Software Engineering Department
ORT Braude College

Capstone Project Phase A – 61998

Musical minds - educational Music game for children

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https://github.com/netanelfar/MusicalMinds

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1. Abstract

Musical mind is an innovative educational musical game designed to immerse players in a fun, interactive learning experience, with a primary focus on music to encourage cognitive improvement in children . The game uses a dynamic 2D environment and hardware elements like MIDI keyboards to deliver educational content. Players start from simple key recognition to identify and play whole songs. The game aims to engage the children in content that some find boring in different ways to make sure the child does not lose the benefits from learning music. Using simple scoring methods the game helps the parents to keep track of the child's improvement. The game is built with children in mind and using Unity engine aim for a more safe and non addictive environment to try and avoid the negatives of modern games both from more visuals that suit children and game mechanics that allow parents monitoring.

2. Introduction

Music has a profound and multidimensional impact on childchildren's development, influencing their growth in various aspects such as physical, cognitive, emotional, and social growth. Engaging with music from an early age fosters motor coordination and flexibility through rhythm-based activities and the use of musical instruments.

Cognitively, music promotes intellectual skills such as memory, concentration, and logical thinking, while also enhancing problem-solving abilities and spatial-temporal reasoning. These are closely tied to academic improvements, particularly in areas like mathematics and science.

Emotionally, music provides children with a creative outlet for expression and better understanding of their feelings, helping them in building self-confidence, emotional awareness, and creative thinking.
Musical Minds is an interactive educational game designed to engage children with music in different ways to promote development. The game provides flexibility by allowing young learners different accessibility options ensuring every child can easily benefit from music, either from a basic environment like a tablet or a phone to connecting a keyboard to their device. Through fun and interactive exercises, Musical Minds introduces children to recognizing musical notes and rhythms and learning to play melodies. Using instant feedback, the game supports the development of their musical ear, encouraging children to progress at their own pace.
By tracking the children's progress Musical Minds enable parents to monitor their musical journey and celebrate their achievements together. By blending the cognitive, physical, and emotional benefits of music into an interactive platform, the game inspires a love for music while fostering skills that extend beyond the musical realm.

3. Related work

3.1 Gamification and Multimedia in Music Education

Research has demonstrated that educational applications and digital tools in music teaching not only enhance learning outcomes and student engagement but also provide meaningful musical experiences while maintaining educational value.
A comprehensive study conducted in basic education found that using multimedia materials for instrumental practice led to remarkable improvements in student preparation and motivation. The study reported that students who had access to multimedia learning materials showed an 83% lesson preparation rate compared to 32% in the traditional learning group. Furthermore, the research revealed that technology integration resulted in higher levels of internal motivation, with 87.5% of students in the technology-enhanced group engaging in voluntary practice compared to 48% in the control group.

The effectiveness of gamified tools in music education has been well-supported by additional studies. For instance, a study analyzing the use of adaptive music learning software highlighted the role of real-time feedback and difficulty scaling in enhancing the learning experience by promoting flow states, which significantly improve motivation and learning outcomes. Similarly, research focusing on gamification in educational contexts for younger learners has shown that interactive tools enhance engagement and collaboration. Platforms that integrate multimedia elements and gamified challenges promote active learning and maintain student interest, particularly in foundational music education.

This impact is particularly pronounced among digital natives, who demonstrate exceptional responsiveness to gamified learning environments. Studies show that interactive music platforms have created a "fertile ground for a new 'folk' culture of music creation," with 100% of students in gamified environments achieving above-average results in summative evaluations, compared to 64% in traditional settings. Immediate feedback mechanisms and progress tracking features further enhance the effectiveness of these tools, as they improve student motivation and self-assessment abilities. For example, an analysis of mobile learning applications highlighted that the integration of feedback and adaptive challenges directly correlates with improved performance in musical tasks.

These findings validate the effectiveness of approaches like those implemented by Musical Minds. The platform’s ability to function flexibly with or without a connected piano keyboard aligns with evidence suggesting that such accessibility increases engagement and practice frequency. Moreover, the use of gamification principles—such as progress tracking, adaptive challenges, and multimedia

integration—addresses the dynamic needs of modern learners, confirming their value in music education.

3.2 Music impact on Child Development

The impact of music on child development has been extensively studied, revealing profound benefits across cognitive, emotional, and social domains. According to Li Meizhuan and Li Jia in their exploration of the "Preschool Piano Educator's Comprehensive Capacity in the Era of Intelligent Keyboards," music education, particularly piano training, fosters significant growth in attention, cognitive flexibility, and motor coordination. This aligns with developmental theories that emphasize the critical role of early experiences in shaping a child's intellectual and emotional capacities.

Studies highlighted in their research demonstrate that engaging with musical instruments like the piano enhances skills such as spatial reasoning, verbal memory, and logical intelligence. For instance, children who participated in piano lessons exhibited superior verbal thinking and motor development compared to those without musical training. Furthermore, intensive musical training experiences are associated with neurological changes, where repeated practice strengthens and streamlines brain connections (Edeline, 1999; Weinberger, 2004). These changes manifest in enhanced speech perception in noise (SPIN), improved linguistic processing, and advanced auditory processing (Coffey et al., 2017; Dubas et al., 2022; Kuhl et al., 2005). Additionally, active participation in music cultivates creativity, emotional intelligence, and long-term focus, which are essential for holistic child development.

Emotional benefits are equally significant. Children engaged in musical activities develop better emotional understanding and social cognitive skills. Musical engagement enhances cultural and social learning by fostering the ability to recognize and interpret emotional and social cues (Koelsch, 2010). Furthermore, these activities contribute to the development of emotional intelligence and social awareness by enhancing neural pathways responsible for processing emotions (Trainor, 2005).

3.3 Musical Ear Training Methods

Musical ear training plays a vital role in fostering a deep connection between children and music, with several proven methods forming the foundation for successful learning.

Repetition and Immersion are fundamental strategies, emphasizing the importance of listening to musical pieces multiple times. By repeatedly exposing children to a set of sounds, they internalize the patterns and develop recognition skills. In "Musical

Minds," the game will play single sounds to the child for recognition, ensuring repetition for familiarity. Each sound will be part of a defined group, and the game will cycle through the group to provide variety while reinforcing the auditory memory.

Playing by Ear Before Using Notation is another critical method. Introducing music through auditory imitation rather than sheet music shifts the focus to sound recognition and reproduction, fostering deeper musical understanding. This practice builds a strong auditory-motor connection, which enhances a child's ability to identify pitches, replicate rhythms, and develop tonal memory.

Informal and Holistic Learning approaches, such as copying audio recordings by ear, integrating listening with playing, and encouraging improvisation, are equally effective. These techniques nurture a child's creativity and enhance aural skills while promoting active participation and exploration of music.

Interactive and Gamified Tools significantly enhance engagement and motivation. Gamified exercises with immediate feedback not only make learning enjoyable but also improve pitch accuracy, rhythm perception, and sound reproduction. These tools support consistent practice and create a fun, interactive environment for young learners.

Focus on Aural Development ensures that children develop their ability to identify sounds, retain musical patterns, and synchronize rhythms without relying on visual aids like sheet music. This method emphasizes listening and sound production, essential for developing foundational musical skills.

Lastly, **Supportive Environments with Parent and Teacher Involvement** are crucial for success. When parents and teachers actively support and encourage a child's musical journey, the child feels motivated to continue practicing and improving. This guidance helps sustain progress, fosters a love for music, and builds the confidence needed for long-term growth in musical abilities

3.4 Comparison of Musical Learning Platforms

Simply Piano

Simply Piano is a widely-used digital platform for learning piano, boasting over 100 million downloads. It offers a structured approach with 33 progressive courses, guiding users from basic note recognition to advanced playing techniques. With a vast song library and an easy-to-navigate interface, it is popular among beginners. However, its primary focus is on technical proficiency, which may not foster broader

musical skills, such as developing a musical ear or creative expression. Musical Minds, by contrast, is tailored specifically for children, aiming to make music learning more interactive and engaging through gamification. This approach creates an enjoyable learning experience that differs from Simply Piano's structured but less dynamic method.

Songsterr

Songsterr is a popular platform for guitar, bass, and drum enthusiasts, featuring a large library of interactive tablatures with real-time MIDI playback and scrolling tabs. It caters to learners of all skill levels and offers advanced features like tempo adjustment, looping, and printing through its premium Songsterr PLUS subscription. These features make it particularly attractive to musicians seeking a professional yet accessible tool for practice. Unlike Songsterr, which focuses on providing tools for experienced players and hobbyists, Musical Minds emphasizes a child-focused approach. Its gamified design makes learning more interactive and developmentally supportive, distinguishing it from Songsterr’s more technical, performance-driven platform.

Yousician

Yousician is a widely-used platform designed to teach instruments like guitar, bass, piano, and ukulele through a gamified and engaging approach. It features tools such as real-time feedback, a dynamic rolling fretboard, and vibrant visuals that make practice sessions enjoyable and interactive. With a combination of lessons, exercises, and a song library, Yousician provides a structured yet fun learning experience, appealing to a broad audience ranging from beginners to casual musicians looking to enhance their skills.
In contrast, Musical Minds takes a more specialized approach, focusing exclusively on younger learners and their development. While Yousician prioritizes accessibility and entertainment for learners of all ages, it does not specifically cater to children’s musical ear development. Musical Minds fills this gap by integrating gamification into a child-friendly platform.

GarageBand

GarageBand is a versatile music creation platform developed by Apple, providing tools for recording, editing, and producing music. It supports MIDI keyboards, third-party plug-ins, and live recordings, offering beginners and hobbyists the opportunity to experiment with music production. With features like Smart Controls, a

virtual Drummer, and built-in lessons for guitar and piano, GarageBand excels as an all-in-one digital audio workstation.
However, GarageBand is primarily a music creation tool and does not focus on educational or developmental goals. Musical Minds uses its gamified design to engage children and help them build foundational musical skills in a way that GarageBand does not.

Comparison Summary

Simply Piano, Songsterr, Yousician, and GarageBand are powerful tools that excel in their respective areas, from structured piano lessons to versatile music production. However, they are generally geared toward broader audiences or specific musical tasks and do not prioritize the unique developmental needs of young learners. Musical Minds stands out by focusing on gamification and interactive learning tailored to children, making it an innovative choice for fostering a love of music and supporting cognitive and motor skill development.

4. Background

4.1 Unity Engine

Unity Engine stands as a versatile game development platform that emerged in 2005, initially designed for Mac OS X before expanding across multiple platforms. As a leading solution for creating both 2D and 3D interactive content, it distinguishes itself through its C# programming framework, offering developers a powerful yet accessible development environment.

The platform excels in its comprehensive development environment, offering developers an intuitive interface for scene construction and asset management. Its robust feature set encompasses advanced physics simulation, networking capabilities, and sophisticated audio integration. The engine delivers consistent performance optimization across various platforms, ensuring smooth gameplay and visual fidelity without compromising quality.

Developers benefit from Unity's streamlined workflow, which includes an extensive asset marketplace and rapid deployment options for multiple platforms. The engine supports seamless creation of high-quality visuals and natural animations, while maintaining reliable performance across different devices. Its built-in tools cater to both 2D and 3D development, featuring integrated physics engines, collision detection, and comprehensive rendering capabilities.

The platform's strength lies in its accessible learning curve and strong community support. Unity Learn provides extensive educational resources, including tutorials and guided pathways for mastering real-time 3D development. Independent developers can use Unity's free-to-use model, making it an attractive option for small studios and individual creators. The engine's cross-platform capabilities enable straightforward deployment across desktop, mobile, and console platforms, streamlining the development process from concept to release.

4.2 MIDI keyboards

In the context of modern technology, MIDI keyboards present a unique opportunity to make music education more accessible and engaging for children. Unlike traditional acoustic pianos, MIDI keyboards are portable, cost-effective, and capable of integrating with digital applications to provide interactive learning experiences.Musical Minds seeks to bridge this gap by developing a music game tailored for children, utilizing MIDI keyboards to create an engaging and developmentally supportive learning environment. The app will leverage the interactive and customizable features of MIDI technology to foster key

developmental milestones, including coordination, rhythm recognition, and auditory skills. By incorporating insights from the study of kids piano education, the game aims to address the challenges identified, such as the need for accessible content, clear objectives, and age-appropriate instruction and feedback, ensuring a comprehensive and enjoyable learning journey for young users.

5. Expected Achievements

5.1 Outcome

The expected outcome for Musical Minds is to significantly enhance children's musical and cognitive development through an engaging and interactive platform. By helping users develop a keen musical ear, the game naturally fosters improvements in various cognitive abilities.
Success in the project includes creating a fun and engaging platform that keeps children motivated through instant feedback and measurable progress. By gradually increasing the complexity of activities—from basic key recognition to mastering full melodies—the game ensures that players remain engaged while steadily improving their skills.
providing real-time feedback during the game will help children recognize their progress, fostering a sense of accomplishment and encouraging them to continue their musical journey. Additionally, the progress-tracking feature allows parents to celebrate their children's achievements, further reinforcing a positive and rewarding learning experience.

5.2 Unique features

5.2.1 Gamification

Musical Minds integrates engaging gamification elements to keep children motivated while learning. The game gamification features include:

Immediate Feedback System:
The game's real-time feedback system provides immediate responses to the child's musical input. As children practice recognizing notes or playing melodies, the system offers constructive feedback. This instant evaluation encourages positive progress, promoting a sense of achievement and motivation.

Progress Tracking:
The game records each child's learning milestones and musical achievements, creating an easy way for parents to monitor the child's musical journey over time, this will allow them an easy way to celebrate their kids successes.

Engaging Rewards Experience:
A combination of point scoring and colorful visual elements transforms the learning process into an exciting adventure. These interactive rewards make practicing and learning music naturally enjoyable and fulfilling for young learners.

5.2.2 MIDI Keyboard Hardware Compatibility

Musical Minds supports MIDI keyboard hardware, allowing children to connect a physical instrument for a more immersive learning experience. This feature enables hands-on practice, helping children develop motor skills and physical coordination while exploring music. The platform's advanced MIDI integration seamlessly recognizes a wide range of keyboard models, making it easy for young musicians to get started in their learning experience.

5.2.3 Holistic Learning Experience

By integrating cognitive, physical, and emotional benefits into a single platform, Musical Minds offers a holistic learning experience. The combination of flexible play modes and engaging gamification elements makes the game a unique and powerful tool for inspiring musical curiosity and in children.
Its interactive design encourages hands-on exploration, helping children build confidence while learning.
With age-appropriate challenges and creative feedback, Musical Minds supports continuous growth and skill development.

5.3 Success Criteria

Our main goal is to create a fun, easy-to-use game that kids will enjoy playing. This game aims to help develop their musical ear while supporting their overall development through musical training.

1. Fun and Enjoyable: The game should be entertaining and enjoyable to encourage children to keep playing.
2. User Experience: The game should keep children engaged with visually appealing, age-appropriate, and intuitive design.
3. Accessibility and Flexibility: The game should support playing with or without a physical keyboard.
4. Progress Tracking: Parents should be able to monitor progress easily.
5. Real-time feedback: immediate feedback should be encouraging to the kids and motivate them to continue playing.

6. The Process

6.1 Research

The research process began by exploring whether the idea was valid. To achieve this, the literature was reviewed to address three key aspects. The first aspect examined whether music training aids children's development. The second aspect focused on whether games are an effective medium for musical education, with the primary focus being how to design a game that is engaging and appealing to children. Finally, the exploration included identifying the most effective methods for training and developing a musical ear, ensuring the approach would incorporate proven strategies. Once a scientific foundation was established and the concept confirmed as both viable and well-supported, the next phase involved gaining knowledge of Unity and game development.

6.2 Unity and game development

The initial steps of the process involved completing Unity’s 2D tutorial, which provided a foundational understanding of the platform and helped build familiarity with its tools and features. The next step is to follow detailed guides specifically focused on creating interactive keyboard and sound controls, ensuring progress is maximized within the project's tight schedule.
Unlike the software we’ve developed so far, the UX/UI aspect of this game is heavily reliant on our design decisions. While we’ve played many games before, creating one is an entirely different experience. To better understand what makes a successful musical game for kids, we will explore various existing apps, identify the most effective ones, and analyze the factors behind their success.
Another key aspect involves finding psychological support to guide the game design. To ensure alignment with proper scientific literature, advice is being sought from external advisers with relevant educational expertise. Periodic meetings with a professor and a child development specialist will help ensure the project stays on the right track.

6.3 Expected challenges

As newcomers to both game development and the Unity platform, managing the development process within the given timeframe is a significant concern. Additionally, we lack access to a controlled group of children for testing, making it difficult to directly evaluate whether the game achieves its intended goals. To address this, we are relying on established and well-researched literature to guide our approach. Another challenge lies in designing an effective feedback system that keeps players engaged and creating a user-friendly experience tailored specifically for children.

6.4 Tools

1. Unity
2. Visual studio community 2022
3. Github + Unity source control
4. ChatGPT, Claude
5. Visual paradigm 17.1
6. Google Docs
7. Unity Asset Store

7.The product

7.1 Requirements

The main requirements for Musical Minds focus on creating an engaging music learning experience for children. The game aims to develop their musical ear through fun gameplay, with a focus on real-time feedback and rewarding progression, while also supporting MIDI integration and parent monitoring.

7.1.1 Functional Requirements

Main Menu Features

- Provide options to select game modes: Imitation, Sound Recognition, and Creative Tasks.
- Allow access to user profiles for viewing progress, rewards, and achievements.

Music Learning and Gameplay Features

- Enable players to progress from basic key recognition exercises to playing complete songs.
- Provide interactive game modes:
    - **Sound Recognition -** where children learn to identify **individual** notes.
    - **Melody Replay -** where they practice by **repeating** melodies.
    - **Free Play -** where children can explore their **creativity** by playing freely.

Progression and Rewards System

- Track and store user progress across sessions.
- Unlock new songs and challenges based on player progress.
- Award stars, medals, or points for completing milestones.
- Display progress and achievements in a child-friendly rewards system.

Parent Dashboard and Monitoring

- Allow parents to view their child's progress, including milestones achieved and overall improvement.

MIDI Keyboard Integration

- Automatically detect and configure MIDI keyboards for plug-and-play functionality.
- Support both MIDI and touch-screen input methods.
- Provide visual and audio feedback for MIDI connection status.
- Process MIDI keyboard inputs with minimal delay to ensure instant feedback and a smooth user experience.

Data Saving

- Save game state, progress, and rewards automatically.

Visual and Audio Effects

- Feature colorful animations and effects for notes, rewards, and gameplay.
- Use high-quality sounds tailored to music exercises and content.
- Include visual aids for understanding notes, scales, and rhythms.

7.1.2 Non-Functional Requirements

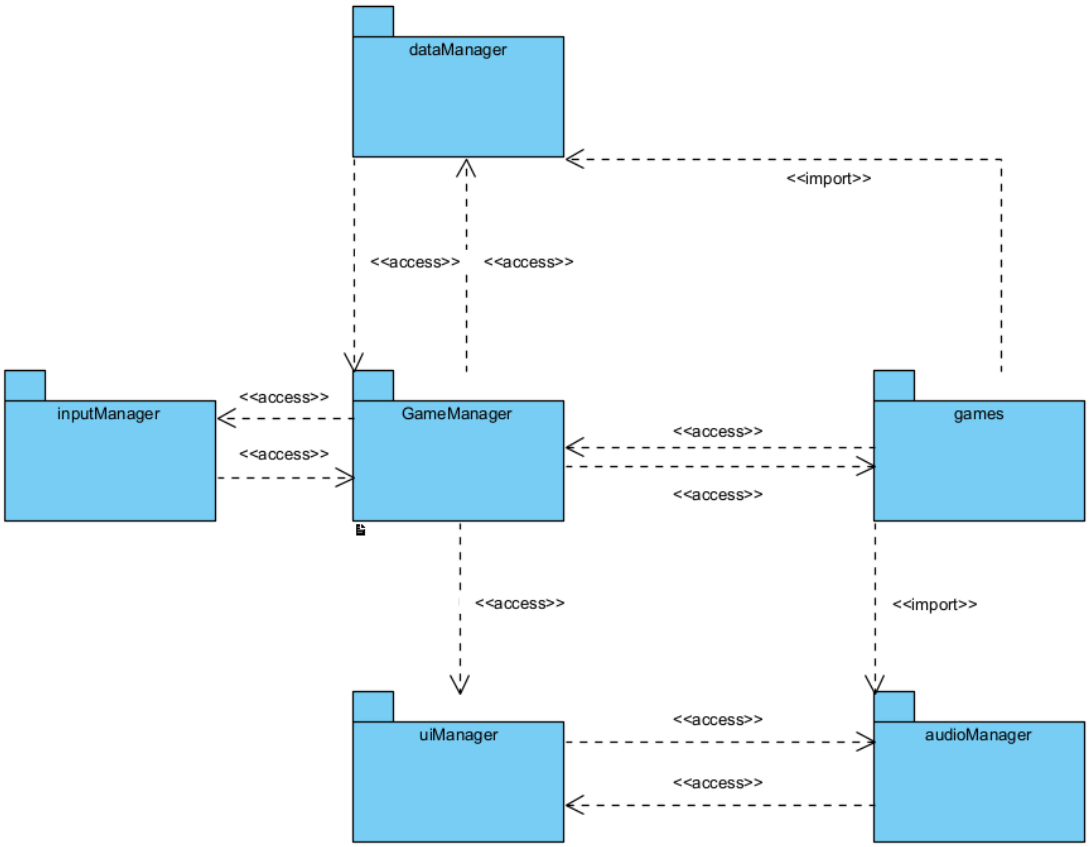
Usability

- Design an intuitive, visually engaging interface for children.
- Use age-appropriate language and instructions.
- Ensure an easy-to-use graphical interface suitable for children, with simple and intuitive controls.
- Provide smooth and responsive interaction mechanisms to enhance the user experience.

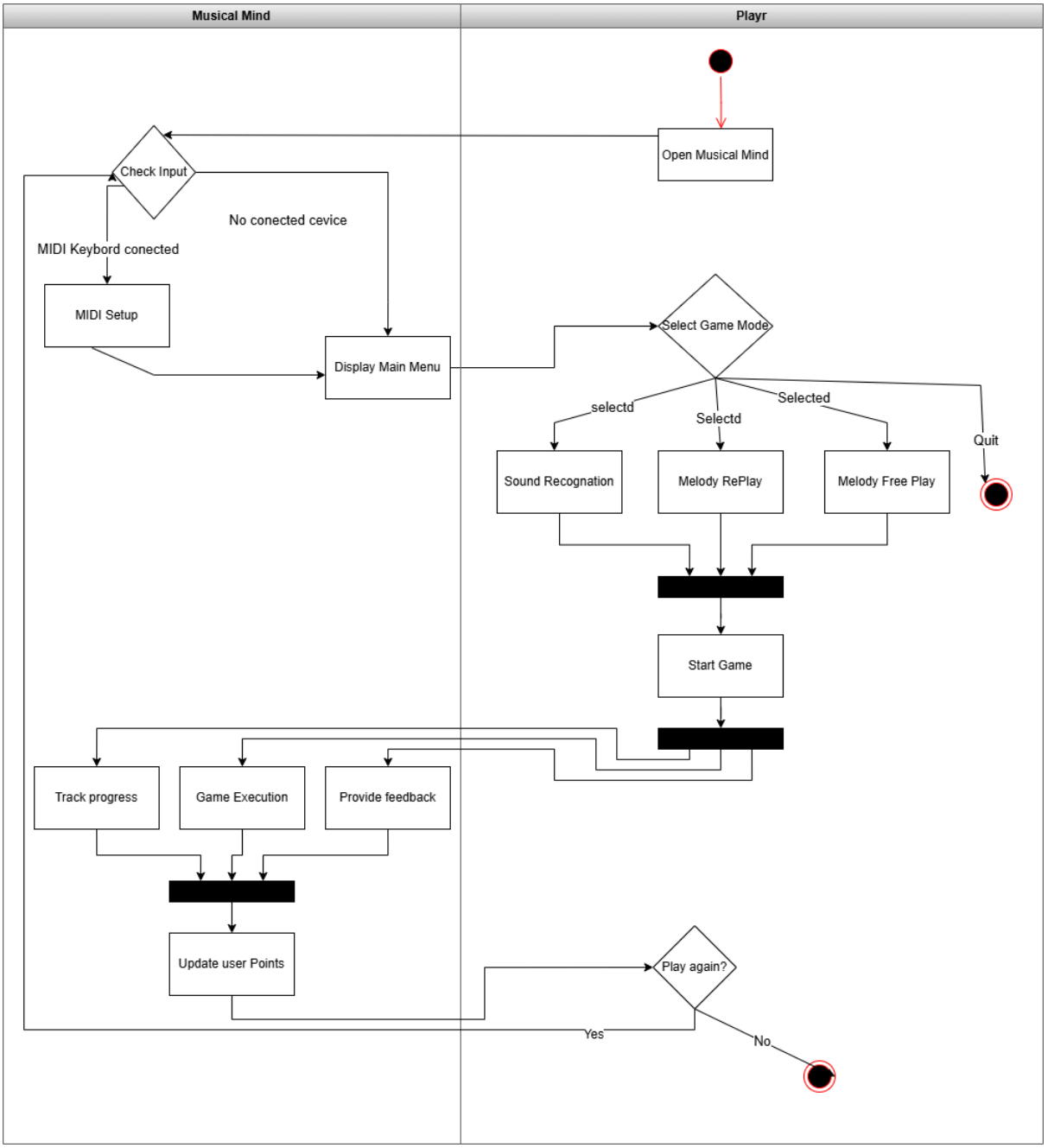
Accessibility and Inclusivity

- Provide flexible learning options, including play-without-MIDI modes.
- Include an adjustable difficulty setting to accommodate children with varying skill levels.
- Provide audio and visual cues to support diverse learning styles.

7.2 Package diagram



7.3 Activity diagram



8. Verification and Evaluation

8.1 Testing plan

We plan to have two type of testing:

1. Manual testing - try the game ourselves and look for bugs.
2. Unity testing - if we will manage to learn how to implement tests in unity we plan to do it as well.

Test	Module	Tested Function	Expected Result
1	Main Menu Features	Game mode selection	Correct game mode is selected without errors.
2	MIDI Keyboard Integration	MIDI keyboard detection	MIDI keyboard is auto detected and connected.
3	Gameplay - Imitation Mode	Note or sequence imitation	Player imitates notes/sequences with feedback.
4	Gameplay - Sound Recognition Mode	Identifying notes or sequences	Player identifies notes/sequences with feedback.
5	Gameplay - Creative Tasks Mode	Creating melodies	Player experiments with free play.
6	Accessibility Features	Play without a MIDI keyboard	All modes playable without MIDI keyboard.
7	Rewards System	Progress tracking and rewards	Progress saved, rewards displayed accurately.
8	Usability	Intuitive interface for children	Children navigate the interface easily.
9	Performance	Smooth gameplay	Game runs smoothly without crashes.
10	Visual and Audio Effects	Interactive visual feedback	Visuals and sounds engaging and appropriate.

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