett et al. 2021 2020).

Additionally, the inclusion of various supporting characters throughout the game's levels helps to further develop the narrative and provide the player with a sense of progression. These characters can guide the player, provide additional background information, or even set up new challenges and quests for the player to complete. This helps to maintain player engagement and make the game world feel more alive and responsive, rather than just a series of abstract levels to work through. By having these supporting characters advance the story in meaningful ways, the design of the game aimed to create a more immersive and meaningful experience for players, where they feel invested in the protagonist's journey and the resolution of the conflict with the antagonist.

The narrative elements were also seen as a way to improve the overall usability and accessibility of the game. By providing a clear story context and motivation for the player's actions, it can help make the game's objectives and mechanics more intuitive and natural to understand. The supporting characters can also serve as guides, providing tutorials and hints that are grounded in the story world rather than feeling like disconnected game systems. Overall, the narrative aims to create a more cohesive and enjoyable experience that draws the player in, rather than presenting them with a series of abstract challenges.

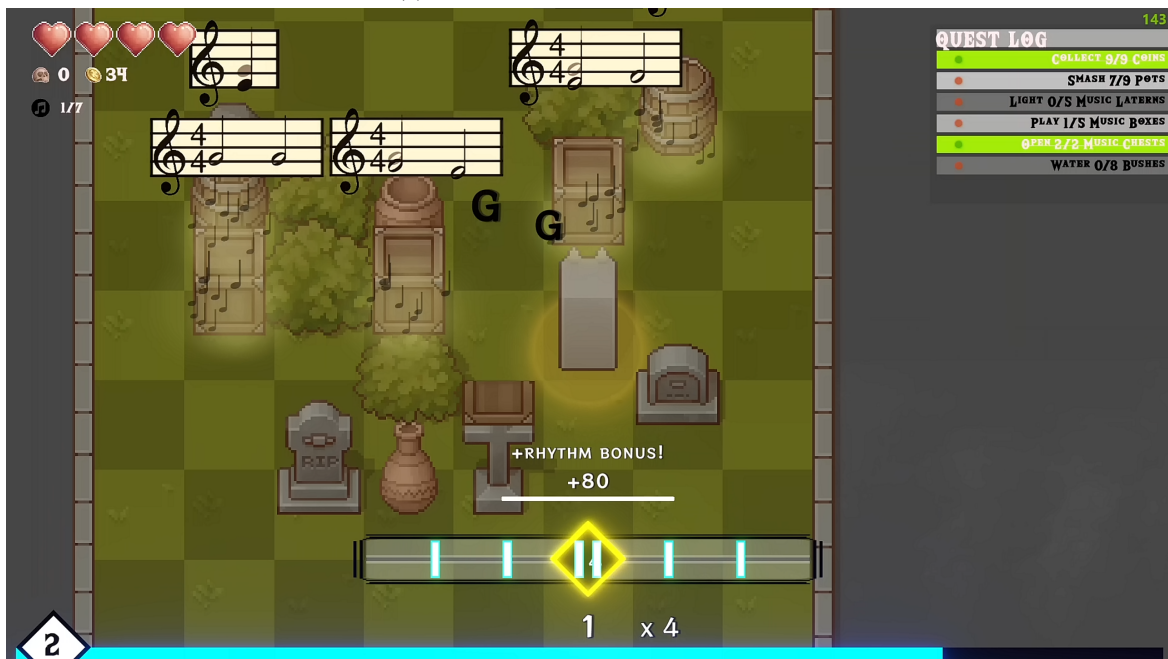
In terms of content, a mix of both hand-crafted and procedurally generated levels was adopted to create the 'The Crypt of Notation'. There are 51 levels in total, 5 of which are hand crafted by the lead developer and include additional layers of game design such as narrative, secret paths and basic key/door mechanics. The other 46 levels are procedurally generated but still include puzzles and intelligent enemies. This approach was taken due to the size of the development team being mostly a sole developer and designer (plus at the same time researcher).

By grounding the game in a distinct narrative, with a clear protagonist, antagonist, and supporting cast, we ultimately sought to make the overall gameplay experience feel more immersive and meaningful for players. The story elements were intended to complement the core music-based mechanics, providing an engaging context and motivation for players as they navigate the challenges presented in 'The Crypt of Notation', building on previous findings in the field (Brett et al. 2021 2020).

The sound design of 'The Crypt of Notation' served multiple pedagogical and experiential purposes. Background music was carefully composed to match the gothic-themed

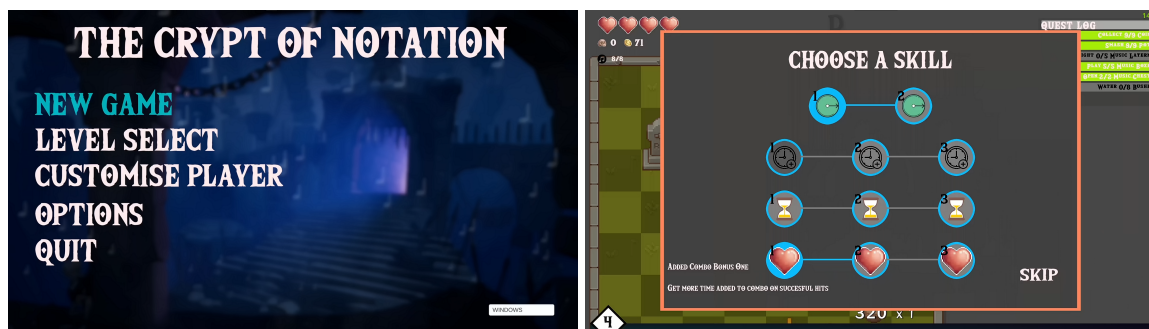


(a) Screenshot of hand-created level



(b) A procedurally generated level

Fig. 7.1 The Crypt of Notation Levels



(a) The Crypt of Notation main menu

(b) The in-game skill tree menu

Fig. 7.2 The Crypt of Notation Menu Systems

environment while maintaining clear rhythmic patterns that support the learning objectives. Each level featured a distinct backing track that plays at a consistent tempo, helping players maintain rhythmic accuracy while moving and playing notes. Audio feedback is strategically implemented: correct note plays produce clear, pitched tones that harmonize with the background music, while incorrect attempts trigger a subtle dissonant sound that provides feedback without being discouraging. The metronome features both visual and auditory cues, with a distinct "tick" sound that can be adjusted in volume independently of other audio elements. Environmental sound effects - such as enemy movements, item collection, and level completion - are all designed to occur on-beat with the music, reinforcing the rhythm-based nature of gameplay. Additionally, the game implements adaptive audio mixing, where background music dynamically adjusts in volume during critical gameplay moments (such as enemy encounters or notation challenges) to ensure that important audio cues remain clear and distinguishable. Players can adjust various audio levels independently through the menu system, allowing them to customize the balance between background music, metronome clicks, gameplay sound effects, and their own played notes to suit their learning preferences.

7.3 The Longitudinal Study

A repeated measures design was chosen for this study as it offers several advantages. By measuring the same participants multiple times, we could control for individual differences, increasing the sensitivity of our analysis. This design is particularly effective in detecting smaller effect sizes, making it a powerful tool for evaluating the impact of interventions.

While this design was ideal for our study, there were potential limitations, such as practice effects. To mitigate these, we employed specific strategies, including counterbalancing the order of conditions and incorporating sufficient rest periods between testing sessions (whilst

ensuring freedom to choose for participants to reflect the nature of the real-world practice environments).

Alternative designs, such as independent groups designs, were considered. However, these designs required a larger sample size to achieve comparable statistical power, which would have been less efficient and costly. Additionally, individual differences between participants could have introduced more variability into the analysis, making it harder to detect significant effects. Thus, we opted for a repeated measure designs as it was the most optimal method that would help achieve our goals and align with the key goals of understanding how knowledge and skills retain over time and whether or not the method of practice has a significant impact on the outcome of assessment.

Within this study, the goal was to measure the improvement of a learners ability to read music over a period of one week within their own environments (i.e., measure the real-world application of the developed training game). Participants were administered a pre-test to measure a baseline of the skill before either practicing with the novel training game or standard practice tool for a week. The comparison training tool was the same online tool (Leafo 2023) that was used in the prior pilot study, as the results showed that it was a valid and worthwhile tool for meaningful comparison. After the week period, they conducted the same skill tests as before (with a slightly varied order of questions and exercises), and the differences in the pre/post scores will be observed. Participants will complete post practice session surveys throughout the study to measure engagement of each solution; tracking how long they play for; what they do during the session and what effect the practice had on their motivation and confidence in context to playing and learning. Participants will also fill out a final survey helping to give insights into engagement, overall usability and preferability of each solution. The intended outcome is that the game is engaged with more so (and is ranked higher regarding all Likert style questions) and therefore improves the skill of reading music more so compared to the training tool within real-world contexts of learning (i.e., not in a controlled environment).

7.3.1 Key Questions

- Does the prototype training game improve the skill of reading music in a real-world context? (i.e., outside of a lab-based setting) when compared with a market standard practice tool?
- Can this improvement of skill be applied to other areas of playing/learning (in this case, can practising the skill of reading music/playing our developed game help our learners to read a piece of music more fluently)?

- How do factors such as practice environment, frequency, technique, feedback, and individual differences influence the long-term retention of the skill of matching musical notation to keyboard keys, particularly in relation to muscle memory?
- Is the developed prototype game more engaging than a typical standard training tool? (how motivated and confident does each group feel to practice?)
- Does amount of time spent practising correlate to how much skill is improved and are there any other factors that contribute to the acquisition or improvement of the skill of reading musical notation?

7.3.2 Participants

In total, 162 participants signed up to take part in the study initially, however, the number of participants who completed the study in full was eventually 30. All 162 participants completed the initial survey sent to them which provided demographic data and helps to provide some interesting information on particular learners and their learning preferences. Out of the 162 participants, roughly 60 began the second phase of the study (the skills test) and went on to begin the practice week. The number of participants began to reduce over the course of time - some participants were too busy to complete the remainder of the study whilst others had major life events occur forcing them to drop out of the study; leading to eventual number of participants that fully completed the study to 30.

As participation in the study was completely remote, participants did not need to be based locally to the researcher and as such the recruitment could be extended globally. As a result, the total 162 participants were located in multiple countries across the world where most were based in either the UK or the USA; the map below shows the specific origins of the participants for the total 162 that had initially signed up. Of the 162 participants, the methods of learning and practice varied but there were 3 popular methods that were observed: online videos and applications, self-taught and tutor based. Interestingly, those that had claimed they were competent learners and could read notation confidently, had slightly different methods of learning that were most popular, which included: self-taught, tutor-based and books – with online videos and applications still being used but not as much as the 3 most popular methods (the graphs below help to demonstrate this difference and highlight the need for a very precise target audience when designing such learning solutions).

The eventual sample consisted of 7 females and 23 males with the majority of participants either aged 25-34 (40%) or 35-34 (27%). Most participants were either absolute beginners with no experience of reading musical notation but had a desire to begin learning keyboard or piano (and had tried to at some point in their lives); 5 participants were competent musicians

Table 7.1 Pilot Study Participant Demographics

Demographic Information	Age Group				
	18-24	25-34	35-44	45-54	55-64
N (Count)	4 (13%)	12 (40%)	8 (27%)	5 (17%)	1 (3%)
Gender (count)	1F	2F	3F	0F	1F
Experience Reading Music (out of ten; mean)	2.25	3.58	3.13	2.6	4
Gaming Habits mean)	1-2 Hours Per Day	Once a week	Once a week	2-3 times a week	1-2 hours a day

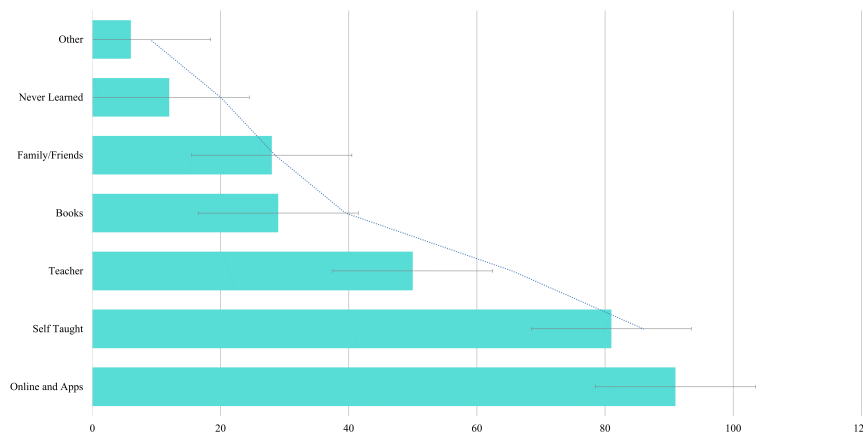


Fig. 7.3 Participant's learning habits

who were skilled at reading musical notation and playing their instrument (typically keyboard, piano or both). Out of the 30 participants, only 3 stated they did not play games whilst the majority of participants played either at least once a week or once a day (there were no relationships found between age ranges and time spent playing video games). There were a total of 4 participants who did not own a MIDI keyboard (either owning no instrument or a key-based instrument which lacked MIDI capabilities), and were able to either borrow the required hardware from a friend or from the company on a loan basis.

7.3.3 Study Protocol

The initial sample size was calculated, based on the previous studies and calculating effect size: .05 level of significance, 90% power, 20% increase in score and standard deviation of 2.5 resulted in 34 required participants. This was a rather high number of participants, particularly when one considers the complexity of the study and the amount of time required for each participant to spend; thus the end result of 30 total participants is satisfactory. Initially, participants were recruited through the existing mailing lists as well as through Bournemouth University. The initial recruitment advert requested that participants meet a certain demographic, listed as:

- 18+ years of age
- Aspiring musicians who are absolute beginner to intermediate keyboard/piano learners (participants could apply if they were competent musician but beginners had priority)
- Little to no experience reading musical notation (participants could apply if they were competent in reading music but beginners had priority)
- Enjoy playing video games (ideally on a regular basis) or are interested in gamified learning in any capacity
- Ideally own a MIDI keyboard with at least 48 keys (4 octaves); there was potential to loan hardware to particular participants, where feasible

As the study was rather involved and conducted over a longer period of time than any other study, it was important to offer worthwhile incentives. Therefore, all participants were initially awarded a £30 Amazon voucher and were entered into a prize pool. The winner of the prize pool would receive hardware from the sponsor company and the second prize was an additional £50 Amazon voucher. The initial numbers from the first round of recruitment was low, and whilst some participants had completed the initial demographic survey to show interest, many did not follow through on the next stages of the study; about 5 total participants had completed the full study based on the first round of recruitment. Based on these low numbers, it was decided that the second round of recruitment would increase the incentive and other avenues to seek out potential participants were explored. The base incentive increased to £50 whilst the prize pool second place was raised to an additional £100 Amazon voucher. Additional mailing lists were consulted at Bournemouth University whilst also emailing those from the companies mailing list, whilst they may have some interest, they would not fit the ideal demographic but could still offer meaningful data. The number of participants who filled out the initial survey rose extensively and over 20 participants continued to the next stage of the study. However, only around 10-15 participants actually continued through all the stages of the study as some participants had serious life events preventing them from continuing, whilst others simply did not respond after a certain stage.

Therefore additional areas of recruitment were explored further, particularly focusing on online forums that were relevant to the research. Specifically, sub forums used on a popular website, Reddit, were used, focusing on those dedicated to music, keyboard and piano learning whilst also posting on a sub forum dedicated to academic study recruitment. Through this and advertising through LinkedIn resulted a surge in the total of number of participants filling out the initial demographic survey. Although the large number of sudden new participants was positive at first sight, it also raised questions. Upon closer inspection,

many of the responses appeared to be highly similar, if not completely identical to one another; unfortunately, even with added measures to prevent such an occurrence, there had been particular answers provided either by bots or by participants using software which would fill out multiple instances of responses automatically. The issue of attempting to recruit a substantial number of participants had required posting the advert to multiple locations which in turn had led to unwanted responses. There were precautions in place to prevent this, such as the requirement of open-ended answers and additional hidden optional items, yet the advent of intelligent software appeared to overcome these precautions. After analysing all the responses and determining the 'fake' data (which was rather obvious when multiple responses were identical and provided within an extremely short space of time), the total number of responses went from 382 to 162; 220 fake responses were removed and analysis of the results that remained could be analysed.

All participants that had completed the initial survey, and matched the ideal demographic, were sent instructions on completing the first stage of the study, the pre skill tests. Each participant was required to complete two tests, a skill acquisition and application test (see further details below). Each test the participant undertakes is downloaded from a secure server and their scores are automatically uploaded to a remote server which the researcher will have access to. It will record participant number, the time the test was taken and all the data relevant to the test itself (how many mistakes made, time taken). This data is fed into a comma separated value document which will be translated by spreadsheet software (Microsoft Excel). If participants did not complete the tests within 5 days there were contacted by the researcher; only those who complete the initial pre-tests were progressed to the next of the study.

Once a participant completed the two skills test, and their data was found on the server, they are emailed the next steps. At this stage, the participant is split into one of two groups: the control group will use a basic notation reading practice tool found on the web and the experimental group will play the developed prototype training game. The game group was guided by an in-game tutorial and the tool group were given basic instructions on how the training tool works and what each option does. Each group was required to use either solution for at least 10 minutes per session, for 5 days within one week – the days were not required to be consecutive and the time could not be stacked (it had to be 10 minutes day - 20 minutes one day did not count for two days of 10 minutes practice). The 10 minutes could be completed over multiple sessions over a day (such as, 2 sessions of 5 minutes rather than 10 minutes in one go). The minimum total practice time was therefore 50 minutes of practice time if participants only play for the allotted time required. Participants will be informed that they can practice outside the time if they wish to do so but this is not a requirement of the study. Participants are also instructed to not practice reading musical notation using other

training or practice methods during the 7 days but are permitted to practice other elements of their keyboard learning. Participants were also required to fill out a short questionnaire at the end of each practice session to gain insight into what they had been playing and practising and their general views on either practice solution (specifically, how long they had used the solution for and the effect it had on their motivation and confidence to learn and play).

After the 5 sessions of practice had been completed, participants were required to undertake the same skill tests as before, in which the order of questions were and exercises were shuffled. The difference in scores between the pre-test and post-test were measured with the assumption that both groups will have a significant difference in score (with the hope that the game groups improves more so than the tool group purely because they have practiced more as the game is more appealing than the tool). These tests follow the exact same format as before and all data will be recorded and uploaded to a secure, remote server. Following the skill tests, participants are required to fill out a survey (once again, in a JISC Form which the researcher will have access to the answers) about their experiences. They will be asked about how engaging, usable, and educationally valuable they thought their practice tool was. This will be in the form of mostly Likert style questions with some questions asking for more detailed answers (general comments rather than a 1-5 answer). This section of the experiment, in conjunction with the post session surveys, will give insight into how engaging and usable each solution was; the assumption being that the game will be used more and receive a higher rating for engagement as well as more overall positive feedback compared to the practice tool. Details of each question can be found in the appendix.

Skill Acquisition Test

As the pilot study demonstrated the effectiveness and reliability of the Flash Card test in assessing the acquisition and improvement over time of the fundamental skill of reading musical notation, essential for overall musical proficiency, this methodology was again employed in this study. Skill acquisition, in this context, refers to the process of learning to associate visual symbols (musical notation) with specific motor actions (pressing keys on a keyboard) and the subsequent development of automaticity in this process. This process involves learning, practice, and memory consolidation over time. To enhance the test's reliability and validity, a standardised approach was adopted. Unlike the previous version, which randomly selected notations, this study utilised a predetermined sequence of notes, ensuring consistent and comparable results across all participants. The scores were calculated based on two primary factors: recall accuracy and recall time. The note sequence was carefully designed to increase in difficulty, aligning with common music theory curricula and standardised tests (noa 2021, Gritton 2019)), thereby providing a robust measure of

skill acquisition and progression over time. By focusing on this core skill, the study aimed to gain insights into the factors that influence the development of musical ability and to identify effective strategies for teaching and learning music. By understanding the factors that contribute to the acquisition and retention of this fundamental skill, educators and researchers could develop targeted interventions to enhance musical education and improve student outcomes.

Skill Application Test

Based on limitations found in the pilot study that the SASR tests lacked standardisation and the specific data that made up the total score could not be assessed, a custom reading exercise test was developed. The test was similar in nature to the SASR score; however it allowed more time to read the exercise to help reflect the skill of reading music rather than the skill of sight-reading, whilst also ensuring that every participant received the same exercises, in the same order. The test showed participants a basic reading exercise (a monophonic motif) and they could familiarise themselves with the exercise by reading over it for a total of 40 seconds. Once the 40 had passed, the test would count the participant in (a count of 4) and they were required to play each note seen to both the metronome and simple backing track. Participants could navigate to a help screen before or after each session to ensure that their keyboards were connected and in the correct octave whilst also reading the instructions on how the test works. There were 4 exercises that were completed in total, where the first exercise was used mostly to help participants acclimatise to the test before being introduced to more complex exercises. Score was based on 3 factors: total correct notes, total incorrect notes and rhythm accuracy. Rhythm was measured by the time either side of the exact moment of the tempo on the note; three accuracies were scored: slow (around 0.5 seconds from the beat), OK (around 0.3 seconds from the beat) and perfect (around 0.1 or less than the beat). Score was a sum of the correct notes played multiplied by their corresponding rhythm scores whilst removing a point for each incorrect note played; a total score of all the exercises was calculated by simply totalling the scores of all 4 exercises. This custom developed test ensured that there was a standard across all participants and that the individual data could be analysed in depth.

7.3.4 Results

There were three main categories of data from the results of the study: the skill test data, the data from the post sessions and finally, the data that was extrapolated from the final surveys participants completed. The skill test data comprises of the results from both skill tests, the Flash Card and Reading Notation test - specific criteria was analysed regarding both

tests. The post session survey data helped to gauge the time each participant spent practising with their given practice solution as well as how the solution impacted each participants motivation and confidence regarding playing and learning their keyboards or pianos. Finally, the end survey data helped to measure the opinion data relating to how participants rated pedagogical value, usability, competence and autonomy (both competence and autonomy being used to measure overall engagement), in which comparisons were made between the two groups. The end survey also allowed participants to feedback in their own ways on the overall experience and any reasons that may have led to specific Likert ratings.

Skill Tests

As mentioned, the skill test was split between the results of the Flash Card and Reading tests. Below is a summary of the data found for each test, including relevant reliability and validity discussions.

Flash Card Test

The data for the Flash Card test was comprised of two key criteria (in which the pilot study helped define): recall accuracy (total mistakes and mistakes per questions) as well as recall time (how much time it took to answer each question and the total of all questions).

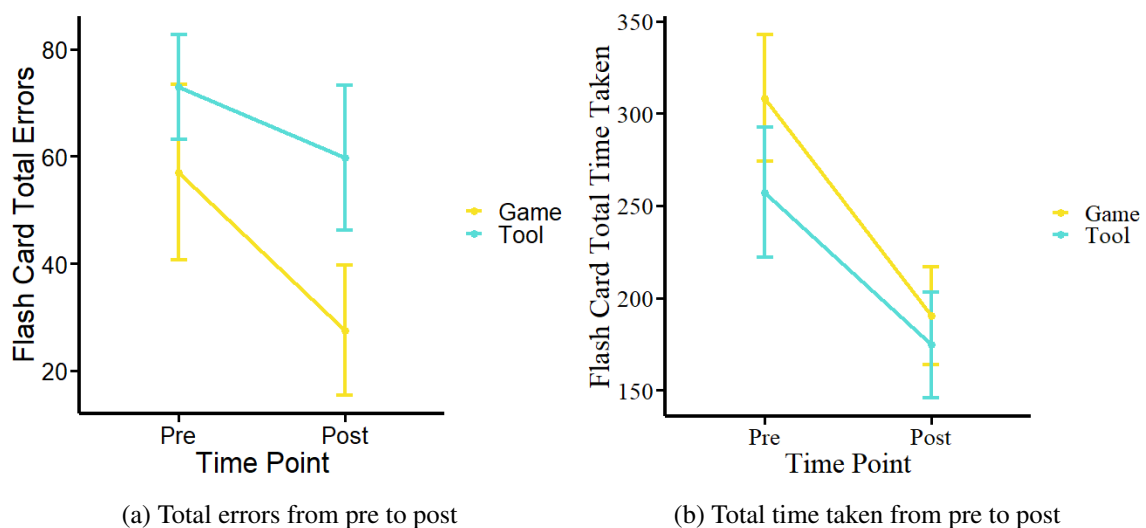


Fig. 7.4 Flash Card Results

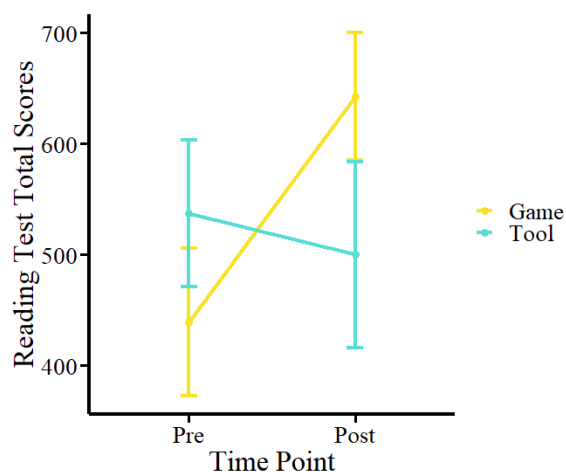
Regarding the recall accuracy, it was found that only the group which used the game for practice had a significant difference from pre to post ($p < 0.05$); the data shows they had made fewer mistakes, rather than a significant difference showing they had more mistakes.

Comparing between the groups, there was, not surprisingly, a significant difference between the groups regarding their differences of total mistakes made from pre to post ($p= 0.002$). This result shows that the game group had far less errors from pre to post and the difference compared to the tool group was significant.

When analysing recall time scores (i.e., how much both groups had improved regarding time required to answer correctly), it was found that both groups had improved significantly from pre to post. When comparing between the groups, there was no significant difference between both groups ($p=0.191$); the result does show that the game group had improved more than the tool group, but the difference was not great enough to be significant. In summary, only the game group had improved from pre to post regarding recall accuracy, however, both groups had improved in context to recall accuracy in which there was no significant difference between the groups.

Reading Test

The data for the reading tests were split into three smaller items, which the total score is based on. These smaller data criterion were: total correct and incorrect notes played and total rhythm score (measured with three scores: slow, OK and perfect). Each of these scores were totalled from all four exercises as well as comparing the total scores of the individual exercises to determine if there was a specific exercise which skewed the overall summaries. Below is a summary of the overall scores summarised from the individual scores as well as a breakdown of the individual scores from each exercise.



(a) Overall Reading score from pre to post

	Pre		Post	
	Game	Tool	Game	Tool
Count	15	15	15	15
Mean	439	537	643	500
SD	258	257	223	324

(b) Study Two Recall Accuracy Scores

Fig. 7.5 Overall Reading Test Results

Regarding the overall total scores (i.e., the sum of the individual exercises), only the game group had improved significantly from pre to post relating to the total score, correct and incorrect notes played and rhythm accuracy. As a result, there was a significant difference between the groups for each of these criteria and it can be concluded that the game group had improved significantly higher than the tool group (over a 30% improvement in all categories).

When reviewing the total scores for the individual exercises, the game group had a significant improvement from pre to post whereas the tool group had only a significant difference on exercise 3 ($p=0.014$). Upon further inspection, it was apparent that the significant difference was a negative one (participants scores were significantly lower from post to pre). This is also reflected within the game group as all scores are lower on exercise 3, however the game group still had a significant improvement, whereas the tool group was the opposite. The results showed that the game had significantly higher difference in score when compared to the tool group ($p<0.05$).

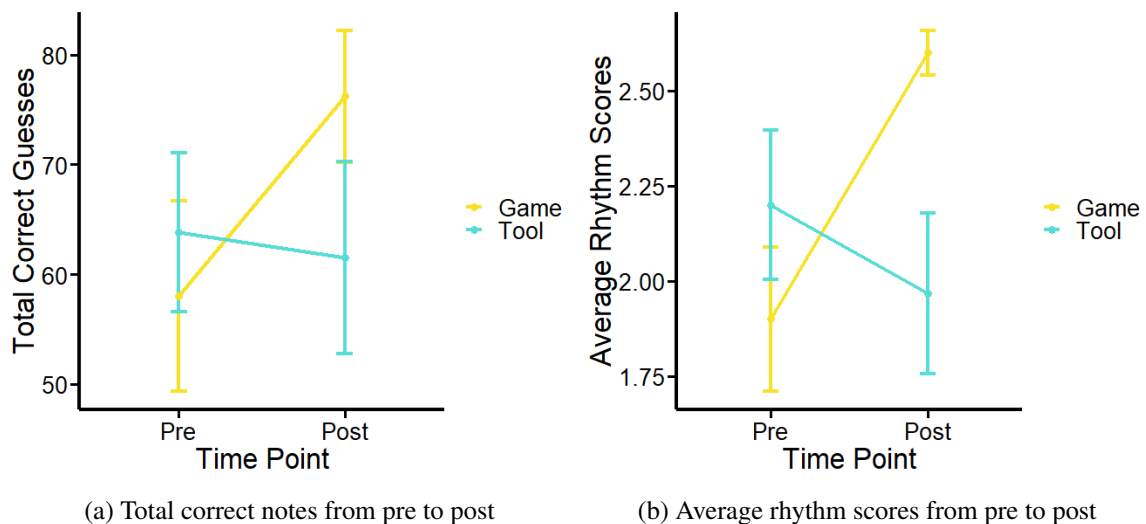


Fig. 7.6 Reading Test Specific Results

From these results, one can safely assume that the participants who practiced using the game had improved in the reading test significantly more so than those who practiced with the training tool; the difference in score is substantial and because there was an even difference on all exercises, there is no particular exercise that skewed this result (helping to ensure validity of the reading tests).

Predicting Future Trends Using Multiple Regression

Although the initial results were successful in meeting the expectations of our hypothesis, we were still not entirely satisfied with the implications of the results. As the study only ran a week and some of the participants did not meet the requirements every practice session, we decided to investigate the longer term impact that these results indicated. The concept of our research had led to this idea of game-based learning being the most impactful method of practice that would help with longer-term retention of information and encourage practice over longer periods of time to greater success. With this study, we had supported this claim, but we wanted to establish whether or not our results indicated that this success would be true over longer periods of time by retro-analysing the data and predicting future trends. As such, we conducted further statistical analysis on our data set to help explore intention to use the game in the future.

We carried out multiple linear regression to investigate specific relationships in order to determine whether or not our game-based learning method would yield greater performance metrics over given periods of time and whether or not participants would still engage frequently with our game method. Specifically, we investigated the relationships between the willingness to use the game as supplement to standard learning (future usability) and intention to use the game (intention to use) and the willingness to practice with the game again (willingness to practice), the perception on others learning the game quickly (learnability), the perception that the game is complicated (over-complication) and total errors made during the practice (total error of both Flash Card and Notation Reading exercise overall results). The goal was to identify variables that could predict both the performance outcomes of specific skill-based exercises and participants' intentions to continue engaging with the practice method. Understanding these variables allowed us to assess the educational value and overall engagement of each practice method. Furthermore, it provided insights into the relationship between engagement, time spent learning or practising, and skill retention.

The scatter plot of standardised predicted values versus standardised residuals showed that the data met the assumptions of homogeneity of variance and linearity and the residuals were approximately normally distributed; thus allowing us to conduct multiple linear regression between these variables. Several factors, including learnability ($p < .001$), over-complication ($p = .007$), intention to use ($p = .023$) and total error ($p = .038$) had a significant relationship with the intention to use the game. This was found to be specific to the two units of learnability, such that, relative to each unit of learnability, future usability scores increase by 0.474 units. Likewise, a one-unit increase in intention to use led to a 0.279 point increase in future usability, suggesting that higher levels of user interest in a game result in a higher level of perceived usability within that game. This also decreased the over-complication in

the game which increased future usability scores by 0.254. Finally, significant improvements in total errors were linked with small but measurable improvements in future usability, with each unit of error reduction (from the low error requirement) increasing future usability by 0.001 points.

Group	Model		Unstandardized Coefficients		Standardized Coefficients Beta	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
			B	Std. Error				Lower Bound	Upper Bound	Tolerance	VIF
Game	1	(Constant)	1.764	.476		3.707	.004	.704	2.824		
		I can imagine most people would quickly get on with the solution	.474	.080	.750	5.948	<.001	.297	.652	.718	1.392
		I found the concept of the solution difficult to grasp/understand	-.254	.076	-.407	-3.368	.007	-.423	-.086	.784	1.276
		I want to play/practice using the solution again	.279	.104	.331	2.675	.023	.047	.512	.748	1.337
		TotError	-.001	.001	-.280	-2.390	.038	-.002	.000	.833	1.200
Tool	1	(Constant)	.645	1.168		.553	.593	-1.956	3.247		
		I can imagine most people would quickly get on with the solution	-.102	.178	-.090	-.571	.581	-.498	.295	.509	1.965
		I found the concept of the solution difficult to grasp/understand	.114	.235	.071	.484	.639	-.410	.638	.575	1.739
		I want to play/practice using the solution again	.872	.118	.999	7.402	<.001	.610	1.135	.688	1.454
		TotError	.002	.005	.049	.391	.704	-.009	.012	.793	1.262

Fig. 7.7 Across game and tool groups, variables, such as 'I can imagine most people would quickly get on with the solution' have significant relationships with performance metrics. Demonstrating how recall accuracy is affected by various predictors that were reported by participants and observed by the researchers.

These findings point to the role of several design principles in fashioning the game for usability (a finding which is reiterated from the analysis outlined prior to this section). Learnability has a very strong relationship with future usability, backed by strong evidence that the foundational role intuitive design plays by making sure users can quickly and effectively learn how to interact in the game. Simplicity and clarity (i.e., avoiding *over complication* improves accessibility and satisfaction, helping to glue people in and preventing them from running for the hills; whereas games that straddle the line between too simple and too complex usually end up alienating players. User engagement, as shown in intention to use, emphasises even more that game design should appeal to the target audience by creating ways that are interesting enough and motivating enough to play. Despite this, users are inherently more likely to behave in a positive manner when they are intrinsically motivated, as their perception of usability is greater (Brett et al. 2021).

Finally, while minimisation of error, although its impact is less significant, has positive impact for usability by reducing user frustration and keeping the gaming experience seamless. Such principles argue how the technical aspects of our game (the themes, mechanics and narratives) should interact with one another to create a cohesive experience that targets specific player types and groups. The combination and approach demonstrates the potential

for increased performance metrics (in this case, accuracy of recall) when engaged with by beginners, particularly those who are already interested in such game styles and genres. This is due to the richness of the content of our developed game and the increased motivation to engage with such learning methods, thus having impact on the greater learning journey of each player. These findings highlight the power of game-based learning for its richness of educational content delivery and for its ability to encourage consistent practice which has long lasting effects.

Tests Reliability

In order to ensure reliability (specifically, the internal consistency) of each test, it was important to investigate that the specific criteria of each skill test was indeed measuring one's ability to either recall musical notation or read it within the context of real-world applications (i.e., reading the score with a musical backing track). For the Flash Card test, the two criteria were recall accuracy and recall time. Using Cronbach's alpha an acceptable internal consistency was found ($\alpha = 0.52$) within both groups. The same process was applied to the reading notation test (the application test), with additional aspects to consider. The overall score which was a sum of the individual exercises was used, specifically using the rhythm, correct and incorrect notes in conjunction with the total score that was received for each individual exercise. The reliability of the reading test was higher than the flash card test ($\alpha = 0.73$) and is an acceptable internal consistency for a test which had never been administered before. Whilst the reliability is somewhat low for both tests, it is important to note that there were few measures which were used to gauge both test scores and this inherently will lead to difficulty in ensuring reliability of the tests. The reliability being low as a result of the few measures that were used is highlighted by the difference in reliability between the two tests: as the Reading test used four criteria for assessment and the Flash Card test only used two, the Reading test shows a higher reliability - indicating the Flash Card test must begin to consider how it can further measure the acquisition of the skill of recognising musical notation.

Tests Validity

As with the pilot study, the construct validity was evaluated by ensuring that the scores from both tests converge with the ability of the individual participant (which was self-reported); not only this, but the scores should also be consistent from pre to post in correlation with the skill level of the participant. The data does indicate that the participants who were ranked higher in overall musical skill and competency scored higher on both the Flash Card and

Reading tests (across all assessment criteria), leading to the safe assumption of the convergent validity for both tests. Ensuring internal validity was more difficult when compared to the pilot study, which was conducted in a controlled environment. As the tests were conducted in home environments over a period of a week, one can assume that this is a good representation of real-world scenarios and negate the practice effect from the pre-tests. However, due to the uncontrolled environment, there may have been other factors that helped participants score higher, such as additional practice or learning and time spent at the instrument in general. To help overcome this confounding factor, participants were asked to state what other activities they had been engaged in with their instrument during the practice week as well being asked to not practice reading musical notation outside of their particular practice solution for that week. For the most part, the majority of participants had not been practising on many other skills and were more focused on practising with their given solution. There were participants who had practiced other elements of playing their instrument such as scale and repertoire practice but this was consistent between both groups and as such an even baseline for comparison can be assumed; one can also begin to safely assume that the difference in score is also only due to the time spent (or lack of practice) with each participants practice solution.

Post Session Surveys

For the post sessions, there was two main areas of data: quantitative and qualitative. The quantitative data was in the form of Likert style questions which measured time spent practising, motivational and confidence differences regarding playing each participants instrument after the practice session had finished. Time spent practising was ranked by 6 descriptors (mentioned above); for the purposes of analysis, these descriptors were given a numerical value from 1 to 6 (6 being the most positive, i.e., the longest amount of time spent practising). The median value was calculated for each session and this value was compared between groups to help gauge how engaging each solution was; with the assumption that the more time spent practising or playing, the more engaging the solution must be. When comparing the time spent practising, it was found that the game group had a significant difference to the tool group ($p = 0.007$), indicating that the participants in the game group engaged with this solution much more than the tool group (where the game group's median was '15-30 [minutes of practice]' and the tool group's was 'Only for the allotted 10 [minutes of practice]'). Another interesting insight into the data was plotting the time spent practising over the sessions and how this fluctuated. For the game group, there was a consistent amount of play time whereas the tool group began to lower over the sessions with a steep decrease in the final session. Regarding the motivational scores between the two groups, there was a

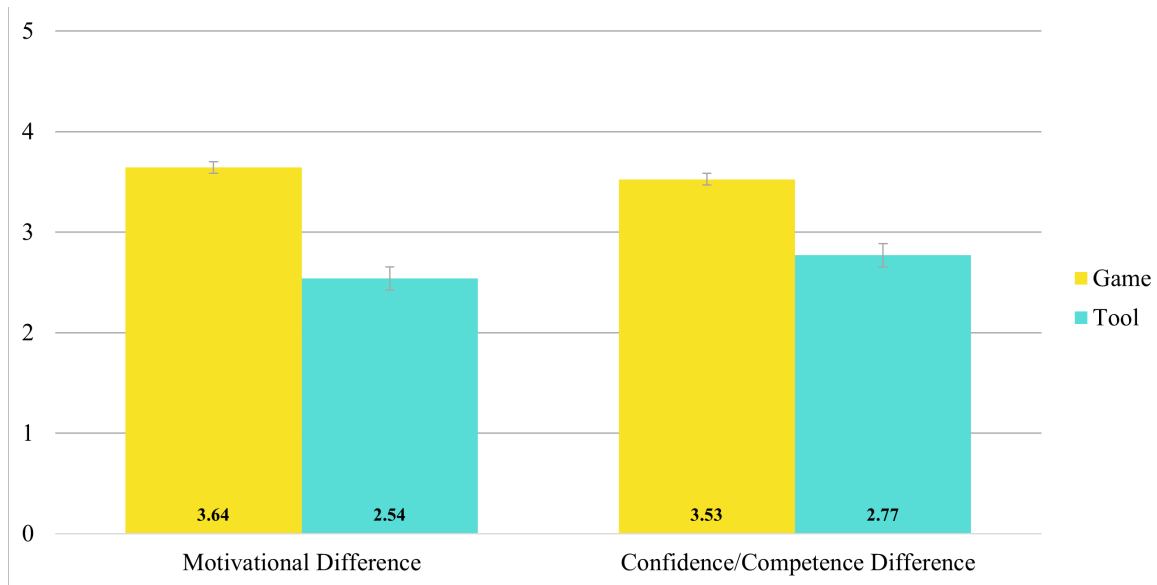


Fig. 7.8 Post session Likert ratings

significant difference between the two groups ($p < 0.05$) and this was also true for the ratings of confidence ($p = 0.005$); both results indicate that the game group was rated much higher than the tool group regarding both of the ratings.

The qualitative data of this portion of the study was in the form one particular optional question relating to specific elements that participants felt may have helped improve any specific skills whilst practising (further details disclosed above). The data helped to reveal insights into what specific areas of playing keyboard were improved using the game more so than the tool. Data also helped to improve specific game elements and highlighted positive areas of the practice tool which were mentioned regularly, that could potentially be included in next round of the games development. There were reoccurring themes that were observed in the answers, which included:

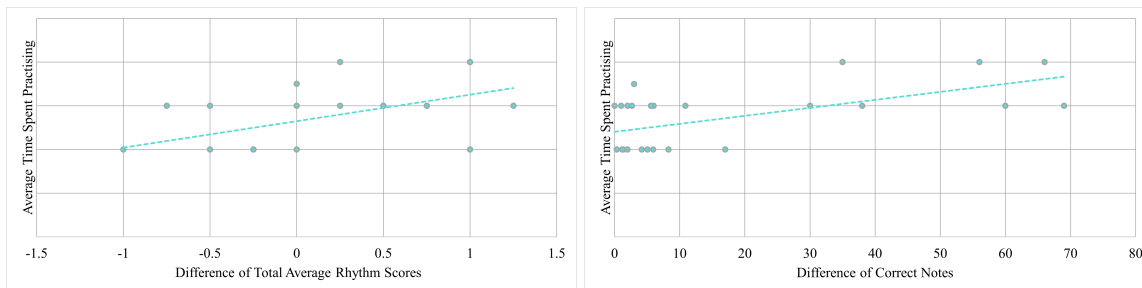
- A key difference between the game and tool feedback was that the game was useful for improving hand positioning and helped participants feel more confident using two hands together; feedback regarding the game was the opposite of this and most participants felt as though the practice style would lead to poorer playing form
- Because of the audio effects and feedback, participants who played the game highlighted that they were not looking at the keyboard whilst playing. This results indicates that practicing in a game-based style (in which multiple musical elements are tied together) leads to greater memorisation and stronger muscle memory

- One of the main issues found was that the metronome in the game was not in sync to the backing track. This is mostly due to the sound of the metronome having a slight delay before the actual sound is heard – an issue that was only noticed once the study had begun
- Another reoccurring issue that the game faced was a lack of keyboard setup which led to confusion when participants were manually determining the correct octave to play in
- The in-game puzzles were received positively but due to their repetitive nature and lack of variation, they became boring
- A key issue was overlapping notation on game objects. As the content was procedurally generated, some objects were placed next to each other and when their notation was shown it would often cover another notation – leading to confusion of which notation is actually being played
- The game’s tutorial was required but many participants claimed they wanted to see tutorials throughout the game and be shown specific elements such as, using the skill tree and shop
- The main positive takeaway for the tool was the variation in modes of practice (such as pure ear training and scale practice); this should be fed into the game in smaller mini games or puzzles which require additional skills
- A final theme was that the training tool had no easy setup or tutorial and participants wanted to know what specific options would do – the use of tooltips and consistent small tutorials is key for a smooth user experience
- Overall, feedback for the tool was negative, most participants completed each session out of necessity rather than for enjoyment. As one participant states: “. . . honestly I do not like the practice tool and would stop using it immediately [outside of the study]”

A final insight into the overall reception of both solutions was the quantity and depth of the feedback given for this question. For the most part, most participants in the game group gave feedback after every session and their feedback was detailed, enthusiastic and personal. In comparison, feedback on the tool group was sparse, overall more negative and was more functioning related rather than personal requests. This helps to highlight the much more positive review of the game when compared to the tool and helps to further strengthen the difference of engagement between both groups. Whilst certainly not a quantitative result, it

is still worth mentioning as it helps to highlight the difference in enthusiasm and personal connection between novel and typical forms of practice relating to key-based instruments.

As the assumption of this study was that the more one practised, the more they would improve a specific skill and gain confidence with playing their instrument, it was deemed imperative to assess this within the data. Therefore, the time played data was correlated with the scores of Flash card and Reading tests. Each specific criteria for assessing both tests was correlated against the median play time for each participant (that is, recall accuracy and time for Flash card and all relevant criterions for the Reading test). Overall, there was a positive correlation for every score, particularly for rhythm ($p = 0.51$) and overall scores ($p = 0.43$) on the Reading tests, the recall accuracy ($p = 0.59$) and time ($p = 0.48$) for the Flash card test.



(a) Correlation between difference in average rhythm score from pre to post on Reading test (b) Correlation between difference in recall accuracy from pre to post on Flash Card test

Fig. 7.9 Practice time correlations

Thus, the hypothesis that the more time one spends practising, the more their skill will improve, can be accepted. However, the correlations are not all extremely strong and there are other factors, which are discussed below, that are factored in to help improve the skill of reading musical notation that are unique to each group.

End Surveys

The final surveys that participants completed were related to how they personally rated pedagogical value, usability and engagement for their given practice solution. Participants also had the option of providing additional feedback into why they gave particular ratings. As mentioned in the protocol, participants were asked to provide a 1-5 rating on specific questions, which would be totalled and used to assess the above categories. For the analysis, each question that related to a particular category (for example, competency rating was comprised of 5 questions) would be totalled and the average of this score would be compared between the two groups. There was only one significant difference in rating, which was the rating of competency ($p = 0.0008$), whereas all other categories were similar in rating. The

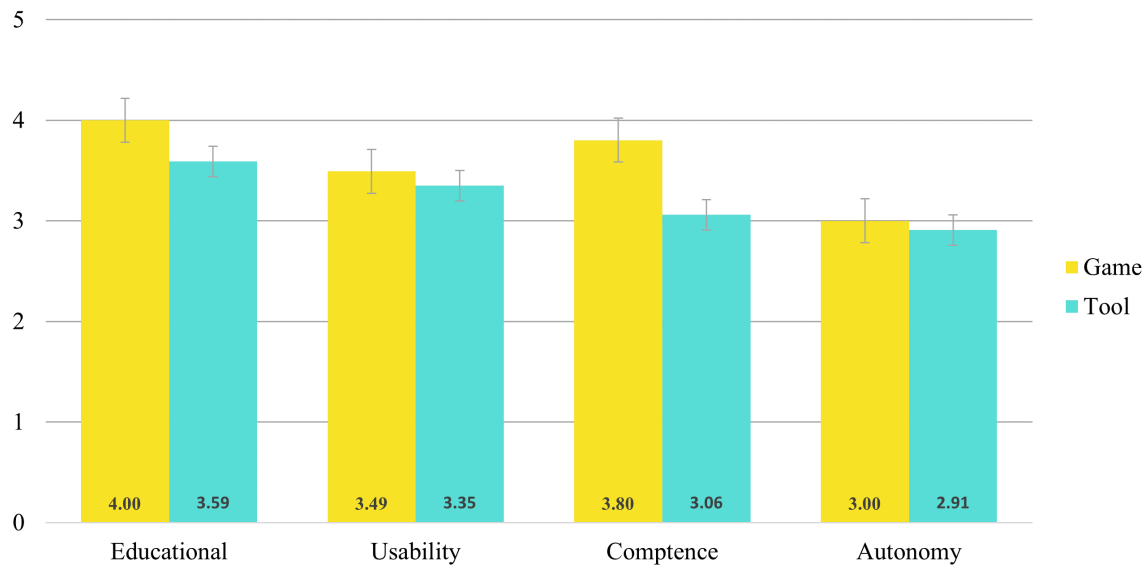


Fig. 7.10 Final survey Likert ratings

open-ended questions help to determine why these findings are as such, which is discussed in further detail below.

To help determine that the questions posed regarding each category of assessment was indeed measuring that particular category, the reliability of the questionnaires was analysed (i.e., ensuring internal consistency). As feedback from the pilot study had been taken onboard, it was assumed that the reliability should therefore be at a higher level; this was true as all reliability scores had improved greatly from the previous study. Specifically, the questionnaire that related to pedagogical value was high ($\alpha = 0.87$), the questionnaire that was related to assessing usability was high ($\alpha = .79$), the questionnaire that measured competency was high ($\alpha = 0.91$), and the questionnaire that was related to autonomy was the lowest ($\alpha = 0.56$). Thus, the internal consistency of the questionnaires relating to pedagogical value, usability and engagement can be determined as high and future studies should be able to replicate similar results (with particular consideration to extending the questions relating to autonomy).

7.3.5 Study Discussion

The discussion of the results is comprised of the skill tests, post and end questionnaires and a final review of the overall themes and takeaways learned through analysis of the results.

Skill Tests

The results show that the game group difference scores from pre to post were significantly different from those of the training tools, with the exception of the recall time on the Flash Card test. Based on these results, one can safely reject the null hypothesis (the game group will not improve the skill of reading musical notation as much as the typical practice method). Whilst this result is positive, it is important to consider why this result has occurred and what other factors may have helped to impact it. The internal consistency of the tests was moderate and both tests were standard (whereas, in the pilot study, questions posed were randomised), which helps ensure that both tests are measuring the acquisition and application of the skill of reading music. Furthermore, correlations between the time spent practising and scores on the tests are positive which helps to further the argument that it was the game that had helped acquire or improve the specific skill. Whilst this is satisfactory, there must be other elements that helped to improve the games score so significantly, especially in comparison with the training tool group; a 30% or more improvement in all but one of the criteria of assessment is significant after all. Consulting the factors that impacted the score on the pilot study help reveal the additional considerations one must take in account for this study. The main umbrella factor is the nature of the practice. The increased use of hand positions and two hands playing together helped to strengthen muscle memory (which is also highlighted directly by feedback from participants) and the incorporation of musical elements helps to reinforce memorisation through equivalence-based learning; not only are participants seeing a notation and matching this to a key, but they are also associating it with sound or a particular character or enemy. This use of music not only helps reinforce memorisation but also helps to strengthen rhythm when playing the notes in the Reading tests.

Finally, how the game builds particular emotions with practice and play has an impact on the post-test performances. The sense of agency that is found throughout the game (beat the enemies before they reach the player, complete the puzzle before time runs out) builds a strong negative emotion with incorrectly guessing a note and this is reflected in how accurate participants responses were in the post Flash Card test. Finally, the overall positive emotion that the game associates with practice led participants to be much more involved with the study and give more in depth feedback. This positive association leads to participants generally giving more care to their post-test performances where, in contrast, those who practiced with the tool were looking to complete the study for sake of completion, not for the association and relationship they had built with the training tool.

Post Session and End Surveys

Time spent practising was significantly higher within the game group compared to the training tool group, which was the expected result. The difference of practice time over the sessions is also a good indication of engagement. Results showed that the game group did not decrease their practice time and in some cases, it was increased, whereas the opposite is found the training tool group. This highlights how engaging the game actually was and shows that with further development, such a novel practice method could have the potential to aid learners over much greater amounts of time. The significant difference in ratings of motivation and confidence correlates to the scores from the difference in scores on the skills test: those that were more motivated and felt more confident playing were found to have higher scores on the skill tests also. Such a result is significant and shows that this form of practice, whilst novel, is incredibly impactful and future researchers, teachers and developers should seriously consider how their learning can incorporate game-based learning.

Whilst the only significant difference in rating on the final questionnaire was found in competency, it should be noted that all the ratings for the game were higher than the tool. When comparing these scores to the pilot study, all areas had improved. The lack of significant difference in pedagogical value rating was not surprising as the tool is highly effective for practising reading notation. However, the fact that the game group was rated higher, regardless of a lack of significant difference, is still a meaningful result and has shown that feedback from the pilot study regarding the game has had a positive impact; demonstrating the model of iterative development and testing is an ideal model to implement. The ratings for usability had once again improved for the game from the pilot study scores, although it did not lead to a significant difference when compared to the training tool, this is expected as the training tool is inherently simple to use. Specific feedback will help to improve the overall UX and onboarding for the game such as, a keyboard setup screen and tutorials fed into the game at certain points rather than showing all information during the beginning stage. Not only this, but participants also highlighted reoccurring bugs such as enemies getting stuck and notation covering one another, leading to a lower score for usability. The majority of participants enjoyed seeing both staves (treble and bass) but wanted to see the grand staff as well – this would reflect well into real-world applications also. Finally, feedback from both the game and training tool showed that participants would want a post-practice ‘review’, to highlight where they struggled the most and perhaps offer additional game levels that cater to these areas of difficulty per learner.

Whilst competency was the only rating that was significantly higher with the game group, with one participant stating, “. . . I think it sits outside of the normal [practice] routine for most [learners]”, there were still elements which could improve this further. This includes

late game levels and content being more varied and complex. Due to time constraints and lack of resources, designing hand-built levels and play testing was tricky and led to the game being not as personal as it could have been; this lack of personality and hand-crafted content will naturally lead to a lower review but is also remedied with more time and resources. Not only this, the difficulty curve and progression was not steep enough for the majority of participants, who were competent video gamers. This demographic is familiar with video games and expects more challenge – attempting to cater to a wider audience led to lower satisfaction with the primary target audience who are versed with challenging video games. Specific feedback regarding immersion also reflected areas of improvement: the narrative and puzzles requires more depth and the main bugs removed participants from the ‘magic circle’ (Tekinbas and Zimmerman 2003) of the game.

The lack of difference in rating for autonomy was surprising, as it was expected that the game would be rated much higher than the tool. There were multiple factors that affected this score: the training tool did indeed have a multitude of choice and participants noted that this was useful and helped to increase engagement. Whilst participants were excited to explore the levels in detail, “. . . I felt like exploring every nook and cranny of the levels”, they also noted the lack of variation across levels. Whilst the levels increased in size and notations, the premise was rather similar and this is due to a lack of resources which led to procedurally generated content (another case where a lack of personality is detrimental to the games design). Not only this, but the mechanics themselves could be more intricate and complex, such as adding required timings on certain items, specific patterns that are required to be recalled which unlock secret areas - the list of additions is almost endless. Fortunately, these points can be fixed easily with more time and resources, perhaps better suited to a full-time game developer or a small team of developers and researchers.

General Discussion

Overall, the results have shown that the game improved both the acquisition and application of the skill of reading musical notation over a given period of time, within a real-world setting. Furthermore, the game was much more engaging and all Likert scores were higher for the game group. It was clear from the depth, quality and quantity of the feedback which group was more invested in the study - those in the game group were much more positive and receptive. Participants also wanted to pursue practice using the game after the study was conducted, with one participant excited to purchase the game once it had been fully developed, “If it was a real game, I would buy it!” The significant difference between the scores found on the skills test are a reflection of this positive reception. Those who practiced with the game, were more invested in the study and as such their efforts on the skills tests

were more serious than those in the tool group (who were simply completing the steps of the study to simply finish their participation).

Study Limitations

Whilst the null hypothesis was rejected and the results showed that the game group was rated higher in all categories in comparison to the training tool, there were still some limitations of the study. These include:

- The practice time was self-reported and ambiguous (it lacked specificity). Whilst self-reporting is not a bad practice, the time frames participants could choose from were quite wide (for example, 15-30 minutes could mean near to 15 or near to 30 minutes – a large difference!). Self-reporting can also be inaccurate and participants should not be expected to be gate keepers of the time practised.
- Criteria that measured both the Flash Card and Reading tests were not extensive and this lowered overall reliability (i.e., only measuring recall accuracy and time where other factors could also help to determine skill acquisition/improvement, leading to an increase in internal consistency).
- Determining a participant's 'musical competency' was also self-reported and whilst the data is consistent (i.e., participants who reported higher competency scored higher on skill tests), if one wants to ensure fair comparisons then other methods of assessment must be required.
- The game was only compared to a single practice tool. Although the practice tool used for comparison is a market standard and a popular tool, there are a multitude of other solutions that should be considered for comparison (taking into account gamified practice tools).
- The lack of control due to the environment that participants completed the study potentially led to confounding factors. This also led to inconsistent practice sessions over longer periods of time for some participants. Some participants completed all practice sessions within 5 days where some took up to 7 days and some participants did not complete all practice sessions and conducted the post-test after 7 days since starting their first practice session. This is the trade-off between real-world reflections and the need for control in experimental design. Whilst this is could be considered a limitation; it actually reflects what real-world practice looks like – not all learners have time to practice and major life events will impact this further.

- The game itself had issues which led to lower scores for autonomy and usability. This is the unfortunate issue of lack of resources and time able to be committed to development and testing.
- While the game provided a platform for practice, the absence of precise usage tracking limited the ability to accurately measure skill acquisition over time. For instance, tracking the total time spent practising, the frequency of practice sessions, and the specific exercises completed could have provided valuable insights into the extent of practice and its impact on skill development. Additionally, monitoring the rate of progress through different levels or challenges, the accuracy of responses, and the types of errors made could have offered a more nuanced understanding of skill acquisition and areas for improvement.

7.3.6 Future Directions

All of these limitations can be related to one another with two main limitations: a lack of resources and the trade-off of controlled environments for real-world reflection. With additional resources committed to improving the skill tests and implementing additional forms of musical assessment, one could develop a test battery to accurately depict the competence of a learner in regard to a specific skill. Additional resources could also ensure that the game is developed further, with less bugs and more personality, leading to increased engagement and more serious applications within a commercial placement. The lack of control led to self-reporting somewhat ambiguous amounts of time practised, future studies must create a way to determine specific time values which can be reported on a regular basis to the research team. Finally, an issue of both lack of resources and the lack of controlled environment led to inconsistencies with practice sessions over the week period across individual participants. Whilst this does reflect real-world practice and the issue of motivating this particular demographic to consistently practice, one must consider what would be possible if an existing pool of participants or users that fitted this demographic was used for recruitment. The issues faced during recruitment led to a varied range of participants: some were serious and dedicated whilst others may have dropped out and were not worried about completing or particularly invested with the research at all. Conducting such an experiment in the future should attempt to use existing user groups that have been defined, perhaps more applicable to development and research teams who already have an existing loyal group of users that are most appropriate to reflect the target population. If one were to recruit using such methods and advertise to a large body of potential participants,

then the recommendations would be to setup further safeguarding to ensure that bots or auto-fill software is prevented. These techniques include (Skerrett 2019, Xu et al. 2022):

- Questions that are similar in nature that would yield the same answers from human participation but would vary greatly in responses from a computer
- Timestamping responses and determining the total time taken to complete the survey: if response time seems impossibly quick, it is likely that this is a human response
- Include ‘attention questions’, which are questions that are unrelated to the study and somewhat absurd; human responses should easily be spotted whereas machine responses may be rather generic
- Include open-ended responses which generate meaningful responses. It was often found that the answers to game-related questions were all unique as participants had varied favourite games and play times; spotting the machine or scripted responses was obvious as they were often repeated or highly generic

Even though these techniques should help prevent scripted or bot responses, it is never completely possible to be void of such a phenomenon. Such responses became obvious through analysis and there was often at least ten responses received within a short period of time and the responses all shared highly similar answers. One must approach analysis of surveys carefully and ensure that these answers are completely removed. Finally, it is important to only offer incentives based on the success of completed surveys or the entire study; offering incentives for simply completing the survey will increase the likelihood of fraudulent responses.

7.4 Chapter Conclusion

This chapter has discussed the improvements to both the methodology of the pilot study and the game, which was based on the feedback from the pilot study itself. The developments to the game were extensive and led to a concept which was highly novel in nature whilst still retaining the key elements of pedagogical value. The study helped to prove that such a novel approach to practice is much more engaging than current methods and can help to increase specific skills and overall confidence and motivation of learning to play specific instruments. This does not come without limitations, however. The two main limitations that both the study and the research as a whole suffered from was lack of resources and attempting to build robust empirical experimental studies whilst reflecting real-world applications. Furthermore, whilst

the skill-tests were validated within this context, they should contain additional assessment criteria or additional tests to help build a robust battery of assessment to a particular skill. Future research should consider the immense work that has been invested to achieve this level of results and how potential stakeholders can support such a journey. With further resources, time and an existing base of users to help test these solutions further, the potential for such novel concepts is limitless and the results from this study should inspire other researchers, teachers or developers to seriously consider how video games can be used to offer meaningful educational value and build skills which have real-world transferability.

Chapter 8

Conclusions

8.1 Chapter Introduction

This chapter presents how each research question was constructed and how the research has helped provide answers to each (i.e., a summary and reflection of the research outputs). This is followed by a discussion of the key limitations that was found through the process of the research; highlighting the specific limitations of the final study and how these limitations reflect on the entire research. Finally, a concluding statement is presented which summarises the main outcomes of the research and offers the larger scale implications of such research, and similar research that have also helped to contribute solutions to the issue presented in the introduction.

8.2 Research Journey and Key Findings

The research journey began by investigating how video games could effectively reduce high dropout rates among adult beginner keyboardists, a key issue highlighted by multiple studies showing that a majority of adult beginners abandon their musical pursuits within the first few months (ABRSM 2018a, Evans 2009, North et al. 2000). The initial exploration was broad, encompassing various technological approaches including virtual and augmented reality solutions, before evolving into a more focused examination of game-based learning's potential for skill acquisition.

The initial research was guided by the central question:

"How can video games help to reduce the high early dropout rates exhibited by adult, casual and independent beginner keyboardists?"

Our preliminary investigation and background review revealed some important limitations in existing solutions. Traditional methods emphasised rote practice without considering engagement (Gordon 2012), while current gamified applications often prioritised surface-level engagement over meaningful skill development (Deterding et al. 2011). Commercial solutions, such as piano learning apps, typically attempted to gamify the entire learning process, leading to short-term engagement but ultimately failing to address the fundamental challenges faced by adult beginners (Cremaschi et al. 2015b).

Early exploration with VR and AR technologies, while promising in terms of novelty, revealed significant limitations in terms of accessibility and practical application. The development of prototypes using technologies such as the HTC Vive (HTC 2016) and Microsoft HoloLens (Microsoft 2020) demonstrated that while these platforms could create engaging experiences, they often introduced additional complexity that detracted from the core learning objectives. Our initial reviews and investigations were central in shaping our understanding that technology should not be replaced entirely by traditional learning methods.

The research's evolution was significantly influenced by our work with the LUMI ecosystem, which helped to provide valuable insights into how technology could be effectively integrated into music learning, particularly with beginner keyboardists. The development of the LUMI keyboard and its companion learning application (ROLI 2022) helped identify specific areas where game-based learning could most effectively support skill development. This innovative design and development of hardware highlighted the importance of focusing on fundamental skills that could be improved through targeted practice, rather than attempting to create comprehensive learning solutions. As most marketplace solutions offer a wholly experience we often found that users would lose interest when the experience became too difficult or monotonous, preferring an experience which would integrate with their existing learning.

Through systematic investigation and development, we established that video games could be most effective when designed as supplementary practice tools rather than complete learning solutions. This finding represented a significant departure from existing approaches and led to the development of our framework for game-based learning tools that could:

1. Transform repetitive practice into engaging experiences while maintaining pedagogical value through designing game mechanics in an iterative fashion (Chen 2007).
2. Build positive associations with learning through immediate feedback and progressive challenge systems (i.e., through associating learning or practising with enjoyable video game experiences).

3. Provide structured skill development while maintaining player motivation through balanced game mechanics, drawing upon key gamification techniques (Chou 2019a).
4. Support broader learning journeys and integrate into various learning/teaching techniques by focusing on specific, fundamental skills rather than attempting to replace traditional methods.

These insights and deeper understanding of the question and problem statement that was originally proposed, supported by early prototype testing and user feedback, led to our secondary research question:

"Can adult, casual and independent beginner keyboardists passively acquire or improve specific skills, which typically requires rote learning and have meaningful real-world application, through playing video games?"

We have addressed this question through discussing our findings within the four experimental chapters (chapters 4, 5, 6, and 7) each building upon the findings of the previous ones while addressing specific limitations and gaps identified in existing solutions. The progression of our research is evidently an iterative approach to developing and validating game-based learning solutions which is discussed in more detail below.

Chapter 4 established the potential of mini-games for practice, aligning with theories of flow and engagement in educational games (Csikszentmihalyi 1997). This initial study introduced multiple prototype games, each targeting different aspects of musical skill development. The study revealed significant improvements in engagement when game mechanics were properly integrated with learning objectives, with participants showing increased willingness to practice and improved retention of basic musical concepts. Importantly, this chapter also identified key limitations in existing assessment methodologies (not only illustrated by our own research but prior research that is included in the background review), leading to the development of more robust evaluation frameworks in subsequent studies.

Building upon these limitations and with an increased demand for higher specificity in the research, Chapter 5 refined our approach by focusing specifically on notation reading skills, addressing a critical gap in existing literature regarding targeted skill development through games (Pesek et al. 2020). This chapter introduced a more systematic categorisation of game types, ranging from basic training tools to fully gamified experiences. The study demonstrated that even the most gamified approaches could maintain high levels of engagement while achieving specific learning outcomes, particularly when games were designed with clear pedagogical goals in mind. This work was instrumental in establishing the balance between engagement and education that would guide our later developments. Most importantly, the findings demonstrated that we could build solutions that were essentially video games and

still retain a high amount of pedagogical value (helping to build the positive associations and increase skill aptitude).

The experiences and limitations identified in these early chapters led to significant methodological improvements. We developed more rigorous assessment methods, incorporating standardised tests for measuring skill acquisition and validated questionnaires for assessing engagement and usability (IJsselsteijn et al. 2013). This methodological evolution was an important step in helping to address the defined gap in existing research, where assessment methods often lacked rigorous validation or real-world applicability (opting for more qualitative methods that were focused on anecdotes rather than being grounded in replicability and empiricism). This step was key in addressing some of our key objectives that related to building methods which were robust, replicable and most importantly, founded upon scientific rigour that often eludes research within this domain.

Our understanding of effective game-based learning design was further refined through extensive user feedback and iterative development. Key insights included:

- The importance of immediate feedback systems that reinforce learning while maintaining engagement (often looking to engaging ‘mini-game’ style mobile games).
- The need for careful balance between challenge and skill level to maintain flow states (using the ‘saw-tooth model (Holleman 2019)).
- The value of incorporating narrative elements to enhance engagement while supporting learning objectives (something that was introduced in the latter design cycles).
- The critical role of clear, measurable learning objectives in game design which would help to feed into our assessment methods during the longitudinal study.

These insights were pivotal in shaping the development of more sophisticated game prototypes in later chapters, leading to significant improvements in both engagement and learning outcomes. This chapter paved the way for our final game concept as the findings helped to show that the most gamified learning method was both most effective and educationally valuable from the perspectives of learners and educators alike.

Chapter 6 marked a key advancement in our research with the introduction of "Note Reader Adventure," a more sophisticated game in both design and development which incorporated advanced principles of player motivation and skill acquisition (Ryan et al. 2006). The pilot study demonstrated substantial improvements in both engagement and skill development compared to traditional practice methods (through statistical analysis). Participants showed improvements of recall accuracy and reading fluency, with the game

group demonstrating a 30% greater improvement in notation reading skills compared to the control group.

The pilot study was particularly valuable in validating our assessment methodology and identifying areas for refinement. Key findings included:

- The effectiveness of combining skill acquisition tests with application tests to measure real-world learning transfer as well as reiterating the findings through qualitative methods such as surveys and interviews (adopting a mixed-methods approach where previous studies were mostly qualitative in nature).
- The importance of standardised assessment procedures to ensure reliable measurement of progress. In this study we noticed that use of third party assessments would lead to less replicability so future studies adopted standardised assessments that were designed and developed by our own research team.
- The value of collecting both quantitative and qualitative feedback was crucial for understanding the full impact of game-based learning. As reiterated in the first point, a mixed-methods approach was unique to our research and often overlooked in this domain. This approach proved to be a powerful tool for gathering key insights and collecting data that could be analysed in multiple ways. Furthermore, this approach encouraged a higher degree of replicability for future research, an aim of this research.

Chapter 7 represented the culmination of our research with our developed game, "The Crypt of Notation" and the comprehensive longitudinal evaluation that accompanied it. The outcome of our final study provided evidence for the effectiveness of game-based learning in real-world settings, with participants demonstrating sustained engagement and significant skill improvement over their practice week. Those who played the game for practice showed consistently higher rates of practice and greater improvement in both recall accuracy and reading fluency compared to the control group using the more traditional practice tool.

The longitudinal study yielded significant findings that help to demonstrate the potential of game-based learning in music education. One key area was practice engagement, where participants in the game group demonstrated higher levels of commitment compared to their control group counterparts. On average, game group participants spent 15-30 minutes per practice session, a notable increase from the control group's 10-minute average. It was evident that this increased engagement was sustained throughout the study period, suggesting that the game-based approach effectively maintained learners' motivation over time. This sustained engagement was further reflected in participants' self-reported motivation and confidence levels, which were consistently higher among the game group.

Another insight from the findings related to skill acquisition, where those who played the game for practice showcased significant improvements. Particularly noteworthy was the significant enhancement in recall accuracy ($p < 0.05$) observed among game group participants. This improvement extended to other essential musical competencies, such as rhythm accuracy and note recognition. Moreover, these acquired skills demonstrated stronger retention of skill, as demonstrated by the game group's greater performance in post-test assessments.

The real-world applicability of these findings was especially promising. Game group participants displayed improved performance in the sight-reading tests, demonstrating an ability to transfer the skills learned within the game environment to authentic music reading scenarios. This transferability was accompanied by a greater sense of confidence when approaching new musical material, suggesting that the game-based learning experience equipped learners with not only technical proficiency but also the self-assurance needed to approach more complex learning.

Through this research, we have made three primary contributions to the field, each addressing specific gaps in existing knowledge and practice:

1. Novel Game-Based Learning Framework

Our framework for creating educational games effectively balances engagement with skill acquisition, building upon existing theories of gamification (Chou 2019b) and music education (West 2015a). Unlike existing solutions that often treat gamification as an afterthought (Deterding et al. 2011), our framework integrates game mechanics with pedagogical objectives from the ground up. The success of this approach was demonstrated through both quantitative improvements in skill acquisition and qualitative feedback indicating higher engagement and motivation levels; this is particularly notable in our final study, outlined in Chapter 7.

2. Empirical Assessment Methodology

We established a robust methodology for evaluating game-based learning tools in real-world contexts, addressing a significant gap in current research methods (Gomes et al. 2016a, Raymaekers et al. 2014). This includes:

- (a) Standardised tests for measuring skill acquisition and application that demonstrated high reliability (Cronbach's $\alpha > 0.7$). Specifically, this refers to the Flash Card and Notation Reading Tests refined throughout Chapters 6 and 7.
- (b) Validated questionnaires for assessing engagement and usability based on established frameworks (IJsselsteijn et al. 2013). Specifically notable within Chapters 5, 6 and 7.

- (c) Methods for tracking long-term engagement and skill retention in real-world settings; most prominent and refined during our final study outlined in Chapter 7.
- (d) The integration of both quantitative and qualitative assessment measures in our final study represents a methodological contribution to the field of game-based music education research. By combining statistical analysis with the depth of qualitative insights, our mixed-methods approach offers a comprehensive framework for evaluating the impact of gamified learning experiences. This innovative methodology not only provides a robust, replicable model for future investigations but also sets a new standard for assessing engagement and educational value in the context of game-based experiences.

The reliability and validity of these assessment tools has been demonstrated through multiple studies, providing a foundation for future research in this field. We believe that our methodology particularly emphasised the importance of measuring real-world skill transfer, addressing a limitation in existing research approaches that was outlined in the beginning of this thesis within Chapters 2 and 3.

3. Open-Source Development Framework

Our comprehensive set of resources that was created throughout the development of our educational games builds upon established game design principles (Holleman 2019) and music education theory (Gordon 2012b). The framework includes and is not limited to:

- (a) Reusable code components for MIDI integration and rhythm mechanics.
- (b) Reusable code components for developing musical based RPG style games which also includes a host of art and music assets.
- (c) Design patterns for balancing educational content with game mechanics.
- (d) Guidelines for implementing effective feedback systems.
- (e) Documentation of successful implementation strategies.

We hope that this contribution can lower the barrier to entry for developers and researchers seeking to create similar educational games, while providing a tested foundation for future development. One can find access to these resources within the appendices of this document.

Regarding the broader applications of our research, we have provided resources that have implications which can extend beyond music education, offering insights for domains where

skill acquisition that requires sustained practice and engagement (mostly rote learning). Our findings align with broader research on the effectiveness of game-based learning in various educational contexts (Al-Azawi et al. 2016c), suggesting potential applications in areas such as:

- Language learning and acquisition.
- Technical skill development (in domains such as business/professional training and exercise).
- Other areas of learning that often require sustained practice and engagement where rote learning or the domain has natural repetitive learning cycles (from simple ideas such as times tables to more complex concepts such as learning the periodic table).

The longitudinal study in Chapter 7 provided particularly compelling evidence for the effectiveness of our approach, demonstrating that game-based learning can significantly improve both engagement and skill acquisition in real-world settings. These findings challenge traditional assumptions about the relationship between entertainment and education in learning tools, suggesting that properly designed games can enhance rather than detract from educational objectives. We believe that implementing learning into games rather than building games around a lesson is the key to effective gamified learning.

Looking toward the future, our research provides a solid foundation for continued development in game-based learning for music education. The open-source nature of our development framework enables other researchers and developers to extend and adapt our work, potentially leading to a new generation of educational games that effectively balance engagement with meaningful skill development.

This research has provided comprehensive evidence for the effectiveness of game-based learning in music education, while establishing practical frameworks and methodologies for future development in this field. The success of our approach, particularly as demonstrated in the longitudinal study, suggests that properly designed game-based learning tools can play a crucial role in supporting adult beginners in their musical journey, potentially helping to address the persistent challenge of early dropout rates in music education.

8.3 Key Limitations

This research explored how video games could be most effective in solving the issue of the high number of adult beginners dropping out early from their music learning journeys, particularly focusing on those who learn to play keyboard. Through the course of the research,

the limitations of both the developed solutions and the methods of assessment had been improved. The lack of specificity and empiricism often led to interesting games but a poor method of assessing them. Through multiple studies, an assessment method was defined in which the goal was to measure the acquisition of a particular skill and the real-world application of such a skill. The pilot study (study three) helped to build a model of assessment which could measure the opinions of engagement and usability in a reliable and valid way. The final study helped to prove this within a real world context, ensuring that the concepts of engagement and pedagogical value (i.e., acquisition and application of a skill) could be quantitatively measured in real-world settings. However, there were limitations to the study which must be considered going forward. The two overriding limitations can be summarised as follows:

- **A lack of resources in regard to development of the game and assessment tools as well a lack of an existing user base**
- **The balance of a controlled environment whilst trying to reflect real-world applications**

Feedback for the game highlighted key bugs that were not detrimental to the gameplay but certainly hinder the overall engagement. The lack of time and resources that stem from a single developer attempting to develop such a large scale game which is playable on multiple platforms and machines, whilst simultaneously conducting research activities. There are two schools of thoughts in this regard. The limitation could be seen as the choice of game that was developed for the final studies or the lack of support and resources available at the time. Development of an RPG style game is no small feat and developers must design artwork, mechanics, complex menu systems and ensure that all the parts are working in unison. This complexity did indeed lead to a lot of time being dedicated to development and whilst a novel and enjoyable game was produced, one must consider what other genre of game may have been more optimal. As mentioned, the consideration to pursue the more arcade style of game was the other option after the second study was conducted. Could choosing this style game led to a game which was completely bug free and ensured more time was spent on the assessment tools? It is possible but this also would have led to a solution which was less of a video game and more of a gamified practice tool; the game would have required vast amounts of design and artwork to actually ensure high amounts of engagement (whereas the RPG focused on the individual mechanics) and such talent was not available. So the limitation is more likely due to the lack of resources and support at the time. Regardless of the choice of game that was taken forward, with a small team comprised of designers and additional developers, the potential for any of these games would be immense; it is unfortunate that the

researcher was not able to find collaborators or find the support from stakeholders but going forward perhaps other researchers or developers can assist in this pursuit.

Additional resources would also be useful in helping to build a more robust method of assessing a learners abilities with a particular skill. As mentioned in chapter 7, the ideal solution to this limitation is to build a battery of tests that would specifically measure the skill of reading musical notation (with the extension to other skillsets). Whilst the skill tests that were developed for the final study were certainly reliable and valid, they have significant room for improvement and it is only due to lack of resources this envisioned goal was never fully accomplished. This limitation of lack of resources is not just applicable to time and the size of the research and development team, but also to the user base available. As covered in chapter 7, recruiting such a large number of participants to participate in highly extensive study proved tricky. Most participants in the study all showed great initiative and were extremely viable candidates, but finding these participants was not easy. This result shows that there are particular users that are ideal for this research and recruitment would have been a lot easier with an existing user base to advertise to. The placement company's mailing lists were useful in this regard, but a lot of users were from the prosumer groups, rather than the consumer ones; as a result, they were either uninterested in learning concepts they already knew or were simply not the right fit for the demographic. There is serious thought into how successful such a study would be if it was conducted by stakeholders who had a large user base of the particular population in mind; there are certainly user bases out there but these are typically 'professional user testers' and access to such method of recruitment will, once again, require substantial resources. The idea of this research and the solutions that have been developed are worth merit but do require further time and resources to ensure their success; it is the hope of the researcher that other stakeholders and research bodies will help to support this success.

The second overriding limitation, the balance of controlled environments and reflections of real-world applications was constant through the research. The pursuit of attempting to quantify and build empirical methods in a field of research which is typically dominated by qualitative research proved tricky, but was never abandoned. Most of the research in the field was either interested in assessing musical abilities or building solutions to improve musical abilities. Authors who were developing solutions typically assessed their prototypes with interviews or questionnaires, rarely considering how others could utilise their assessment methods nor how reliable they were; there was a lack of empirical research in this regard, hence the desire to pursue such a goal. Whilst the final study is mostly quantitative in nature, there are still significant questions which participants answered based on their own interpretations. How long they practised for, how confident they felt reading music and all

questions relating to usability were opinions. The desire for empirical science whilst also attempting to measure such concepts in real-world settings led to confounding factors. As observed in the final study, the variation in the practice session competition was significant and not all participants completed the study in the intended manner. Of course, this does reflect the real-world complexity of learning and practising but does also reduce the merit of the study. The solution to such a complex problem is not simple but does relate back to the primary overriding limitation of lack of resources. With the correct user groups, these issues would be less so as such users would undertake the study in a much more serious capacity. Not only this, but additional developments could ensure specific measurements of practice time and a robust method of assessing ones musical abilities that would not require self-reporting by the participant.

The final limitation that became apparent from the final study was the comparative tools used. The studies only concerned themselves with one tool to compare against. Ideally, with a large user base there could be multiple control groups to compare the game against and each group would use a slightly more gamified solution. However, the need for a comparison group at all could be questioned. The fact that the game group significantly improved from pre to post in all categories is a worthwhile result and perhaps the limitation of multiple comparative solutions indicates the need for longer studies to be conducted. Whilst the study was conducted over a period of a week, this is still a short amount of time (although, longer than most studies found in the literature). This limitation is once again due to lack of resources and a lack of access to the correct user groups. The question one must consider is how long is enough? When the research initially begun, the idea was to run studies for a much longer period of time than a week, ideally for months, if not a year. This long period of time would reflect the longevity of a learner more accurately and would clearly show whether this novel method of practice would be effective in reducing the drop out rates of adult beginner keyboardists. Unfortunately, within this research, this was never attainable; the author offers cautious optimism that running such studies would yield results that prove these learning-based games do provide a much more positive practice and would lead to increased motivation and less amounts of drop outs.

8.3.1 Limitations and Opportunities for Future Research

The development of learning-based games for music education presents unique challenges that span technical implementation, pedagogical design, and empirical validation. While this research has advanced our understanding of how games can support adult beginner keyboardists, several key limitations emerged from an initial round of feedback that warrant further investigation. These limitations not only highlight areas where the current research

could be strengthened but also indicate future directions for our research, particularly regarding learning design and implementation methodologies. The complexity of integrating game design principles with educational objectives while maintaining scientific rigour has revealed significant opportunities for methodological advancement in this field.

Assessment and Pedagogical Framework Integration

A significant limitation emerged in the lack of standardised assessment tools for measuring specific musical competencies within game-based learning environments. While the research developed reliable evaluation methods for its immediate context, the field would benefit from establishing validated measurement frameworks that could be applied consistently across different learning approaches. This standardisation would enable more meaningful comparisons between pedagogical methods and facilitate cross-reference analysis of multiple studies in the field. The research also revealed challenges in translating traditional music pedagogical frameworks into game mechanics. The necessity of conducting empirical quantitative research in a field traditionally dominated by qualitative methods required novel assessment approaches, though these would benefit from further validation and refinement. Future research could explore systematic methods for mapping pedagogical principles to game design patterns, ensuring that educational foundations remain robust while maintaining methodological rigor.

The challenge of validating educational outcomes while maintaining engagement presents a particular area for future investigation. Research frameworks must evolve to accommodate both the rigorous assessment of learning outcomes and the evaluation of player engagement, considering how these elements interact within the learning process. This includes developing more sophisticated methods for measuring skill transfer between game environments and real-world musical performance, particularly over longer periods of time.

Adaptive Learning and Multi-Modal Integration

The current implementation revealed limitations in the learning progression system's ability to accommodate diverse learning styles and adapt to individual needs. Future developments could explore more sophisticated adaptive mechanisms that respond not only to performance metrics but also to individual learning patterns and preferences. Such systems could incorporate dynamic difficulty adjustment based on learning curves, personalised progression paths, and adaptive feedback systems that evolve with player development. The implementation of hybrid methods, combining controlled experimental conditions with real-world learning

scenarios, could provide more comprehensive insights into the effectiveness of these adaptive systems.

The research highlighted opportunities for enhanced integration of different learning modalities. Current implementations emphasised visual and interactive elements, potentially discrediting auditory learning approaches. Future work could investigate methods for effectively combining these modalities while establishing empirical frameworks to measure their comparative effectiveness. The development of more sophisticated feedback mechanisms could better support the complex nature of musical skill acquisition, particularly in areas requiring fine motor control and rhythmic precision.

Cross-Domain Applications and Learning Process Complexity

The research's focus on keyboard skills, while yielding valuable insights, limited our understanding of how these game-based learning principles might transfer to other musical instruments or skills. This limitation extends beyond interface adaptations to fundamental questions about how different instruments might require distinct approaches to game-based learning. The complexity of music education processes suggests the need for extended study periods that can better capture the nuanced development of musical abilities. Future work could investigate how successful elements of our approach might be adapted for different musical contexts, considering both immediate skill acquisition and long-term retention.

This investigation could lead to more flexible game design frameworks that accommodate various instrumental techniques or unique instruments while maintaining effective learning progression. The establishment of partnerships with educational institutions and musical community groups could provide access to authentic learning scenarios, enhancing the ecological validity of future studies while preserving methodological precision. Through this iterative process, researchers may continue to develop and refine solutions that remain effective in evolving technical educational environments.

Methodological Considerations and Future Directions

The balance between controlled research environments and authentic learning contexts presents ongoing challenges that future research must address. While controlled studies provide necessary scientific rigour, they may not fully capture the complexities of individual learning journeys. Future research frameworks could explore innovative approaches to combining empirical methodology with the flexibility needed to accommodate diverse learning styles and contexts. This might include the development of more sophisticated data

collection methods that can track learning progression without disrupting the natural flow of skill acquisition.

The research also highlighted the need for more robust long-term evaluation methods. Future studies should consider implementing extended observation periods to better understand how game-based learning influences sustained musical development and practice habits. This could include investigating the transition from supported game-based learning to independent musical practice, examining how learned skills transfer to traditional performance contexts, and assessing the long-term impact on musical confidence and competence.

The integration of quantitative and qualitative assessment methods remains an area for methodological development. While the current research established viable frameworks for evaluating game-based learning outcomes, future work could explore more comprehensive assessment approaches that capture both measurable skill improvements and subjective learning experiences. This might include developing new tools for analysing the relationship between engagement metrics and learning outcomes, as well as methods for evaluating the effectiveness of different game mechanics in supporting specific learning objectives.

8.3.2 COVID-19 Impact Evaluation

During the global COVID pandemic our research was greatly challenged, and we were forced to transform how we do our research. The pandemic's impact was both beyond a simple contextual footnote and a critical methodological intervention that required a full reflection. Across some very critical domains we have outlined the challenges that the research encountered.

Participant Engagement and Recruitment:

- Significant reduction in willing research participants. Not only were we restricted by resources to help recruit participants, the policies in place during the pandemic either restricted members of the public being able to enter our space to conduct in person testing or reduced their willingness to participate; participants did not feel as though engaging with such a study would outweigh the risks of endangering their health.
- Heightened individual and institutional risk aversion. On top of individuals not willing to participate, sometimes being restricted by policy, the company itself needed to stress safety so we could often not have members of the public enter the workspace. If they did, they would have to undergo testing which led to an increased decline in participation.

- Increased psychological and logistical barriers to in-person research participation. As outlined further below, observational data was restricted because of the space required between the researcher and participants. Additionally, participants did not want to spend significant portions of time inside or give much verbal feedback as they were often prohibited by face coverings.

Methodological Observational Constraints:

The pandemic dramatically altered the fundamental mechanisms of research observation. Mandatory protective measures, particularly mask-wearing, created substantial impediments to comprehensive data collection. Researchers found themselves navigating a complex landscape where traditional observational techniques were rendered partially ineffective. Non-verbal communication became substantially more challenging to interpret, with facial expressions, clear indicators of emotional and cognitive engagement, obscured by protective coverings. As mentioned, participants were less willing to give verbal feedback due to face-coverings or because they were not willing to spend more than a certain amount of time within an enclosed space. This separation between researchers and participants led to a weaker rapport between the two parties and as such feedback was impacted in uncertain ways.

Technological and Procedural Adaptations:

Responding to these challenges required sophisticated methodological pivots. Digital platforms emerged as crucial alternative research spaces, though not without their own inherent limitations. Remote data collection methodologies were rapidly developed and implemented, necessitating innovative approaches to maintaining research integrity and participant engagement. These adaptations were not merely technical solutions but represented a profound reimagining of research methodology in a globally disrupted academic ecosystem where the impact of their introduction is still yet to be fully understood.

Key Methodological Considerations:

- **Enhanced awareness of the flexibility of research methods:**

Traditionally, research methodologies have been predicated on relatively stable, predictable models. The COVID-19 pandemic disrupted these assumptions, requiring us to recognise the inherent need to adapt our own methodology to still ensure our research goals were attainable. These insights transcend pandemic-specific challenges and fundamentally challenges long-established research paradigms. Methodological flexibility emerged not as an exceptional strategy but as a core demand of the times. Rigid, predetermined protocols would fail when faced with unprecedented global disruptions and the pandemic demonstrated that research methodologies must be dynamic

and responsive frameworks capable of change in response to external environmental pressures.

- **Recognition of Technological Mediation in Academic Research:**

Technology transformed from a supplementary research tool to a critical meditative infrastructure during the pandemic. Digital platforms, previously considered peripheral, became primary research spaces. This shift revealed implications for data collection, participant interaction, and research integrity. Conducting interviews remotely, online surveys, and remote observation tools were no longer mere alternatives but became essential research methodologies (as without it, we could not have run our core studies). This shift in our approach showed opportunities, such as potentially broader geographically dispersed participant pools, and significant limitations, including reduced qualitative depth, technological access inequalities, and challenges in capturing nuanced interpersonal dynamics.

- **Insights into Adaptive Research Design Strategies:**

Adaptive research design emerged as a necessity during the pandemic. Rather than viewing research protocols as fixed plans, we began conceptualising them as living, responsive documents. This approach demanded continuous methodology reflexivity, constantly reevaluating research strategies, anticipating potential disruptions, and building adaptability into research methods. This involved creating multiple potential research protocols for each study, developing robust contingency mechanisms (such as multiple ways to conduct interviews or testing), and maintaining methodological modestness. We learned to design studies with built-in flexibility, allowing for rapid pivots without compromising our core research aims and objectives.

The COVID19 pandemic was more than a logistical challenge; it represented an overhaul of our methodological process. This fostered new ways of thinking about research practises, participant interactions and how data was collected. The methodological innovations and challenges resulting from this event and the evaluations encompassed here will inform future investigations.

8.4 Concluding Statement

The developed games have comprehensively addressed both research questions posed at the outset of this investigation. Through systematic research and development, we discovered that learning-based games could be most effective in reducing high dropout rates among beginners

when designed as supplementary practice tools rather than attempting to replace traditional learning methods. This finding represents a significant departure from existing solutions, which typically attempt to either replace traditional methods with digital technology or gamify entire learning journeys through mobile applications. Our research demonstrates that the most effective use of video games in this context is as supporting aids that help beginners build foundational skills, making the learning process more approachable and less frustrating while building positive associations with practice. This approach, distinct from existing solutions that often consider gamification as an afterthought, has shown significant promise in promoting sustained engagement and skill development.

The research has made three original and significant contributions: novel artifacts in the form of learning-based games, a framework for design and development that others can utilise, and a robust methodology for assessing such solutions. The games developed through this research demonstrated that carefully designed game-based learning tools can significantly improve both engagement and skill acquisition, as evidenced by our longitudinal study which highlighted sustained practice and improved performance among participants.

However, significant limitations must be acknowledged. The primary challenges encountered were focused around two main areas: resource constraints and the balance between controlled research environments and real-world applications. The development of comprehensive game experiences by a single developer introduced limitations in terms of bug fixes, feature implementation, and overall polish. Additionally, while our assessment methods showed promise, they would benefit from further refinement and validation across larger participant pools and longer time periods.

The implications of this research extend beyond keyboard learning to other areas requiring sustained practice and engagement, such as language learning or technical skill development. The framework and assessment methodologies developed through this research provide a foundation for future developments in game-based learning across various domains. Our open-source contributions enable other researchers and developers to build upon this work, potentially leading to more sophisticated and effective learning solutions. Looking forward, the potential for this research to impact music education is significant, particularly in addressing the persistent challenge of early dropout rates among adult beginners. While our studies demonstrated promising results in terms of engagement and skill development, future research should focus on longer-term studies to validate these findings over extended periods. The development of more comprehensive assessment batteries and refined game mechanics could further enhance the effectiveness of these learning tools.

We hope this research will not only inspire learners to practice more consistently but also help them recognize that learning itself can be inherently enjoyable, especially when

the pursuit is creative in nature. By providing frameworks, methodologies, and practical examples of effective game-based learning tools, this research contributes to the broader goal of making music education more accessible and engaging for adult beginners and educators while maintaining pedagogical rigour and effectiveness.

Chapter 9

Considerations and Future Recommendations

As stated, the three original and significant contributions were the novel artifacts that were the learning-based games, the novel assessment method created and the framework of design and development that other researchers can use to ensure their pursuits in developing learning-based games have focus and are as smooth as possible; the repository of the code can also help expediate the entire development process. Whilst the framework and overall development cycle is highlighted throughout the thesis, it was important to distil the main points into a concise and easy to digest format. This chapter is composed of two sections: the first section is broken down into three subsections of considerations useful for: designing, developing and the assessment of learning-based musical games. The final sections presents the future recommendations that future researchers should consider when reviewing this work. The recommendations are based on further developments of the game and assessment methods as well as future directions on from a wider perspective, with consideration to the main issue this research proposed from the beginning.

9.1 Design Principles

Through developing a large array of new video games and practice tools, a lot of valuable information was gained that is believed to be useful for other researchers and developers regarding design considerations for gamified practice and learning. Whilst this information is most useful and pertains to music and keyboard learning, the lessons can be applied to any area of learning which shares similarities, most notably, learning any other instrument

or a language. A set of design considerations which one should consider when developing musical practice games is listed as follows:

- Ensure an iterative flow of development and testing is adopted, focusing on testing regularly which has a clear aim and correct participant demographics. This cycle of development and testing was key to this research developing novel learning games; whilst the design of new ideas was never short, testing would always lead to unexpected insights and help further the research. If the focus were on design and development then the games developed would have been far less reflective of the needs of the learners and as such had a less significant meaningful applications
- Hold consistent meetings with designers and developers. The meetings that were held were intended to be free of judgement, allowing freedom to express ideas to any degree. Furthermore, one should seek advice and insights outside of the development team, this process allowed the research to consider ideas which were not from the perspective of a game developer, but the player themselves
- Consider other areas of inspiration besides the one you are developing for – go beyond this and look to areas which are not solely based on video games for further inspiration – going outside the box will lead to novel ideas. As discussed throughout the thesis, there were a number of inspirations and it was typically from reviewing games that one would not consider applicable to the solution that the most novel and effective ideas were generated
- Design concepts with a lot of choices and observe play sessions to understand which choices are most impactful. Through the design process, there were a huge number of ideas and smaller concepts that were imbedded into each of the games. Through testing sessions, some choices were not used at all whilst some were the sole focus of the play session; without developing multiple choices, there was no way to understand which mechanic or design would yield the most engagement or enjoyment
- Try not to force any play style or assume a game will be played in a certain way: open ended interpretations are crucial and lead to the most valuable knowledge. This point was learned throughout the research, as it consistently discovered that the games would be played in a certain way and mechanics were designed to cater to this. However, through play testing sessions, these play styles were not adopted and each player would use mechanics in their own way. The ideal option was to develop a set of mechanics and rules within a game environment and allow players to define their own styles (their meta games) which led to increased personal investment and depth to the games

- Users want progression more than they want to beat their high scores; whilst mobile games focus on the infinite high scores, this does not equal longevity – ensuring your game has a reason for others to return which is not just beating a previous score, leads to personal investment and a greater return rate (this was most apparent when players were seeking to complete multiple missions in the RPG style game and wanted to return to the game simply to complete them)
- Tutorials cannot be a single instance and must be reiterated throughout the process. Whilst it is important to show how each game works during the beginning of the game, certain mechanics may not be obvious to players and this must be highlighted throughout the game. Not only this, but a tutorial must also be ‘hands-on’ and not just reading text; the application of what a player has learned ensures they will retain this information. It is important to develop tutorials as the game is developed, do not leave this until last
- Lay out all the attributes you wish to include in your development and use a MoSCoW (Spiru et al. 2019) or similar method to ensure that the most important ones are always included; a solid plan before beginning is crucial to ensuring that development does not get overly complex. It is important to not add attributes because they may be perceived as interesting - always ensure there is a reason for adding them and don’t waste time on developing things which will never be used
- Understand that certain mechanics may never be as useful in your design when put into practice; don’t get hung up on this – remember you are developing for others, not yourself
- Menu system and UI design needs to be simple but still have strong feedback – simple things such as button click sounds and background music help to separate a low quality game from high a quality one
- Plainly and succinctly state your goals for your intended prototypes – if developing for a specific goal does not work then move to another one and try not to defend an idea if you truly don’t believe it has merit
- Do not attempt to replace an entire system of learning, it is better to try and use gamification to aid learning, rather than trying to set unrealistic standards
- When building educational concepts, only have a few educational goals in mind and consider how other mechanics can improve other areas

- Do not just use new technology because its novel – have a meaningful approach which will build on retention rather than trying to stand out

9.2 Development Principles

This subsection shares the key lessons that were found through the development of musical learning games. The key principles and pitfalls one should consider when developing such games, and the main applications and use cases for the code repositories one should find most useful are listed:

- Avoid over developing the mechanics and, most importantly, the design of game – if you can ensure the most simplified version of your game is engaging then adding more to this will make it even more engaging. If using a model such as MoSCoW, then stick to this as close as possible but remember that plans will change during the course of development – being flexible and ensuring that a plan is followed is an important balance
- Setup a system which can be called upon to avoid repeating yourself per prototype by using generic functions and assets which can be used on many prototypes – this also applies to design elements too including UI; particularly studying SOLID (Kexugit 2014) principles when using object orientated programming
- Use other people’s work, especially when prototyping and you want the players to understand the full picture –this helps avoid spending too much time on creating assets or figuring out complex ideas
- Setup source control from the beginning of the development process and keep your project tidy. This will help during testing – there were multiple instances where an older mechanic or design paradigm was preferred and as source control was in place, it was easy to revert these changes. Furthermore, source control allows collaboration and others to create their own instances of your project – this can help with development times and allows others to demonstrate their ideas visually

9.2.1 Available Code Use Cases

- Whilst the project used a third party plugin to aid connections with MIDI devices, this was extended using custom listeners. A class can be found which handles various inputs and outputs based on MIDI devices and can be used to help other researchers

setup MIDI connections within their own games and make the process of connecting the events of the MIDI device to practically any action. The implementation uses the event systems and is contained within a namespace whilst also being static. This ensures that developers do not need to have an instance to the script in every other script that may use MIDI but simply call the static event every time they wish to connect a MIDI action to a mechanic. The event also takes into account ‘pressure’ of the key pressed which could be used to carry out mechanics which may not want players to fully press keys in (such as puzzles)

- A simple rhythm clock class is included which gives developers access to specific public variables that can be changed within the unity editor and ensures that the accuracy of rhythm is not dependent on framerate. This is a great for ensuring mechanics can be synchronised with rhythm or particular animations or movements
- A system which can generate notes within a given scale is also provided. Developers can implement a public class which other scripts can call upon if the use of scales within their games is desirable. For the sake of ease, the public class uses strings (i.e., the names of scales) rather than the numerical values. Developers can choose a particular scale, and a series of notes is generated based on that scale; additional methods include choosing a random note from that scale or even generating random but musically pleasing patterns. The system takes into account both sharps and flats and can even generate accidental notes; future implementations will also generate chords and satisfying chord patterns (following music theory principles)
- Generating simple but effective music based on a set of notes. The procedurally generated music found within the games throughout the research was generated by a class that takes a series of notes inputted by either developer or user and generates a melody. Whilst the implementation of this used Audiohelm (Tytel 2014), this implementation is not restricted to this and can use any sample or sound file that the developer wishes
- The ability to ‘draw’ or generate notation and letter representations from a series of notes. The most basic use case of this is to input a series of notes and allow the system to choose a random letter (or sprite, object - whatever is desirable) and display this to screen. This was extended to allow developers to set a starting position (i.e., the lowest note from the series of notes they are using in their own games) and set specific positions on a musical staff. For example, one could either use the staff sprites provided, or their own, state that the lowest note will be ‘middle C’ and that the system

uses a total of 5 notes. The class will generate logical positions that notation could appear on the staff for; a random note is chosen and the notation is displayed on the staff at the correct position of that note. This is extended further by inputting a total of notes that wish to be spawned and the class will generate horizontal positions and output a random series of notes and consequential notation on the staff. This is essentially a foundation to build musical games focused on the musical staff (such as those found in Staff Arcade and Notes Invaders)

9.3 Assessment Principles

Finally, what is believed to be the most important lessons to take into account when designing and developing assessment methods for gamified practice tools/games are shared. It is believed that if these points were known earlier in the research, significant time could have been spent on developing tools which yielded further meaningful application as well on studies which had additional focus (i.e., more resources spent on the development process rather than understanding how to approach the process). It is the hope of the author that by following these lessons, one can expediate the process and focus on what is most important. Below is a list of key lessons learned:

- Plainly state your participant demographic and stick to this as closely as possible – use the means you have around you and try to avoid opening to the major public too early on; do keep in mind that extending play testing outside of the development team is still crucial
- Do not be afraid to show your work and ensure you test and get feedback as much as possible – you will tunnel yourself in if you don't do this. This was the case during the first development cycle of the research in which it was eventually learned that such novel prototypes required feedback from other perspectives
- Don't be afraid of quantitative methodologies – this leads to more objective and empirical science which is highly replicable. Whilst qualitative research is still highly viable and is required, one should consider how empirical and replicable the research and methodologies can be. This field of research leans to qualitative or mixed methods but if one wants to attain a high standard of reliability and validity then pursue a more empirical route

- Ensure you refer closely to literature for similar assessment models as this helps validate your work and gives a strong direction. This was later discovered in the research and was pivotal to building assessment methods that were focused and robust
- Avoid overly subjective questions which lack meaning such as ‘fun’ or emotional responses as this is hard to validate and will vary from person to person – try to measure these items using more observational or quantitative techniques; this also requires using existing methods of assessment that have already been validated, one should build on others research in this regard
- If you are asking quite open-ended questions or specific ones, ensure the participant knows what you are referring to – if you observe a lot of mid-point scale answers this does typically mean they had no opinion but that they did not fully understand the question posed
- Test on specific items rather than general; you know your game is quite fun by the initial reaction but what specific items ensure its’ enjoyment; particular mechanics or designs? This was specifically explored in chapter 4 in which particular choices were posed to the participants to determine the exact mechanics and designs that led to increased engagement

9.4 Future Recommendations

Recommendations for future research in the development of the learning-based games and the assessment models of such games, as well as the applications of both are presented below. The larger implications and distinct avenues that this research may also take are also presented in which future researchers may consider. Whilst these ‘big picture’ applications are not entirely related to the research directly, the author proposes that with the knowledge this thesis contains, one could pursue other avenues to solve the original issue stated, that of reducing the drop out rates exhibited by beginner musicians.

9.4.1 Recommendations to Further Develop the Learning-Based Games

Recommendations to improve the RPG style game, ‘The Crypt of Notation’ which features in Chapters 5, 6 and 7 are presented below. This includes specific bugs that were found, key design and mechanical changes. Some of these changes are applicable to development of additional music learning-based games and are therefore attainable tangible goals which are applicable to a wide array of domains.

- **Sound Synchronisation:** To enhance player performance and perceived rhythm accuracy in rhythm-based games, precise audio-visual synchronisation is crucial. This research investigated the impact of varying latencies between keypresses and sound playback on a player's sense of rhythm and timing. Specifically, it focused on the synchronisation of sounds related to keypresses and those aligned with the beat of the tempo. To achieve optimal timing, it is recommended to either design custom sounds with no delay or carefully analyse and edit pre-existing sounds to eliminate any gaps or delays. This will help ensure a seamless connection between the visual rhythm components and the auditory cues, thereby improving the overall player experience and learning outcomes.
- **MIDI Controller Setup Tutorial:** A significant barrier to effective learning and performance was identified in the difficulty of MIDI controller setup. Participants frequently experienced frustration due to incorrect feedback, often caused by improper octave settings. Future iterations should incorporate a dedicated setup tutorial to ensure accurate instrument mapping and optimal learning outcomes. This tutorial should be accessible at the beginning of each play session, guiding users through the setup process and emphasising the importance of correct octave settings to prevent confusion and optimise the learning experience. This is a rather common theme among music based games that make use of complex hardware such as MIDI keyboards. Without robust onboarding players and learners alike will feel discouraged if the initial setup is too complex, leading to disinterest and faster drop off.
- **Design and Variation:** Our user-testing of "The Crypt of Notation" (and other previous games) revealed a need for more diverse and narrative-driven puzzle design. To enhance the player experience, we aim to integrate puzzles seamlessly into the narrative, unlocking crucial game progression and enriching the story. Beyond simple pattern recognition, we will explore a wider range of mechanics, such as spatial reasoning, logical deduction, and code-breaking, to create more engaging and challenging puzzles. By carefully calibrating the difficulty curve, we can ensure a satisfying experience for players of all skill levels. Furthermore, we will empower player agency by providing multiple solution paths, encouraging exploration and strategic thinking. This idea of introducing complexity into puzzles also applies to other mechanics in our games. Based on the user feedback we suggest that future designers do not make their games simple experiences which focus primarily on the educational nature of the game but allow players to explore the complex intricacy of their games, allowing extended exploration and thus increasing satisfaction and engagement.

To refine our approach, we aim to conduct in-depth player research to gather insights into player preferences, frustrations, and expectations. By studying behavioural data, we hope to identify patterns and inform future design decisions useful for own research and others within this domain. This iterative process will allow us to continuously refine our game design based on data-driven insights. This research-driven methodology can be applied to various game genres and platforms, ensuring that not only puzzle design remains innovative and player-centric, but all aspects of a game's design. The core concepts outlined here are not new and are found throughout typical game design/development cycles; adopting our research to be more aligned with these typical practices will help create more complex and satisfying games that reach a wide audience.

- **Procedural Generation vs. Handcrafted Content:** A final future recommendation is to consider how content is generated for such games. For most of the games, levels and progression was procedurally generated in an exponential progressive manner (using the 'saw-tooth' model of difficulty (Holleman 2019)). Whilst this style of development ensured that a lot of content could be developed, it often led to a feeling of repetition and a lack of overall depth to each game. Feedback from the final study highlighted that the initial phase of the game was highly enjoyable and participants thoroughly enjoyed the hand-created levels but often felt the other levels were rather repetitive in nature. Although developing each level by hand and ensuring that all mechanics, sounds and visuals match is a much longer process and is most suitable for those who can dedicate their time solely to this ambition or work with a team, one must consider the trade-off between large amounts of content which lacks variation with a smaller amount of content that has a vast amount of depth and personalisation. This once again highlights the need for the game-based learning approach in music education and the steps that we should take to maximise this ethos; demonstrating the positives of this approach and the increased demand for resources to implement it.

Summarising

To align with the core principles of game-based music education, we aim to create more immersive, educational, and enjoyable experiences for players. To achieve this, we will focus on these core principles in our current and future game developments:

1. **Enhancing Audio-Visual Synchronisation:** Improve the accuracy and consistency of audio-visual synchronisation to enhance the player's sense of rhythm and timing.

2. Streamline MIDI Controller Setup: Develop a user-friendly setup tutorial to guide users through the process and minimise frustration.
3. Elevate Puzzle Design: Create more diverse, narrative-driven, and challenging puzzles, incorporating a variety of mechanics and solution paths.
4. Refine Procedural Generation: Strike a balance between procedural generation and handcrafted content to ensure a satisfying and engaging player experience.

9.4.2 Recommendations to Further Develop the Assessment Methods

Recommendations to further the developed assessment methods that were constructed over the course of the research are now presented. These recommendations include building a battery of tests to further measure learners musical capabilities, how one considers measuring practice time on a specific scale, and building a more robust methodology which still reflects the real-world measures and controls confounding factors with more stability. With such recommendations, the implication is that these assessments should be used in longitudinal studies over much longer periods of time to further assess the ability of such games in the lives of the independent, adult learners that this research targets; helping to prove that this novel method of practice will lead to longevity of learning.

- **Developing a Battery of Musical Ability Tests:** We aim to build a series of tests which can be used to further assess a learners ability to read musical notation (or the skill that one is attempting to develop game-based solutions for). Whilst the final study proved that the testing methods were appropriate and reliable, this reliability needs to be increased to ensure that these tests can be used in an empirical fashion over longer periods of time. Other methods of assessment will be consulted where we particularly study the domain of psychology for these tests to pursue a more quantitative approach to testing. This development will help satisfy the two limitations found from the final study: the average reliability of both tests and the self-reporting of the participants competence of playing the keyboard and reading musical notation. With further developments of both tests, one could determine for definite the skill that a learner possess and their musical competence; this would help increase the validity of tests whilst ensuring they are reliable when used in long term testing practices.
- **Utilising Telemetric Data for Accurate Practice Time Measurement:** It is recommended that self-reporting how long a participant plays for is not pursued and that using telemetric data is preferred. Implementing such facets is not a hugely large

undertaking when using development tools such as Unity; in fact, there was work conducted into tracking telemetric data of the participants play experiences. However, this was not used in the final study as capturing this data in the comparison practice tool was not possible and would lead to unequal comparisons. Going forward, one should incorporate this and ensure that if any comparative tools are used, they too capture this data, leading to specific time frames which can offer more specific quantitative analysis.

- **Tracking In-Game Activities with Telemetric Data:** we aim to track specific activities which are recorded using telemetric data. Understanding exactly what the participant was participating in when playing the game would have led to a deeper understanding on specific mechanics that were most engaging and further developments would focus on this. Future research will consider how to track such data and what data is most important. For example, in ‘The Crypt of Notation’, it would be imperative to know how much the cosmetics were used, what items were purchased and how often the arena was used.

Summarising

1. Develop a reliable battery of musical ability tests to assess skills like musical notation reading.
2. Use telemetric data to accurately measure practice time, replacing self-reporting.
3. Track in-game activities with telemetric data to understand player engagement and identify engaging mechanics.

9.4.3 The Bigger Picture

The above recommendations are directly related to the games developed within this research and relate to the methods of assessments that have been developed over the course of multiple studies. Considering the main question that this research originally proposed, there were other research directions and solutions that one could also consider. It is recommended that these directions are pursued whilst using the assessment methods that have been developed as these methods have been proven to be effective at measuring improvements of musical abilities within real world settings, the usability, engagement through custom questionnaires and measuring specific practice rates. These recommendations include the other games that could have been developed and how other researchers could pursue distinct genres, the incorporation of new technology that has improved over the course of this research as well

how to implement AI and machine learning techniques that have also been improved during the doctorate.

- **Exploring New Game Genres and Prototypes:** We aim to further develop and evaluate the potential of arcade-style and hybrid game genres for music learning, building upon the foundational work of 'Staff Arcade' and 'Notes Invaders'. We want to prioritise the development of promising prototypes from the list in Chapter 1, leveraging the established framework to expedite the process. Additionally, we plan to investigate the potential of novel game concepts that address identified gaps in music education, such as games focused on rhythm, improvisation, or music theory (where we had focused on previously but lacked resources to develop them further).
- **Leveraging Advancements in Virtual and Augmented Reality:** We would like to utilise the latest VR and AR technologies, including advanced hand tracking and haptic feedback, to create immersive and interactive music learning experiences. Develop innovative VR and AR-based games that provide real-time feedback and guidance, enhancing the learning process. Additionally, with the emerging research of AI, we will also explore the integration of AI-powered adaptive learning systems within VR and AR environments to personalise the learning experience for each user. An example of this would be intricate finger tracking combined with AI tutors that help to guide learners to use correct form when playing specific pieces; tutors would learn over time with the students to form a cohesive learning environment.

Summarising

1. **Game Genre Innovation:** Explore and develop new game genres, such as arcade-style and hybrid models, to enhance music learning experiences.
2. **Leveraging Advanced Technologies:** Utilise VR and AR technologies, including hand tracking and haptic feedback, to create immersive and interactive learning environments.
3. **AI-Powered Personalised Learning:** Integrate AI and machine learning to develop intelligent tutoring systems that can analyse learner performance, provide tailored feedback, and adapt to individual needs.

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Appendix A

Study Questions

A.1 Study One Questions

Timeframes

A rough estimation of how long each interview will take is outlined below; these times will vary per individual but hopefully provides a reasonably accurate guide.

- Introduction and consent: 10 minutes
- Introduction Questions: 20 minutes
- Main Play Sessions with Questions: 5 minutes with 4 games, 20 minutes
- Closing Questions and Remarks: 10 minutes
- Total Time: 1 Hour

Introductions & Instructions

An introduction to the lead researcher and the background/reason for conducting this study and research. Following this, a brief outline of what will take place during the interview will be offered and any questions or concerns can be answered at this stage.

Recording, Ethical and Data Consent

A breakdown of how the collected data will be used, how this information will remain anonymous and any ethical issues that arise from this will be discussed and approved by the participant; a sheet will be provided with this information and any NDA/relevant consent forms will be signed.

Introduction Questions

Questions that are indented are considered follow up or probing questions.

1. How old are you?
2. Music Experience/Preferences:
 - a. Do you take any lessons or have taken any lessons in the past?
 - i. Anything in particular that you found repetitive or mundane?
 - b. Do you own any instruments?
 - i. How much experience do you have with the instrument?
 - ii. What do you find the most tedious (boring) about learning [piano/keyboard]?
 - iii. [If a lapser] Any reasons to originally stopping learning?
 - iv. [Lapsers] What made you want to start again/start initially?
 - v. Why do you want to learn to play [keys]/general musicianship?
 - vi. What prevents you from starting learning (e.g. embarrassment/nervous etc.)?
 - vii. How long would you be willing to spend each day for learning?
 - viii. How would you go about learning to play a keyboard/piano?
 - a. Prompts: Teacher, online videos, friends etc.
 - ix. Have you tried using learning applications e.g. Yousician?
 - a. Were they helpful/beneficial for your learning experience?
 - c. How creative of a person do you feel you are?
 - d. How often do you listen to music?
 - i. Any particular genres that stand out?
3. Are you a gamer at all; do you play video games?
 - a. How often do you play games per week?

- b. Have you/do you play any musical games or games revolved around sound/music?
- c. What genre are you typically fond of?
 - i. Specific Games; Reasoning?
- d. Why do you play the games you mentioned?
 - e. Do you typically play on a mobile, console etc.? How do you play?

These are the questions that will be asked after each game has been played:

1. A question for those who have used other learning applications is appropriate; how would you compare this to the scale practise in [e.g. Yousician]?
2. How would you describe your experience?
 - a. How educational did you find each game (i.e. did you learn or take something away from it?) [Likert scale 1-5]
 - b. Did you find the experience fun? [Likert scale 1-5]
 - c. Is there anything in particular that stood out, either negative or positive?
 - d. Thoughts on the layout of the score etc. on screen and the design of each game?
 - e. How would you describe the overall theme of the game?
 - f. Would you change the design or style of the game?
 - g. How would make it different; any features you would like to see or any existing features you would remove or change?
3. What did you like the most?
 - a. And the least?
4. What caused, if any, stress or frustration?
5. I noticed you spent the most time on [particular game] and less time playing [game]; any reasons for this?
6. I noticed you seemed a bit confused at one point; any insights you can share into why this may be?
7. Observational Points:
 - a. Navigation of menus and overall experience
 - b. Understanding the concept of each game
 - c. Understanding of what is being taught or practised
 - d. Particular mechanics or features that they struggled with or used a significant amount?
 - e. Are there any areas in which getting a high score is particularly easy or hard?
8. How likely is it would you recommend this game to a friend learning keyboard, theory etc.? (1-5)
9. If you could use this as a practice tool alongside typical learning methods, would you?
 - a. How often? i.e. would this replace a typical practice tool and could you see yourself using it more if it could teach more lessons and provide more than simple things to practice?
10. Any remaining comments about your experience?

Closing Questions and Remarks

Closing remarks which thank the participant for coming in and will go over the purpose of the study once more and ensure participants of their data anonymity when discussing this data.

1. Of all the games played today, which was your preferred one?
 - a. And why do you say that?
2. Any last notes regarding the hardware and would you be inclined to come back for testing?
3. Is there any other information regarding your experience that you think would be useful for me to know?
4. Any creativity related questions? (Extension; could feed much later into the project)

Recording devices switched off.

Interviewer Reflection

After the participant has left, the head researcher/interviewer will take five minutes to reflect on the answers given and organise the work space for the next interview. After each interview has been conducted, a reflection sheet will be provided to fill out after each interview to ensure the data and experience is captured in as much detail as possible.

A.2 Study Two Questions

Timeline

A rough estimation of how long each interview will take is outlined below; these times will vary per individual but provides a reasonably accurate guide.

- **Introduction and Questions:** 10-15 minutes
- **Main Play Sessions with Questions:** ~45 minutes (depending on users' willingness to play for longer/give longer answers)
- **Closing Questions and Remarks:** 10 minutes
- **Total Time:** ~60 minutes

Introductions and Instructions

An introduction to the lead researcher and the background/reason for conducting this study and research will be provided. Following this, a brief outline of what will take place during the interview will be offered and any questions or concerns can be answered at this stage.

Recording, Ethics and Data Consent

A breakdown of how the collected data will be used, how this information will remain anonymous and any ethical issues that arise from this will be discussed and approved by the participant; a sheet will be provided with this information and any NDA/relevant consent forms will be signed.

Introduction Questions

Questions that are indented are considered follow-up or probing questions.

1. State what age range they fall into
2. Music Experience/Preferences:
 - a. Do you own any instruments?
 - i. How much experience do you have with the instrument/music in general?
 - ii. Why do you want to learn to play [chosen instrument]/general musicianship?
 - iii. How would/did you go about learning to play a keyboard/piano?
 1. Prompts: Teacher, online videos, friends etc.
 - iv. Anything in particular that you found tedious and/or mundane about learning or practising your chosen instrument?
 - v. [Lapser] Any reasons to originally stopping learning?
 1. [Lapser] What made you want to start again/start initially?
 - b. How long would you be willing to spend each day for learning?
 - i. What prevents you or puts you off hitting this goal?
 - ii. What does this practise typically look like?
 1. Where can games be most effective?
 - c. Have you tried using learning applications e.g. Yousician?
 - i. Were they helpful/beneficial for your learning/teaching experience?
 1. Useful, risk of incorrect playing, 'hamburger model'
3. Do you play video games?
 - a. What type of games do you typically play – preferred genre/platform?

- i. Why do you play the games you mentioned?
 1. Escapism, relaxing, pure enjoyment/personality (who you are) etc.
- b. How often do you play games per week? [List: once a day, 2/3 times a week, once a week, when I get the chance]

Questions & Observations Post Game Play Session

Open-Ended Questions Relating to the Overall Experience

1. How would you describe your experience?
 - a. Thoughts on the design of the game?
 - b. Would you change the overall design or style of the game?
 - i. General comments on the theme; would you change it or add to it?
 - c. Any features you would like to see or any major existing features you would remove or change?
2. What caused, if any, stress or frustration? (Observational probes)

Questions Regarding Specific Mechanics

A table of each game and consequent mechanic/design choice can be made available. Users will play each game with and without the varied mechanic/design and then be asked simple preference questions and probing questions into why. The variances are not major (for example, do users prefer to choose settings or use a set up level) and there are only a few variances per game therefore, testing these specific mechanics should take no longer than a few minutes – allowing users to spend the majority of time playing the core of each game rather than discussing minor changes.

Questions Regarding Educational Impact

1. How educational did you find this game (i.e. did you feel like you had improved your skills/felt more confident playing?) [Likert scale 1-5]
 - a. Any reasoning for this score?
 - b. What can be done to increase this score?
 - i. Specific design choices
 - ii. Obvious changes to incorrect features (e.g. a note may be in the wrong place or sound may be wrong etc.)
2. How likely would it be for you to use this as a practise tool alongside your learning? [Likert Scale 1-5]
 - a. [if low score] What could be implemented to increase this likeliness?
 - b. [if high score] How often? i.e. could you see yourself using it more if it could teach more lessons and provide more than simple things to practise? (Serious application)
3. How likely is it would you recommend this game to a friend learning keyboard, theory etc.? [Likert scale 1-5]

Questions Regarding Usability

1. How difficult did you find the game's menu and setup to navigate? [Likert scale 1-5]
 - a. Any reasons for this? (Follow up observation questions)
 - b.

- c. What can be done to improve the overall UX?
2. How difficult was it to grasp the concept of the game? [Likert 1-5]
 - a. Observations should highlight this
 - b. If low, any reasons for this? (Follow up observation questions)
3. Was the use of the lights useful or potentially distracting?

Questions Pertaining to Competence (feeling of fun, competition, being good at the game and being able to apply a level of skill)

1. How satisfying did you find the game? [Likert Scale 1-5]
 - a. Did you find a specific game mechanic satisfying?
 - b. Was there something in particular that helped this feeling?
 - i. Aesthetics and Sounds
 1. Specific design choices e.g. flashing screen etc.
2. How challenged did you feel playing this game? [Likert Scale 1-5]
3. How skilful did you feel playing this game? [Likert Scale 1-5]
 - a. Why do you feel this way?
 - b. Did you feel as though you were applying a specific skill?
 - c. Was the difficulty gradient too steep or shallow?
4. How likely would you be to return to the game? [Likert Scale 1-5]
 - a. Why is this?
 - i. High scores/leader board?
 - ii. Getting to next level? Unlock the next level?
5. How immersed did you feel when playing? [Likert Scale 1-5]
 - a. Were you engrossed by the gameplay?
 - b. The music and sounds?
 - c. The story or specific designs?

Questions Pertaining to Autonomy (Choice perception)

1. How much choice did you feel you had during gameplay? [Likert Scale 1-5]
 - a. What lead you to give that score?
 - i. E.g. the ability to pick up bonus points but risk losing a life
 - ii. The idea of playing on beat for extra points
 - iii. Or a lack of choice such as, you could only play the correct note
2. Did you feel as though your choices had meaning?
 - a. E.g. users could go down path left or right but always end up in the same place
3. Did you feel as though you could/wanted to explore the game? [Likert Scale 1-5]
 - a. Why provide this score?
 - i. Different settings, themes, shop items etc.
 - ii. Actual exploration of themed levels
 - iii. Exploring the intricacies of the game itself
 - b. Did the user attempt to 'break' the game mechanics?
 - c. Did the user desire to replay a specific part or level to beat their previous score and see how the mechanics/rules can be bent to maximise score?

Questions Pertaining to Relatedness (social aspect, leader boards, badges etc.)

1. Was recording scores (streak, incorrect, correct) a motivator to play again?
 - a. In what capacity, the idea of beating your previous score or would you prefer to compare against other players?
 - i. Beating the main leader boards?
 - b. Would this game benefit from social elements?
 - i. E.g. personal profiles with total time played, total correct scores, badge collections etc. which can be directly compared against?

Closing Remarks

Closing remarks which thank the participant for coming in and will go over the purpose of the study once more and ensure participants of their data anonymity when discussing this data.

1. Of all the games played today, which was your preferred one?
 - a. And why do you say that?
2. Would you like to give any final comments regarding the games (and the testing itself)?
3. Would you be inclined to come back for a longer form of testing?

Recording devices switched off.

Interviewer Reflection

After the participant has left, the head researcher/interviewer will take five minutes to reflect on the answers given and organise the work space for the next interview. After each interview has been conducted, a reflection sheet will be provided to fill out after each interview in order to ensure the data and experience is captured in as much detail as possible.

A.3 Study Three Questions

Introduction Questions

Questions that are indented are considered follow-up or probing questions.

1. State what age range they fall into
2. Music Experience/Preferences:
 - a. Do you own any instruments?
 - i. How much experience do you have with the instrument/music in general?
[The instrument which has the most experience will be the ‘primary’ instrument for a given participant]
 - b. How long would you be willing to spend each day practising?
 - i. What prevents you from hitting this goal?
3. Do you play video games?
 - a. What type of games do you typically play – preferred genre/platform?
 - b. How often do you play games per week? [once a day, 2/3 times a week, once a week, when I get the chance]

Questions & Observations Post/During Game Play Session

Open-Ended Questions Relating to the Overall Experience

1. How would you describe your experience?
 - a. Participants should be free to discuss their experience whilst they are playing but will also provide answers post session
 - b. Would you change the overall design or style of the game?
 - c. Any features you would like to see or any major existing features you would remove or change?

Questions Regarding Educational Impact

1. How educational did you find this game (i.e. did you feel like you had improved the skill of reading music at the keyboard/felt more confident reading music in general?) [Likert scale 1-5]
 - a. Any reasoning for this score?
2. How likely would it be for you to use this as a practise tool alongside your learning? [Likert Scale 1-5]
 - a. How often? i.e. could you see yourself using it more if it provide more than simple things to practise e.g., advanced notation, reading times etc.? (Serious application)

Questions Regarding Usability [1,2]

1. How difficult did you find the game’s menu and setup to navigate? [Likert scale 1-5]
 - a. Any reasons for this? (Follow up observation questions)
 - b. What can be done to improve the overall UX?
2. How difficult was it to grasp the concept of the game? [Likert 1-5]
 - a. Observations should highlight this
 - b. Difficulty curves; was it too easy or too hard?
3. What caused, if any, stress or frustration? (Observational probes)

Questions Pertaining to Competence (feeling of fun, competition, being good at the game and being able to apply a level of skill)

1. How satisfying did you find the game? [Likert Scale 1-5]
 - a. What lead you to give that score?
 - i. Aesthetics and Sounds
 1. Specific design choices e.g. flashing screen etc.
2. How challenged did you feel playing this game? [Likert Scale 1-5]
 - a. What lead you to give that score?
3. How skilful did you feel playing this game? [Likert Scale 1-5]
 - a. What lead you to give that score?
4. How likely would you be to return to the game? [Likert Scale 1-5]
 - a. What lead you to give that score?
 - i. High scores/leader board?
 - ii. Getting to next level? Unlock the next level?
5. How immersed did you feel when playing? [Likert Scale 1-5]
 - a. Were you engrossed by the gameplay?
 - b. The music and sounds?
 - c. The story or specific designs?

Questions Pertaining to Autonomy (Choice perception)

1. How much choice did you feel you had during gameplay? [Likert Scale 1-5]
 - a. What lead you to give that score?
 - i. Mechanical/menu choices
 - ii. The ability to pick up bonus points but risk losing a life
 - iii. The idea of playing on beat for extra points
 - iv. Or a lack of choice such as, you could only play the correct note
2. Did you feel as though you could/wanted to explore the game? [Likert Scale 1-5]
 - a. What lead you to give that score?
 - i. Different settings, themes, shop items etc.
 - b. (Observation) Did the participant attempt to 'break' the game mechanics?
 - c. (Observation) Did the participant desire to replay a specific part or level to beat their previous score and see how the mechanics/rules can be bent to maximise score (the sense of replay ability)?

Closing Remarks

Closing remarks which thank the participant for coming in and will go over the purpose of the study once more and ensure participants of their data anonymity when discussing this data.

1. Would you like to give any final comments regarding the game (and the testing itself)?
2. Would you be inclined to come back for a longer form of testing?

Recording devices switched off.

A.4 Study Four Questions

Ethical Consent

A breakdown of how the collected data will be used, how this information will remain anonymous and any ethical issues that arise from this will be discussed and approved by the participant; a sheet will be provided with this information (sent via email in PDF format). Participants will be sent the attached agreement form and will sign this electronically before sending it back to the researcher; any participant that does not send back the signed form, will not be able to participate.

Introduction/Background Survey

- [1] State what age range you fall into (years old):
 - a. 18-24
 - b. 25-34
 - c. 35-44
 - d. 45-54
 - e. 55-64
 - f. 65+
- [2] Please state your sex
 - a. Male
 - b. Female
 - c. Prefer not to say
- [3] Please state what desktop PC you own
 - a. Apple based
 - b. Windows based
 - c. Other [please specify]
- [4] Music Experience/Preferences:
 - a. Do you own any instruments?
 - i. How much experience do you have with the instrument/music in general? [The instrument which has the most experience will be the 'primary' instrument]
 - ii. Please state how you have learned so far (online videos, books, teacher etc.)
 - iii. Have you ever undertaken any formal musical training? If yes, briefly describe
 - iv. How confident do you feel reading sheet music/musical notation [out of 10]? Where 1 is never attempted to read sheet music and 10 is can sight-read without any issues and with maximum confidence
 - b. How long do you currently spend/ would you be willing to spend each day practising (minutes)?
 - i. 5
 - ii. 10-20
 - iii. 30-60
 - iv. 60-120
 - v. 120+
 - vi. What prevents you from hitting this goal (if you do not achieve it regularly)?
- [5] Do you play video games?

- a. What type of games do you typically play – preferred genre/platform?
- b. How often do you play games per week?
 - i. 3 or more hours per day
 - ii. At least 1-2 hours everyday
 - iii. Once a day
 - iv. 2/3 times a week
 - v. Once a week, when I get the chance
 - vi. Rarely play

Mid-Week Survey (Optional)

- [1] How much did you use your practice tool this week?
 - a. Only for the allotted 15 minutes
 - b. 15-30 minutes
 - c. 30-60 minutes
 - d. 60-120 minutes
 - e. 120+ minutes
- [2] What did you do regarding playing/learning with your instrument? (if you had practised outside the allotted 15 minutes of practice time)
- [3] Did you feel more inclined to practice or learn this week (compared to your average week)?
 - a. Do you feel the solution helped increase your motivation to play and learn?
- [4] Do you felt the practice tool helped you improve your playing form or helped you feel more confident/competent at the keyboard?

End of Study Survey

Open-Ended Questions Relating to the Overall Experience

- [1] How would you describe your experience with your practice solution?
 - a. Would you change the overall design or style of the game/tool?
 - b. Any features you would like to see or any major existing features you would remove or change?

Questions Regarding Educational Impact

- [1] How educational did you find this game (i.e. did you feel like you had improved the skill of reading music at the keyboard/felt more confident playing keyboard in general?) [Likert scale 1-5]
 - a. Any reasoning for this score?
- [2] How likely would it be for you to use this as a practise tool alongside your learning (outside of this experiment)? [Likert Scale 1-5]
 - a. How often? i.e. could you see yourself using it more if it provide more than simple things to practise e.g., advanced notation, reading times etc.?

Questions Pertaining to participants learning/playing habits using either solution

- [1] How much did you play your instrument throughout the session on a daily basis?
 - a. Only for the allotted 15 minutes
 - b. 15-30 minutes

- c. 30-60 minutes
 - d. 60-120 minutes
 - e. 120+ minutes
- [2] What did you do regarding playing/learning with your instrument? (if you had practised outside the allotted 15 minutes of practice time)
- [3] Did you feel more inclined to practice or learn (compared to your average week)?
- a. Do you feel the solution helped increase your motivation to play and learn?
- [4] Do you feel the practice tool helped you improve your playing form or helped you feel more confident/competent at the keyboard?

Questions Regarding Usability & SUS [4,5, 6]

- [1] I found it unnecessarily complicated [Likert scale 1-5]
- a. Any reasons for this?
 - b. What can be done to improve the overall UX?
- [2] I found the product easy to use [Likert scale 1-5]
- [3] I found the different features of the solution well integrated with each other [Likert scale 1-5]
- [4] I found the concept of the solution difficult to grasp/understand [Likert 1-5]
- [5] The solution matched my skill level well [Likert scale 1-5]
- [6] I can imagine most people would quickly get on with the solution [Likert scale 1-5]
- [7] I felt confident using the solution [Likert scale 1-5]
- [8] What caused, if any, stress or frustration?

Questions Pertaining to Competence (feeling of fun, competition, how much participants felt they were in a state of flow and challenge they felt during the session)

- [1] How satisfying did you find the solution? [Likert Scale 1-5]
- a. What led you to give that score?
 - i. Aesthetics and Sounds
 - 1. Specific design choices e.g. flashing screen etc.
- [2] I felt just the right amount of challenge [Likert Scale 1-5]
- a. What led you to give that score?
- [3] How skilful did you feel using the solution? [Likert Scale 1-5]
- a. What led you to give that score?
- [4] How likely would you be to return to the solution? [Likert Scale 1-5]
- a. What led you to give that score?
 - i. High scores/leaderboards?
 - ii. Getting to next level? Unlock the next level?
- [5] How immersed did you feel when practising? [Likert Scale 1-5]
- a. Were you engrossed by the gameplay?
 - b. The music and sounds?
 - c. The story or specific designs?
- [6] I did not notice time passing [Likert Scale 1-5]

Questions Pertaining to Autonomy (Choice perception)

- [1] How much choice did you feel you had during each practice session? [Likert Scale 1-5]

- a. What lead you to give that score?
 - i. Mechanical/menu choices
 - ii. The ability to pick up bonus points but risk losing a life
 - iii. The idea of playing on beat for extra points
 - iv. Or a lack of choice such as, you could only play the correct note
- [2] Did you feel as though you could/wanted to explore the solution? [Likert Scale 1-5]
- a. What lead you to give that score?
 - i. Different settings, themes, shop items etc.
 - ii. (Observation) Did the participant desire to replay a specific part or level to beat their previous score and see how the mechanics/rules can be bent to maximise score (the sense of replay ability)?

Appendix B

Analytical Strategies and Game Inspirations

B.1 Qualitative Analytical Strategy (Nvivo12)

This analytical strategy is based on a series of interviews revolving around a series of learning video games with specific purposes relating to keyboard/piano education. Through a series of interviews, we wanted to establish and inductively prove what we have deduced thus far; the reasons for beginner instrumental learners to give up on learning, the fundamental aspects of a music learning journey which is deemed repetitive, tedious and boring. With this deduction, we created several prototype games to help solve this issue of boredom and high drop off rates. Through our analysis of each interview, we aim to provide evidence to our deductions whilst also finding other themes relating to this problem. We also aim to find recurring themes relating specifically to each game and the experience of it, the overall study itself (regarding improving for next time) and to help narrow down the scope of this research in order to help create criteria and build a system which can be used as a catalyst to test our solutions against our given problem. This approach does not commence with a prior hypothesis to be tested and proved but with a focus of inquiry that takes the researcher on a voyage of discovery; specifically relating to the effectiveness of each game, quality of the user experience, the overall testing methodological approach and how to improve this. The aim is to improve each game and ensure that it matches the specific criteria (leading to a solution for our given problem) whilst also ensuring the way we test the validity of these games is thorough enough and is highly relatable to our given problem (i.e., ensure these solutions can actually help solve our problem).

Thematic analysis involves the identification of patterns within data (Braun and Clarke 2006), whereby the patterns are coded until themes are generated (Fereday and Muir-Cochrane 2006). A code is produced when the researcher has identified something of interest or importance within the raw data (Boyatzis 1998), this is done by ‘tagging’ and naming selections of text (Braun and Clarke 2006, p.86). Themes are generated when a visible pattern is identified within the generated codes, themes then help the researcher to address or understand the topic of the research (Boyatzis 1998). Within this approach there are various levels of analysis (semantic and latent). A semantic approach focuses on one level of analysis where the researcher does not delve into the data above and beyond ‘what has been said or written’, whereas latent levels of analysis means that the researcher explores beyond the data to search for meanings above and beyond ‘what has been said or written’ (Braun and Clarke 2006, p.84).

Methods of data collection:

- Observation
- Video and audio recordings
- Interviews
- Likert Scales (asked during interview stage)

In order to manage, organise and analyse the data, the management software system **NVivo 12** was used. Within NVivo two main types of terminology are used to describe the data and

how the data are managed (sources and nodes). Sources refer to the data collection method, for example observation, and nodes store coded data to begin the process of developing and managing themes. Prior to using NVivo in this research two training workshops were previously attended by the researcher on two occasions (hosted by Ben Meehan).

Triangulation in line with Braun and Clarke's (2006) coding scheme, is where the nodes are collated and gathered to search for potential themes and where the developed themes were reviewed. As discussed in the first section of chapter four, multiple method triangulation will be used to gain further insight into the data. This allows individual data sets to come together, forming one overarching data corpus adding validity to the findings if similar patterns were visible across more than one data set. At this stage we started to search for potential themes (phase four). All the raw data was reread and reviewed to ensure that the data was representative of the node and theme within which it was placed. After further refinement, key initial themes were identified, which were collapsed into refined main themes.

Whilst this is a in depth guide, our results/aims do not require a massive amount of analysis; this strategy should be used as a guideline, but analysis does not strictly need to follow this exact route or depth.

Step by Step Guide

- So, for the most part we are applying themes and reoccurring ideas to what we already know
- This gives us a good understanding on answers to our questions
- However, we also have a decent idea of where to go to next; through this thematic analysis and deductive reasoning we will confirm this direction and generate more insights
- So, this research currently is mixed methods; qualitative = case studies whereas quantitative = experimental studies which fall in line with a pragmatic approach
- Our method is thematic analysis in which we use mostly deductive reasoning with some inductive reasoning.
- Semantic view (i.e., explicit – people said this, they mean exactly that)
- Research Design: pragmatic (we have an issue; we solve it with fact & real solutions)

STEPS:

Phase 1 – Familiarisation with the data will involve transcribing data, reading, watching and listening to the initial data whilst noting down general ideas and key takeaways

Phase 2 – Creating initial codes involves coding interesting features and observations of the data and then identifying patterns/themes within this data (a basic coding)

Phase 3 – Themes will involve breaking down the now restructured codes into themes & sub themes to offer more in depth understanding of the highly qualitative aspects under scrutiny such as divergent views, negative cases, attitudes, beliefs and behaviours coded to these categories and to offer clearer insights into the meanings embedded therein

Phase 4 – Review Codes & Themes will involve consolidating themes into a more abstract and conceptual map of a final framework of codes for reporting purposes. Categorising all themes into umbrella ones which relate to the aims of the study as well the research aims

Phase 5 – Writing Analytical Memos against the higher-level codes to accurately summarise the content of each category and its codes and propose empirical findings against such categories. These memos will consider 5 key areas:

1. The content of the cluster of codes on which it is reporting
2. The patterns where relevant (levels of coding for example although this could be used to identify exceptional cases as well as shared experiences)
3. Considering background information recorded against participants and considering any patterns that may exist in relation to participants' profiles
4. Situating the code(s) in the storyboard –meaning considering the relatedness of codes to each other, and their importance to addressing the research question and sequencing disparate codes and clusters of codes into a story or narrative which is structured and can be expressed in the form of a coherent and cohesive chapter
5. Considering primary sources in the context of relationships with the literature as well as identifying gaps in the literature

6. Phase 6 – Validation will involve testing, validating and revising analytical memos so as to self-audit proposed findings by seeking evidence in the data beyond textual quotes to support the stated findings and seeking to expand on deeper meanings embedded in the data. This process involves interrogation of data and forces the consideration of elements beyond the category itself, drawing on relationships across and between categories and cross tabulation with demographics, observations and literature. This phase will result in evidence-based findings as each finding must be validated by being rooted in the data itself and will rely on the creation of reports from the data to substantiate findings.

7. Phase 7– Producing a report involves analytical memos into a coherent, cohesive and well supported outcome statement or findings report. Finalising the analysis will result in having produced two draft chapters: namely the findings and discussion chapters.

Analytical Process (Data Analysis Guidelines)	Practical Application in NVivo	Strategic Objective	Iterative process throughout analysis
1. Comparing units of meaning across categories for inductive category coding	<p>Phase 1</p> <p>Familiarisation</p>	<p>Descriptive Accounts</p> <p><i>(Reordering, 'coding on' and annotating through NVIVO)</i></p>	<p>Assigning data to refined concepts to portray meaning</p>
2. Refining categories	<p>Phase 2</p> <p>Initial Coding</p>		
3. Exploring relationships and patterns across categories;	<p>Phase 3</p> <p>Coding on</p> <p><i>Define Themes</i></p>	<p>Data Management</p> <p><i>(Open and hierarchal coding through NVIVO)</i></p>	<p>Refining and distilling more abstract concepts</p>

4. Integrating data to write findings	<p>Phase 4 Review Themes</p> <p>Phase 5 Writing <i>analytical memos</i></p> <p>Phase 6 Validation</p> <p>Phase 7 Synthesising <i>Data</i> <i>Report Writing</i></p>	<p>—</p> <p>Explanatory Accounts (<i>Extrapolating deeper meaning, drafting summary statements and analytical memos through NVIVO</i>)</p>	<p>Assigning data to themes/concepts to portray meaning</p> <p>Assigning meaning</p> <p>Generating themes and concepts</p>
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Table 1 now sets out the Stages and Process involved in Qualitative Analysis as set out in this strategic memo and relates them back to the study's methodological and philosophical underpinnings using the data analysis guidelines

B.2 Music Game Inspirations

64.0
140
#Funtime
0D Beat Drop
A Dance of Fire and Ice
Aaero: Complete Edition
Active Neurons
Akihabara - Feel the Rhythm
AUDICA: Rhythm Shooter
Audio Surf
Audioshield
Auditorium
AVICII Invector
AVSEQ
Bad Hotel
Baila Latino
Band Hero
BandFuse: Rock Legends
Beat Hazard
Beat Rush
Beat Saber
Beat Sneak Bandid
Beatbuddy: Tale of the Guardians
Before the Echo
Bit.Trip Beat
Bit.Trip Core
Bit.Trip Fate
Bit.Trip Flux
Bit.Trip Runner
Bit.Trip Void
BoxVR
BPM: Bullets per Minute
Britney's Dance Beat
Bullet Beat
Cadence
Cadence of Hyrule
Cello Fortress
Chime
Chiptune Runner
Chroma
Cinnamon Beats
Circadia
Circuits
Cosmic DJ

Crypt of the NecroDancer
Cytus Alpha
Dance Central
Dance Collider
Dance Dance Revolution
Dark Witch Music Episode: Rudymical
DEEMO
Def Jam Rapstar
DJ Hero
DJMax Respect
Double Kick Heroes
DubWars
Dyad
Eat Beat Deadspike-san
Electronic Super Joy
Elite Beat Agents
Eloh
Energy Invasion
Every Extend
Everyday Shooter
Fishjn'
Fitness Boxing
Floor Kids
FRACT OSC
Frederic: Resurrection of Music
Freedom Finger
Frequency
Fuser
Gal Metal
Geometry Dash
Groov
Groove Coaster
Guitar Hero
Gun Jam
Hatsune Miku VR
Hexagroove: Tactical DJ
Hide & Dance!
Incredibox
Inside My Radio
Intralism
JAM Live Music Arcade
Just Dance
Just Shapes & Beats
Karaoke Revolution

Kingdom Hearts Melody of Memory
Let's Sing
Lofi Ping Pong
Lumines
Major Minor's Majestic March
McOsu
Melodive
Melody's Escape
Michael Jackson: The Experience
Musaic Box
Muse Dash
Music Killer
Music Racer
Musynx
My Singing Monsters
Neon Beats
Otocky
Overpass
Panoramical
PaRappa the Rapper
Patapon
Pistol Whip
PixelJunk Eden
Project Arrhythmia
Pugs Luv Beats
Quaver
Racing Pitch
Radio Flare
Radio Squid
Radiohammer Station
Rez
Rhythm Doctor
Rhythm Fighter
Rhythm of the Gods
Rhythm Tengoku
Rock Band
Rocksmith
Rolling Sky
Sayonara Wild Hearts
Sentinel
Sentris
SingStar
Songbird Symphony
Sound Shapes

Space Channel 5
Spice World
Spin Rhythm XD
Super Beat Sports
Super Dodgeball Beats
Symphony
Synth Riders
Synthesia
Taiko no Tatsujin
Tapsonic Bold
Thumper
Tone Sphere
TouchMix FX
Track Lab
Vectronom
Vib Ribbon
VOEZ
Wandersong
Wave Trip
Wii Music

UPCOMING/INSPIRATION:

Evertried
Backbeat
Refactor - an idea for music creation more than anything else

Appendix C

Software and Experience Hyperlinks

This appendix contains links to the original software and game that was used in the study mentioned in this publication.

1. [The Crypt of Notation Game](#)
2. [The Crypt of Notation GitHub repository](#)
3. [Standard Assessment of Sight Reading \(control group experience\)](#)

