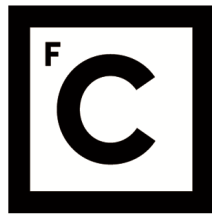


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Games That Spill and Are Fed by Real Life Interactions

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À minha mãe

Resumo

Jogos que são alimentados por interações do mundo real já mostraram potencial em aumentar o envolvimento e a interação com certas atividades. Como exemplo, *Pokémon Go* e *Ingress*, ambos sendo considerados jogos pervasivos, mostraram aumentar a mobilidade dos seus jogadores. Investigação anterior feita nas áreas de gamificação e jogos pervasivos também indicam que estes podem aumentar a motivação e interação com as atividades em questão. No entanto, apesar de já haver bastante investigação sobre adicionar elementos de jogo a certas atividades (gamificação) ou integrar as atividades como parte de um jogo (jogos pervasivos), não há muita investigação em jogos que sejam alimentados pelas atividades, sem modificar a interação em si. Neste estudo, este conceito foi aplicado à prática de um instrumento, por ser uma atividade comum que provoca muitas desistências ao longo do caminho entre um amador e um mestre. Muitas pessoas abandonam o seu instrumento por falta de motivação e confiança na sua aptidão, levando 80% dos aspirantes a músicos a desistir em 2 a 3 anos. Já foram aplicados conceitos como a gamificação e jogos orientados à aprendizagem na área da música, no entanto, ainda não foi usada a prática da música para alimentar um jogo, da mesma forma que, por exemplo, andar alimenta o *Pokémon Go*. Tendo isto em conta, neste estudo foi desenvolvido um jogo alimentado por tocar piano, mantendo a interação com o piano intacta, mas utilizando os dados das sessões para gerar elementos de jogo, num jogo completamente separado da atividade. Para informar as nossas decisões, foi revisto o estado da arte em jogos que foram alimentados por interações do mundo real, jogos pervasivos, gamificação, jogos orientados à aprendizagem e à saúde. Também foi efetuada uma contextualização do efeito destas áreas na motivação, à luz da *Self-Determination Theory* de Ryan e Deci. Para nos ajudar a gerar ideias de como entrelaçar dados provenientes do piano e elementos de jogo, conduzimos duas *workshops* de *design*, uma com investigadores de jogos e outra com músicos, com esperanças de que os investigadores nos pudessem ajudar a descobrir mecânicas de jogo alimentadas pelos dados colhidos, enquanto que os músicos nos pudessem ajudar a descobrir que dados fariam mais sentido colher. Ambas as *workshops* geraram várias ideias de mecânicas alimentadas pelo piano, que foram depois analisadas e serviram de base para as mecânicas escolhidas e implementadas. Foi analisado o que podia ser recolhido através de MIDI e as limitações que os *plugins* utilizados na implementação teriam e, tendo em conta as ideias obtidas nas *workshops*, foi decidido que as métricas a recolher seriam: a nota mais tocada, o acorde mais tocado, a média da velocidade das notas e uma representação simplista da dificuldade, ou complexidade, do que o jogador tocou. Foi então desenhada e implementada uma aplicação para computador capaz de colher estas métricas,

através de *Unity* com o auxílio de um plugin externo que recolhe input MIDI, mais especificamente, as notas, com as suas velocidades. Com isto, a aplicação obtém algumas métricas que irão produzir efeitos no jogo e outras para distrair o jogador e mascarar o que está realmente a produzir efeitos no jogo. Esta aplicação recolhe, nomeadamente, a data e hora da sessão de prática, a localização e meteorologia, as notas tocadas, os acordes tocados, um valor representativo da distância entre mãos e quando é tocado um acorde, guarda uma gravação de 3 segundos. Estes dados são então enviados e guardados numa base de dados no *Firestore*. Foi também desenhado e implementado, através de um processo iterativo, um jogo de plataforma que fosse alimentado por estes dados. O jogo consiste em 4 zonas com inimigos normais e 3 com *bosses*, e o objetivo dos jogadores é derrotar o último *boss* no mínimo tempo possível. O jogador tem 3 *skills*, destreza, força e vida, subindo quando o piano é tocado, tornadas visíveis através do upgrade das roupas do jogador com o aumento das suas *skills*. As métricas recolhidas pela aplicação, em conjunto com cálculos adicionais, para medir a complexidade do que o jogador tocou, alimentam então as mecânicas de jogo, como a vida, probabilidade de *spawn* e cor dos inimigos, os padrões de ataque dos *bosses* e a imagem e música de fundo. Com a aplicação e jogo implementados e testados, foi conduzido um estudo qualitativo com o intuito de perceber o impacto que interligar a experiência musical e a experiência de jogo podia ter em ambas as experiências e na motivação que os utilizadores teriam para tocar piano. Foram recrutados 5 participantes, todos estudantes universitários, com idades entre 23 a 28 anos, com os requisitos de tocarem piano e gostarem de jogar videojogos. Os níveis de experiência com o piano bem como os seus hábitos de jogo eram variados entre os participantes. Durante este estudo, os participantes completaram 4 sessões de prática de piano seguidas de um jogo influenciado pelos dados recolhidos durante a sessão e, em cada uma, preencheram questionários a relatar a sua experiência. De seguida, foram feitas entrevistas individuais remotas, procurando entender o impacto do nosso trabalho na motivação e experiência dos participantes. Ao analisar os resultados, concluímos que, embora tenha havido uma alteração no comportamento de alguns participantes durante as sessões de prática, como tentarem tocar melhor para evitar ouvir os seus erros nas gravações, a falta de clareza sobre como o jogo estava a ser influenciado pela prática de piano deu origem a resultados mistos. Além disso, os participantes não sentiram uma diferença significativa na sua experiência de jogo porque as mecânicas escolhidas para trazer efeito no jogo, mesmo que fossem perceptíveis, não alteravam a estratégia ou o *gameplay* o suficiente. Para melhorar a eficácia desta abordagem, identificamos algumas questões técnicas que precisam de melhorias, como refinar todo o processo de recolha dos dados e ajustar as mecânicas de jogo para corresponder ao nível de habilidade e preferências individuais de cada jogador, entre outros. O nosso trabalho mostra que alimentar jogos com interações do mundo real pode ser uma maneira promissora de moldar a experiência que um utilizador tem com a atividade, no entanto, mais estudos terão de ser feitos para melhor perceber os efeitos reais na motivação e interação com as atividades, sobretudo perceber para quem este tipo de interação seria melhor, com base em experiência com o instrumento, hábitos e rotinas já existentes, idade, objetivos e motivações atuais.

Palavras-chave: Colheita de Interações, Piano, Gamificação, Jogos Pervasivos, Motivação

Abstract

Games that are fed by real-life interactions have shown the potential to increase engagement with those activities. For instance, *Pokémon GO* and *Ingress* increased players' mobility. Gamification, along with serious games and some pervasive games, also tries to foster motivation and engagement with specific tasks. This work explored the harvesting of day-to-day interactions, specifically playing the piano, into gameplay mechanics, and the effects, both in the gaming and playing experience, in the light of motivation and engagement. Our approach differs from common gamification as it doesn't add game elements to the base experience (i.e. playing the piano). Rather, the activity in itself created game elements that were leveraged in a game independent of the piano. To help us generate ideas for a game that could be fed by playing the piano, 2 design workshops were conducted, one with 9 game researchers and the other with 5 musicians. After the game and harvesting application were implemented and tested, a study was conducted for 2 weeks with 5 participants, where we collected data from their piano sessions and used it to shape a game they would play after the practice session. Our work shows harvesting as a promising way to mould the user's interaction with the activity, however, further research needs to be conducted to better understand which players would benefit most from this approach, by bringing to context their routines, age and skill level.

Keywords: Harvesting of Interactions, Piano, Gamification, Pervasive Gaming, Motivation

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Chapter 1

Introduction

In recent years, some games and gamified applications have harvested real-life activities and interactions into the virtual world. The most famous example is *Pokémon Go*¹. In this location-based mobile game (LBMG), the physical world receives a digital layer that allows players to create meaning and interact simultaneously in the game and real life [41]. Similar games and applications to *Pokémon Go* would include *Ingress*² and *Foursquare*³. These pervasive location elements show the possibility of increasing mobility [13][21][41]. However, moving is just one of the tasks we can harvest and feed into a game; there is still an uncountable number of daily interactions that we perform that could be brought into a game context.

One activity that many people engage in is playing an instrument. To master it from a beginner level, the player has to interact with it regularly and consistently. Mastering an instrument involves repeating specific tasks, often perceived as boring, and improving one's skills. Many people give up on their instrument due to a lack of motivation, given the number of skills required to play well, especially those who do not have access to a tutor or teacher to provide them with feedback. Lack of motivation, among other reasons, causes 80% of the players to drop out after two to three years[22]. Gamification and game-based learning try to minimise these reasons, aiming to provide the player with feedback, like *Rocksmith*⁴ or adding a digital layer to the instrument as a way to reduce dependency on sheet music reading skills [28][29][33].

With this project, our objective is to augment the post-play experience in hopes of increasing the motivation and engagement with the instrument, as well as the regularity of practice sessions. We seek to explore the effects of harvesting data from playing the piano into a game, analysing how it affects both the playing and gaming experiences and player motivation, engagement and well-being. Our approach differs from games like *Pokémon Go*, as we expand harvesting beyond location and mobility to more personalised activities, like tasks or hobbies. It also differs from games like *Rocksmith* as we do not intend to gamify playing the piano but to use the activity to create game elements independently from the instrument. To achieve this, the necessary steps were to understand the needs and desires of players, by reviewing the state-of-the-art and conducting

¹(Pokémon Go, 2014)

²(Ingress, 2014)

³(Foursquare, 2009)

⁴(Rocksmith, 2011)

workshops with musicians and game researchers and with the acquired knowledge to design and implement a game that could successfully harvest playing the piano into game elements.

1.1 Document Structure

The remaining of this document is structured as follows:

- **Chapter 2. Related work** - Outlines the state-of-the-art and summarises past work on harvesting, gamification and pervasive gaming. It also briefly contextualises motivation and engagement in the light of the Self-Determination Theory and explains how music and piano practice can boost well-being.
- **Chapter 3. Understanding Musicians and Gamers motivations** - Details the steps we took to understand what both a musician and a gamer want from their instrument and game, respectively. It explains our approach to creating game elements from piano data, by brainstorming sessions and workshops conducted, in detail.
- **Chapter 4. Developing a Game Fed By Playing the Piano** - Explains all the steps to design and implement both the application that collects the data and the game fed by the data.
- **Chapter 5. Exploring the Effects of Harvesting Real-Activities** - Outlines the protocol of the study conducted, describing the recruitment process, the methodology of the study, surveys and questionnaires conducted and the participants. Highlights what we found by analysing the data, discussing them and providing potential solutions to this work's shortcomings.
- **Chapter 6 - Conclusion and Future Work** - Wraps up this project, by summarising every step, and providing some final comments. It also details some potential future work to further expand and understand the harvesting of real-life interactions.

Chapter 2

Related Work

This section provides a state-of-the-art, discussing related work to this project. We will touch upon previous approaches to harvesting real-life interactions, gamifying tasks through gamification frameworks, serious and pervasive games. Then, we will contextualise well-being, from a motivational standpoint and explain how music practice can leverage it.

2.1 Harvesting of Real-life Interactions

We define harvesting as having a real-life interaction be used passively as an input to a different context. Connecting a real-life activity to game mechanics has been seen most popularly in *Pokémon Go* and *Ingress*, which rely heavily on moving through the real world. In *Pokémon Go*, the real world gets its virtual version where we can find collectable creatures (*Pokémons*) hiding on the map, along with places where players can obtain in-game items (*Pokéstops*) or fight for their ownership (Gyms). To move in the virtual world, the player has to move in the real world. Some examples of harvesting in *Pokémon Go* are *Pokémon* eggs, which require the player to move a certain distance to hatch. A player can assign a *Pokémon* as a buddy, displayed on the map accompanying its owner. When players have a buddy, the game incentivises them to care for it, namely feeding it and walking it. Moving with a buddy rewards the player with its respective candy, which they can use later to level up the *Pokémon*. This is considered harvesting because walking is contributing passively to the game, as the player can still receive candy and hatch eggs while their game is closed. So, the player doesn't need to be walking while they are playing, rather, they can harvest the benefits of their mobility when they want to play. Other mechanics that require the player to interact with the game, like receiving items at *Pokéstops*, would not classify as harvesting. Still, it can be seen that physical movement is essential to this game, as it is tough to progress significantly without doing so. To understand how this game has led to the gamification of public places, Woods [41] conducted 22 interviews with *Pokémon Go* players. The author reveals that the digital layer that the game overlays on the world makes places more attractive for players to discover, incentivising them to explore both familiar and unexplored locations in more detail. Sobel et al. [38] explore how the parents of children who play *Pokémon Go* perceive these types of games. In this study, parents stated that the game had motivated them and

their children to go outside and engage in physical activity. The game also led to family bonding experiences as parents watched their children play or co-playing, with some families sharing the device by taking turns or assuming roles.

Similarly, *Ingress* rewards the player by moving and being in certain places. In this game, the mobile device is seen as a scanner to detect and harness particles called Exotic Matter (XM). XM is emitted into the virtual world through physical landmarks named Portals, but it is also scattered around the map. The more player scanners are in an area, the denser the XM. Players take part in one of two opposing teams, collecting this matter and receiving in-game items by hacking portals. These portals can be collected and fought over by the teams. This game makes it possible for the players in the same faction to communicate if they are close. Players create communities and negotiate between factions, even creating novice-players-only areas [21]. This communication translates to real life, as players report meeting their teammates in person. Like in *Pokémon Go*, Players tend to alter their mobility and routines, walking to new places and creating new habits[21]. This game requires the players to have the application open, unlike *Pokémon GO*, but collecting XM from walking doesn't require any other interaction with the game, so it is still classified as harvesting.

Another application that gamifies users' locations, although different from the games above, was *Foursquare*, a location-based social network (LBSN). It was later divided into two applications, but we will focus on its design before the division. This social network allowed users to share their locations with friends and, most relevantly, rewarded users for going to physical locations, awarding them badges for checking in at specific venues and events. When users had the most check-ins at a venue in the last 30 days, they would receive mayorship of the place. Users also received badges for being present in the application and maintaining a habit. Frith [13] conducted interviews with regular *Foursquare* users, focusing on how they used the applications' gaming elements and if they had altered their mobility. The author finds that the participants were competitive about earning and maintaining these mayorships. The reward of winning the mayorship affected where the participants chose to go and how often they would check in. Mayorships also incited loss aversion, making people check in more frequently when they lose a Mayorship.

Given the past examples, we can infer that connecting mobility to game elements can impact how the players engage with the surrounding space and their mobility choices. Likewise, gamification and serious gaming intend to increase motivation and engagement by adding a game context for non-entertainment purposes.

Micheloni et al. [27] designed a game with the objective to induce learning of complex interface controls like a piano, whilst having no explicit musical purposes. In this game, keys are associated with powers needed to overcome obstacles. As the authors state, their approach consists of a video game and not gamification. We can think of this game as harvesting the piano, for it's bringing the piano into a different game context. Their approach was tested with children and indicated that their knowledge of the keyboard was improved.

Our approach is similar to Micheloni et al.'s [27] as we do not intend to gamify the piano but

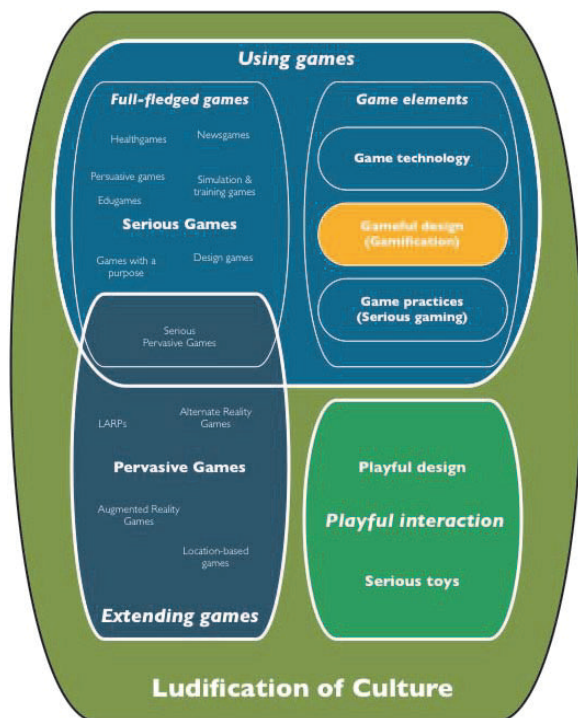


Figure 2.1: Deterding et al.'s [10] classification of Ludification of culture

differs as their approach uses the piano to control the game directly. In our approach, the user will play the piano their usual way while their playing is feeding the game, even if they are not online. This will require the player to play the piano to unlock playing the game or new parts of the game.

2.2 Gamifying Real-life Interactions

Deterding et al. [10] define gamification as using game elements in non-game contexts. With their definition, gamification is separate from serious games; the latter is the design of full games for non-entertainment purposes, while the former only incorporates some elements. These distinctions can be better understood in 2.1.

Gamification has been used to motivate people to engage in various activities, from exercise to marketing and learning [16]. Its effectiveness has been argued many times, but it appears that gamification's effects depend on the context and the user's qualities [16], making it necessary to adapt to them and their psychological needs [36], such as those explained in Self-Determination Theory [34]. These needs can be satisfied in games, including specific motivational game affordances [35].

Similarly, serious games have been applied to multiple fields, most commonly in education and physical activity. Below is an overview of how gamification and serious games have been implemented through various activities.

2.2.1 Gamification in Exercise and Exergames

Exercise is a requirement for physical and mental well-being, however, many people struggle to maintain a fitness routine. Fitocracy¹ is a gamified social network to promote exercise launched in 2011. Users log their physical activity, and points are awarded based on its estimated benefit. Upon reaching a threshold of points, the user levels up and milestones are rewarded with badges. Players compete on a leaderboard by points. Quests with workout activities are presented in order to earn more points. Goh & Razikin [14] studied if Fitocracy's gamification elements were motivating physical exercise. The authors found that attitude and enjoyment towards exercise were improved after using the application and the length of the exercises was increased. Additionally, Fitocracy's social aspects can leverage a sense of community which can positively affect whether the user intends to continue using this service [15].

Since then, mobile devices have improved; many smartphones and wearable devices now track users' activity levels. For instance, applications like PlayFitt² can track exercise repetitions and connect them to gamified elements, like daily and weekly goals. PlayFitt, and many others, even reward users' physical activity with real-world rewards, like gift cards.

In contrast to gamification and tracking, exergames are serious games designed to motivate physical activity by harvesting activity directly into a game context. For instance, Wii Fit Plus is a popular exergame launched in 2009 that uses a balance board as a game controller. Unfortunately, research in exergames lacks theory-based studies and which game elements and mechanics are effective in this context [25].

2.2.2 Health Games

Some medical conditions require people to take medicine or track symptoms and measurements regularly. Gamification and serious games have been designed to motivate users.

Candy Castle [39] is a prototype for a pervasive health game for measuring blood sugar levels for children with diabetes. The objective of this game is to build protective walls around the world map to defend a castle from dark forces. Each time a user inputs a blood sugar level measurement, a wall is built on their location. Over time, the walls deteriorate, incentivising the player to keep measuring regularly. Cafazzo et al. [6] designed an application with the same premise, but for adolescents. In their application, users got points by measuring their blood sugar levels, and upon levelling up, they could usually redeem 1\$ cards. The first trial with 12 people showed an increase of 50% in the daily average frequency of blood sugar measurements, and 88% stated that they would continue using the application.

Breath [23] proposes a game that promotes deep breathing exercises to reduce pulmonary complications after abdominal and cardiac surgery. In this game, the player controls a bird to collect all stars by breathing into a spirometer.

In a literature review of gamification of health [20], which included exercise, mostly positive

¹(Fitocracy, 2010)

²(PlayFitt, 2019)

impacts were found; however, the review also found that the quality of the research in this field was weaker, being in line with the quality of research in general gamification and serious games. Studies commonly use more than one game element or don't use control groups, so it's hard to determine which elements are effective. Moreover, few studies are conducted to explore positive outcomes from motivational theories, and it's still unexplored how to increase intrinsic motivation for health behaviour supported by game elements.

2.2.3 Gamification and Game-Based Learning in Music

As the name implies, gamified learning is the gamification of learning, and game-based learning is serious gaming for learning. When it comes to gamification design, students' profiles can affect how gamification impacts them, so there is a wide agreement that gamified learning needs to adapt to the class and the students [11]. Nevertheless, gamified learning shows small yet significant positive effects on motivation and learning outcomes, in line with Self-Determination Theory [36].

Statistics show that 61% of teachers believe motivation, practice, commitment, and enthusiasm are the key factors in making progress in music [1]. However, a decrease in motivation and perceived competence is one of the most common reasons for students to quit [26], making 80% of students quit after 2-3 years [22].

Music practice has been gamified multiple times as an attempt to increase learning and motivation for practice. For instance, Birch & Woodruff [4] use this concept with a webpage that tracks students' progress as a tower with rows of windows representing exercises they have mastered. Moving up the tower represents the game narrative, and avatars were used to strengthen it. Students also receive a virtual trophy upon mastering, and teachers can award them bonus stars. When tested, students using this approach mastered more exercises than students with traditional teaching methods, however, it was tested for a short time frame and with a small sample.

There are many examples of this commercially. Millions of people use *Rocksmith*, *Yousician*³, and *Simply Piano*⁴. Generally, these gamified applications work by connecting the instrument to a device and associating songs with a score. When playing a song, the user usually receives instant feedback on the correction of their playing. They give the player a palpable sense of progress and clear goals, potentially boosting learning and motivation.

Using *Rocksmith* to learn, however, splits opinions [17]. In the Musician's eyes, the game focuses heavily on Rock music, making it restricting. The player cannot develop musical skills only by playing the game because it distracts them from essential parts of musicality. Musicians know when they are playing incorrectly, as the music doesn't sound right. When interconnected to a game, the player focuses not on what they hear but on what they are getting right. In contrast, from the gamer's perspective, successful learning is affected by effort, challenge, and reward.

Many approaches to game-based piano learning involve reducing the need to have music-reading skills, basing them on a notation system called *Synthesia*⁵, where the notes scroll down

³<https://yousician.com/>

⁴<https://www.hellosimply.com/>

⁵<https://synthesiagame.com/>



Figure 2.2: Synthesia notation used in Raymakers et al. approach [33]

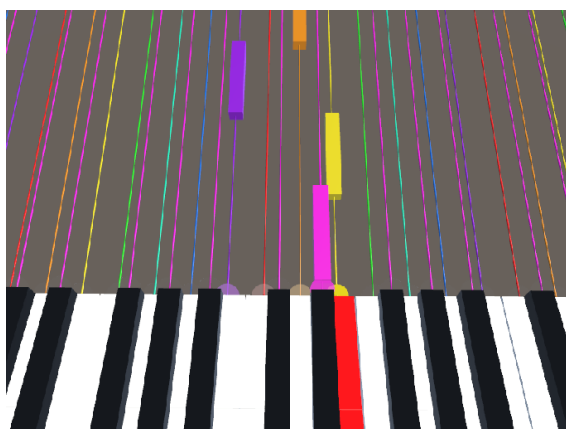


Figure 2.3: Synthesia notation used in Mixed Reality Piano Tutor [29]

until they reach a representation of a piano, at which point they must be played on a physical keyboard. For instance, Raymaekers et al. [33] project this notation on the top of a keyboard, as seen in 2.2, while Mixed Reality Piano Tutor [29] uses this notation with augmented reality, as can be seen in 2.3. Additionally, both these systems also add a gamification layer, where the keys are used as guns to kill incoming aliens or space crafts. Brett et al. [5] present three case studies with the gamification of repetitive training associated with high drop-out rates. The premise is to guide the player to practice musical scales with appropriate rhythm, providing feedback through game elements. In their approach, they use an RGB midi keyboard named LUMI⁶, which can provide players with colour feedback.

Most of these approaches work by connecting a MIDI keyboard to a device, usually a computer, that can decode the notes being played and many other controls or settings that could be relevant.

Our approach works by connecting a MIDI keyboard to a device that feeds the playing data into a game. Players can play how they want, so we don't restrict them to a genre or exercise. We intended to separate the game from the playing as we didn't want either experience to be distracted by the other.

⁶<https://playlumi.com/>

2.3 Pervasive Games

Pervasive games are known for breaking the usual boundaries of play [3] and extending the gaming experience by adding a virtual layer to the physical world [18]. The precise definition of pervasive games isn't quite agreed on by researchers. Hinske et al. [18] summarise them as “*a ludic form of mixed reality entertainment with goals, rules, competition, and attacks, based on the utilization of Mobile Computing and/or Pervasive Computing technologies*”, and Valente & Feijó [40] characterise them as “*games that are played in the physical world where players use context-aware mobile devices to enable the interaction between the environment and the virtual world, which creates a mixed reality*”. While the definitions don't seem too far off from one another, they can significantly influence which games are considered pervasive. Because our interest is in the pervasive elements and not in pervasive games as a whole, let's consider the definition given by Arango-López et al. [3] “*A pervasive game delivers to the player an enriched experience of game through an evolvment of the dynamics of the game, expanding the space of the game according to the context where it is played. This allows breaking the boundaries of the game world, making reality part of it and that the elements in that reality have an influence during the game.*”

Additional to providing a definition, Arango-López et al. [3] identify the components of pervasive games:

- **Devices** - Mobile devices provide freedom of movement in the real world while having access to all their content.
- **Context** - Sensors can detect the position of the player and influence the context of the game.
- **Social Interaction** - The game provides new ways for face-to-face communication.
- **Time** - The game is played when the player wants and can be running even if the player is disconnected.
- **Space** - Mixes the real world with virtual world objects and adds a virtual layer.
- **Multi-Reality** - Alternate realities are created when merging the real and virtual environments.
- **Crossmedia** - Played across different media.
- **Pervasive Narrative** - Gives order and logic to the player experience; The narrative links all components into a story.

Pervasive computing can be used to support (i.e. replace something in a traditional game), augment (i.e. add a virtual component to a traditional game) or realise completely new games [18].

The games mentioned in 2.1, *Pokémon GO*, *Ingress*, and *Foursquare*, can be considered pervasive because the physical world context alters the game context. With a mobile device and an

internet connection, these games can be played anywhere, anytime, while permanently connected to other users in one way or another.

Pløhn & Trond [32] present HiNTHunt, a pervasive game aimed to help first-year university students become familiar with the campus and the city and meet the other students and academic staff. In this game, each student had an automatically generated game board they had to fill with specific diamonds. These could be registered on the board when found and the player got points for completing special configurations, for instance, rows. Every student participating was assigned a diamond that could be registered by other users. Diamonds could also be found hidden in the town and among the lecturers and professors, or by participating in activities. The authors state that active players in this game found the game to help them get familiar with their new life.

Caon et al. [7] propose a game concept for a location-aware role-playing game (RPG), based on mobile devices and public displays, aiming to promote social interaction in the real world. In this concept, players move in the physical world to find game items or fight and capture monsters. Players increase their level by completing quests and fighting monsters. To start a quest, players must be co-located and collaboration between them is required, as the game provides hints that can be solved together. These quests can also use the physical world, by using, for instance, inscriptions on monuments. In combat, mobile devices are coupled with public displays and players duel with their captured monsters. Additionally, the game would feature a trading mechanism, that would take place at specific meeting points.

Valente & Feijó [40] describe a pervasive game like hangman, where the players have to find the word by guessing the letters within a certain amount of time. This version requires the player to point the camera at a colour and the letters of the colour are revealed in the word. If the player is in a place with many wireless devices, the clock runs slower.

Candy Castle [39], mentioned before, can be considered a pervasive game since the physical location of the player affects the game.

Examples of augmentation through pervasive computing are Quest - UbiquX [43] and W41K [19]. The idea behind Quest - UbiquX is to digitally augment the tabletop game Quest: Zeit der Helden, by replacing some elements of the gameplay with virtual counterparts and adding player location as a trigger to game events. W41K [19] represents a digital augmentation of the game Warhammer 40.000 (W40K). The authors used RFID tags to determine the location and orientation of game pieces and dice that automatically recognize results. The system checks the rules and the validity of the players' decisions and stores information on all units of the session. Players can turn off the automatic validity of rules, to focus on strategy and explore the game. These changes are focused on the user experiences and they relieve the burden on cumbersome tasks, like measuring units in W40K, and add new experiences, like location-based quests and shouldn't change the original look and feel of the game [19]. Moreover, some traditional board games take hours and through digital augmentation, the user can be allowed to pause the gameplay and resume later.

Pervasive games have been brought to support learning as well and much like gamification in

general, show an initial boost in motivation but there's the same need to rigorously test their learning outcomes connected to design elements [37]. Pervasive games in learning offer the advantage that is forcing the students to go outside

Our approach draws some components from pervasive games such as time, the game is running and collecting data even if the player is not playing, space, the game adds a digital layer to the real-world piano and connects it to game elements and devices. In theory, our approach's mobility is only affected by how portable the digital keyboard is, as the game can be designed for any platform.

2.4 Well-being from Motivation & Engagement

In light of the Self-Determination Theory (SDT), Ryan and Deci argue that psychological needs must be met to achieve well-being [34]. According to this, the three basic psychological needs are autonomy, competence, and relatedness. If the pursuit of a goal aligns with these needs, it can lead to enhanced well-being. The authors show the three types of motivation: amotivation, extrinsic motivation, and intrinsic motivation. Amotivation is a lack of desire to act, while intrinsic motivation is the desire to act solely from the reward of doing the activity. Extrinsic motivation is the intention to act based on an external regulator, for instance, rewards or punishments. Extrinsically motivated behaviours can vary in terms of autonomy. The less autonomous behaviours are externally regulated, acting for an external demand or reward. The most autonomous behaviours are characterized by integrated regulation, where one internalizes the value of the activity but they do not find it intrinsically rewarding. The fulfilment of the three basic needs can help to internalize the value of an activity. When externally regulating an activity, like external rewards, intrinsic motivation values can diminish, so, for instance, in a gamification context, it should only be used in extrinsically motivated tasks, while supporting these needs. Moreover, failing at a task in real life has implications as it hurts our perceived competence and, subsequently, diminishes motivation. Hence, gamification is often used as a way to reduce this feeling of failure through gamefulness experiences.

Music practice can take the player into a state of flow [9]. Flow has been described as the state in which a person is fully immersed in a task. Proposed by Csikszentmihalyi, the experience has been considered an essential element for well-being and a life worth living. Flow has also been analyzed through the scope of gamification, however, a lack of consensus on the methods to be used [30], along with general caveats in gamification research makes it hard to infer the real effects of gamification on flow experiences.

Ideally, by fulfilling the player's psychological needs, the player can engage with the instrument and enter a flow state achieving, therefore, increased well-being.

Gamification, however, exists to motivate action for a task by adding game elements to it. We intended to test the opposite. By adding the action into a game, we tested how it affects either experience and player motivation.

Chapter 3

Understanding Musicians and Gamers Motivations

As we can see, harvesting interactions for games is little explored and the related area of gamification still has some methodological limitations in the research, specifically in terms of motivational outcomes and engagement [2][16]. Micheloni et al.'s [27] approach requires direct input from the piano while playing. In contrast, our intention is to create a system that collects multiple metrics from the user while playing (e.g. time, keys pressed) throughout the practice session to affect a game, without restricting the player to a specific genre, song, or exercise. With this the player has control of how to play and when to play, maximizing their volition. Our interest is in how the gamer and the musician profiles are affected when they

Firstly, we decided that playing the piano should be mandatory, as opposed to complementary, for having the effects reflected in the game, and the piano should be played before playing the game. It was also decided that whichever algorithm was used to collect the piano and used in-game, it should be hidden from the player, as to prevent the player from altering their normal practice sessions to exploit the game.

In order to understand what motivates both musicians and gamers and inform our design decisions in regards to game mechanics and what could be collected from the piano, we've conducted two design workshops, the first with game researchers with experience designing games and the other with musicians. In preparation of the workshops, we created and organised the content we had up until that point, to better communicate the concept of this project and also to promote the discussion of the subject, during the workshops.

For this, the piano's effect on the game was divided into four categories:

- **Novelty** - playing the piano introduces new game elements
- **Resources** - playing the piano alters game resources
- **Unlocks** - playing the piano unlocks playing the game
- **Difficulty** - playing the piano changes the difficulty of the game

Using these categories, we brainstormed some game mechanics that would reflect the data harvested from the piano. The initial ideas can be seen in the table in the appendix.

Then, we tried to understand and connect the ideas to the musicians' and gamers' needs and desires. Below we dive into how we conceptualised the harvesting ideas, collaborating with both researchers and musicians, seeking to understand what would be both engaging and impactful.

3.1 Game Design Workshops

Having the initial ideas organised, the workshops were conducted. We hoped we could use the musician's musical understanding to guide us through the musical metrics that made the most sense to collect. So, first, we conducted a workshop with researchers, to get valuable information on the technical aspects of creating a game and game mechanics, and so that we had some ideas already, to serve as a guide for the musicians. The musicians could provide us with their musical knowledge and insights on musical ideas for the harvesting while the game researchers could provide us with the best game-related ideas on how to feed the game with harvested data.

3.1.1 Understanding the Gamer's Point of View

After we had brainstormed some effects on the game, on the initial table, we brought these ideas into an in-person game design workshop with game researchers, to fetch more ideas and areas of effect.

Participants

The participants consisted of 3 researchers, 2 PhD Students and 4 MSc Students, from the faculty, all researching the area of games. Regarding musical ability, 2 participants played the guitar and 1 played the drums. 1 participant played their instrument for 1 to 5 years, another from 6 months to a year and the other for more than 10 years. 2 participants reported having abandoned their instruments, while the other still played, although less than 1 time per week, with practice durations from 30 minutes to an hour each.

Regarding their gaming experience and habits, board games, casual phone games and computer and console games were equally played among participants. Half of the participants reported playing between 1 and 3 hours a week and the other half reported playing for over 5 hours a week. A quarter of the participants considered themselves to be a casual gamer, another quarter to be somewhere between casual and hardcore gamers and the remaining half considered themselves hardcore gamers.

Procedure

Firstly, we asked everyone to take the Quantic Foundry Gamer Profile questionnaire. The Quantic Foundry Gamer Motivation Profile is a research-based questionnaire designed to assess a player's gaming preferences and motivations. It was developed by Nick Yee and Nic Ducheneaut, both

researchers in the field of gaming psychology, as part of the Quantic Foundry project. It consists of a series of statements or scenarios related to gaming preferences, behaviours, and attitudes.

Based on the responses, players are categorised into different gaming motivation profiles, each representing a unique set of gaming preferences and motivations. These profiles are based on factors such as the desire for challenge, competition, exploration, social interaction, and strategic thinking in gaming. This questionnaire was chosen to contextualise and understand the diverse motivations behind our participants' gaming behaviour and habits.

After completing this questionnaire, the participants were then prompted to think about game mechanics that could be fed by playing an instrument and write down 5 ideas in 5 minutes. At this stage, we didn't have a game concept with a defined genre, so the ideas for game mechanics were generally broad. There were two requirements: playing the piano must be separated from the game to not have anyone playing both piano and the game simultaneously and the game must not interfere with how the piano is played (e.g. by requiring specific exercises or songs). After the 5 minutes passed, we collected all answers on the board, while merging similar concepts.

We had participants isolate what could be collected from the piano and have them match with the game effects that made the most sense. Next, we had the researchers vote on their favourite ideas. Then, for the 5 most voted ideas, researchers were given 10 minutes to write down the advantages and disadvantages of each of them. The group then discussed what they considered the advantages or disadvantages of the mechanics.

Findings

The most voted ideas were:

- The quality of the performance influencing the dexterity of the player
- The genre of the performance influencing skills of the player
- The performance influencing world creation
- The quality of the performance influencing buffs or debuffs
- The performance influencing the aesthetic of the game

The researchers also found 3 more categories of effect:

- **Mood** - representing the overall aesthetic of the game
- **Rules** - representing the rules of the game
- **Control** - representing the control of the character

All the ideas generated, along with the new categories were inserted into the table and then reorganised, eliminating redundant mechanics. From these ideas, we isolated what could be collected from the piano: specific notes, playing chords, song genre, tempo, quality of the performance, playing intervals, recording snippets, practice duration, mood of the song, not playing piano, playing together, number of repetitions and song complexity.

Understanding the Musicians' Point of View

Afterwards, a new game design workshop was conducted with musicians. Building on findings from the previous Workshop, the musician's perspective could provide us with valuable insight and knowledge more specific to the musical part and how they usually practise their instruments, so we could reach a design that could integrate well with musicians' practice sessions.

Participants

Recruitment was open to people who played any instrument and enjoyed playing games. Five musicians were recruited, all college students, aged between 22 and 23 years old.

Regarding their musical experience and habits, 2 participants only played piano, 1 only played guitar, 1 played guitar and piano and the other played piano, guitar and bassoon. 3 participants played their instrument for over 10 years, 1 participant for 5 to 10 years and the other for 1 to 5 years.

In terms of how much they practise their instrument, on average, 3 participants practised one time per week, 1 participant practised 2 times per week and the other 2 times per day. For a given practice session, the average duration was under 30 minutes for 3 participants and between 30 minutes and 1 hour for 2 participants. Regarding their gaming experience and habits, all participants played computer or console games, 3 played board games and 2 played casual phone games. 4 participants considered themselves to be somewhere between a casual and a hardcore gamer and 1 considered themselves a casual gamer, with 2 participants playing for over 5 hours in a given week, while 2 played between 3 and 5 hours and the other between 1 and 3 hours.

Procedure

As done before, musicians completed the Quantic Foundry Gamer Profile questionnaire. No participants had the same predominant player type, being these types the Gardener, the Acrobat, the Bard, the Ninja and the Gladiator. Player types are explained in the subsection above. Only one participant had a secondary type, the Architect.

After completing the questionnaires, participants were given 5 minutes to brainstorm what elements could be harvested from the piano. The ideas were then written on the board and voted on, leaving us with what they considered the best ideas:

- rhythms
- playing patterns
- dynamics
- the shape of the melody
- improvement
- learning a song

- difficulty
- mood of the song
- how many songs does the player know
- performance quality
- improvisation
- hand-eye independence
- register
- complexity of the melody
- mistakes made
- physical effort

Then, using the same requirements from the researchers' workshop, they were prompted to have 5 ideas for how the game could be fed using the piano, in 5 minutes. The ideas were written on the board and then, participants were divided into two groups, who then discussed and voted on their favourite ideas. We've decided to abandon the concept of areas of effect on the game, as it didn't carry much meaning to the musicians.

Findings

The most voted ideas by the groups were:

- Session duration affects the number of lives
- The performance quality influences the weather, quantity or type of enemies or the music of the game
- The specific notes played generate a limited map
- The playing habits influence debuffs
- The genre of the song influences the game's environment
- The genre of the song affects available skills
- Improvement between sessions gives rewards or extra lives
- The mistakes made translate to small consequences or setbacks
- Playing with another pianist gives boosts when playing the game together

All the ideas were then added to the table of ideas and rearranged.

Chapter 4

Developing a Game Fed By Playing the Piano

In this section, the implementation and design of both the application that collects the data and the game are detailed and explained. First, the MIDI protocol and what we can get from it is explained. Then, we combine the ideas from the Workshops and the data we can harvest with MIDI to decide which mechanics would be implemented. Next, the design and implementation of a piano companion application that collects MIDI data from a player session is detailed. The flow of information between this application and the game is explained. Finally, we explain and detail the steps of the design and implementation of a platform game consisting of some zones with enemies and some with bosses, with game mechanics and aesthetics affected by the data collected from the piano.

4.1 Collecting Piano Data

Regarding the collection of piano data, we analysed what we could receive directly from the keyboard into the computer, within the MIDI protocol. The MIDI protocol is the standard for communication in digital instruments and transmitting the information needed for the playback of music. It can be used to connect instruments to computers, with cables that are capable of transmitting MIDI data, either by just using USB-B or by using MIDI cables with MIDI interfaces. It is important to note that the MIDI language in itself does not transmit or define the sound of the music, but only the sequence of instructions to create the desired sound. There are 16 MIDI channels, to send or receive data from. A MIDI message is typically constituted by a Status byte and two Data bytes. The Status byte determines the type of the message, for instance, when a note is played versus when a control knob is changed. The Data bytes that follow are parameters depending on the type of message.

These types are:

- **Note On** - a note was pressed
- **Note Off** - a note was released

- **Pitch Bend** - if there's a note playing, bends the pitch, up or down
- **Control Change** - a control was changed, such as a knob or a fader
- **Program Change** - a different patch was selected (e.g. sound preset from a bank)
- **Polyphonic Aftertouch** - changed the pressure of a note that was being played
- **Channel Pressure** - changed the pressure of all notes that were being played through this channel

In most piano performances and digital keyboards, the relevant and available messages are: note on, note off and control change, to track the pedal's usage. The **Note On** status is followed by the note that was played and the velocity it was played. The velocity of a note represents how much force hits the key, usually triggering a softer sound at low velocity and a higher-in-volume, punchier sound at a higher velocity. The **Note Off** status is only followed by the note that was played. In addition to what we can directly collect, there are also things that we can calculate from these messages, for instance:

- The duration of the note can be calculated between the timestamp of a **Note On** and a **Note Off** message
- Total time played in the session, between the timestamp of the first note and the last note
- Dynamic variation, by the variations in note velocities
- Changes in the duration of the notes, throughout the performance

4.2 Deciding Piano-Game Interactions

Having all these ideas, we had to choose what would be possible and practical to implement, while being engaging and making an actual difference in the gameplay. From what could be captured from the piano using MIDI, as explained above, we have much information regarding the notes being played, but as to the overall structure of the song, it has a lot of limitations. From the Workshop with musicians we had these ideas for what could be collected: rhythms, playing patterns, dynamics, the shape of the melody, improvement, learning a song, difficulty, mood of the song, how many songs the player knows, performance quality, improvisation, hand-eye independence, register, complexity of the melody, mistakes made, physical effort. Below, we discuss what could and couldn't be done, with our setup.

Tempo and Rhythms

Data related to tempo, such as bpm or rhythms, would be very hard to obtain without user input. Firstly, rhythms require a definition of the tempo and time signature, as the note figures are strongly related to the tempo they are played (e.g. a whole note, duration of 4 beats, played at 120 beats

per minute would result in the same note length of a half note, duration of 2 beats, played at 60 beats per minute). Second and most importantly, the tempo information is not available readily through a MIDI stream, only in a MIDI file, requiring the player to have the MIDI file of what they would be playing, and changing it every time they would switch songs, interfering with their normal piano experience. Additionally, as the tempo is felt mostly intuitively and even though there are some features to look for, it would be complex to create an algorithm to detect the tempo. The only simple way to implement this would require the player, either to input the tempo using GUI or tap the tempo before playing the song. This would obviously affect playing the piano, breaking one of our requirements, as it would need a player input that would not be natural to the practice session and the tempo would need to be changed every time the player switched songs or just wanted to play at a different tempo.

Playing Patterns And Melody Detection

Playing patterns, shapes of melodies, and similar ideas would require a complex algorithm that would result in a significant amount of computations, for it would be needed to compare every bit of playing to each other, as the computer does not know the pattern it should look for beforehand.

Improvements, Mistakes and Learning

Data related to specific songs as improvements, improvisation, learning or mistakes need something to compare to. Without user input, the algorithm does not know what the player is playing or if they are playing it right at all, much less if the player actually learned it. Additionally, even if it could have a file, it's hard to discern what is a mistake and what is not, as the player naturally may change the dynamics or tempo or even the notes while they are playing, as stylistic choices. This would be even more noticeable with Jazz, characterised by a strong element of improvisation.

Genre and Mood of the Song

The song's genre is also a complex subject, as it's very hard to understand the genre of a song just by playing the song on a piano by itself. The genre of a song is characterised by all of the components that go into the song, many times informed by what the drums are playing. For example, the piano in a rock song versus a metal song can be the same, have the same chords and in the same way and tempo, while the rest of the instruments make it clear that it would not be the same genre. That being said, there would not be a way to classify the genre accurately just by using a single MIDI instrument. The same can be said about the mood of a song. While chord types and the songs' key can provide some insight into the overall mood, it would be oversimplifying, as it can depend on how these chords are being played and the performance of the musician.

Hand-Eye Independence and Physical Effort

Finally, hand-eye independence or physical effort would require additional sensors and we decided that it would not be worth it.

Register and Dynamics

Both ideas could be implemented, but we decided that they would not bring that much effect into the game, as we also did not have game mechanics that we could tie them nicely to.

Difficulty

Difficulty is a complex and subjective matter. Still, we decided to create a somewhat arbitrary algorithm that could classify a performance's complexity, based on the types of chord played, how much the hands are separated from each other, roughly symbolising hand-eye separation, and the average time between each note, symbolising how fast they are playing.

This has a first exploration of harvesting instrument play for a game we chose to focus on data that we were able to collect without facing the additional challenges described above which could potentially be avenues for future work. Applying these concerns to the ideas generated by the musicians, we chose what would be collected. Our criteria were to minimise the complexity of the implementation but maximise the effect it could bring to the experience, while taking into account the development we already had of the game and the plugins used, leaving us with the following;

- Most played note
- Most played chord
- Average note velocity
- Performance difficulty

4.3 Piano Companion Application

Having decided what was to be collected from the piano, the next step was to create a piano companion application that could harvest the data and send it to a database. This application was implemented in Unity and MIDI input is not native to the platform, so a plugin was needed. We found a public GitHub project, called Minis: MIDI Input for New Input System, that can connect a MIDI device to the Unity input system, for instance, as a computer keyboard, allowing us to receive a MIDI input stream.

The Minis plugin can detect control changes and the notes played, along with their velocity, which was enough to implement the chosen ideas. However, this plugin was not compatible with mobile, so we had to create a computer application and not a mobile one, recognizing that it puts more burden on the user, by not being so portable.

Using this plugin, we implemented an application that harvests some data to influence the game, as well as some data to mask to the user what we were feeding to the game, then synchronises this data with a Firebase real-time database. When the player wants to collect data, they just need to connect the piano and the computer using a cable capable of transmitting MIDI and insert

their chosen player ID, which needs to be the same as in the game. Provided the cable is correctly receiving data and the computer has internet access, the data will be sent to the database. The player can check if the notes are being collected, as the UI displays the last note received from the piano. If the application can't connect to the database or does not detect an internet connection, that is also displayed in the UI.

Below each data being collected is described.

Session Time and Duration

When the first note of a practice session is played, a timestamp is stored in the format: weekday, dd-MM-yyyy hh:mm. The session duration is calculated by subtracting the timestamps of the last and the first notes played. The start session timestamp is taken at the moment the first note is played in the session. The last timestamp is always updated when a new note is played so that we capture the last note that is played. So, after each note played, the duration is calculated and sent to the database. If the last note played was more than fifteen minutes ago, meaning the player stopped playing for fifteen minutes, a new session is then started.

Location And Weather

The location of the session is stored in the format: Country, City. This was collected using the ipgeolocation API, which retrieves the IP location of the device. This location was then fed to the OpenWeather API, to retrieve the weather of the session's location. From the weather, we store the main description of the weather (e.g. clear sky) and the temperature at the moment of capture.

Notes Played

As said before, the Minis plugin can collect the pitch (note) played along with its velocity (pressure). The plugin has an **onWillNoteOn** callback, so when a note is pressed, we have access to the pitch and velocity that was played. We then add a timestamp along with the pitch to a Map containing all the notes that are being played at the moment. The *onWillNoteOff* callback gives us access to the key that was released, so by finding the pitch in the Map, we can calculate the duration of the note. We only stored the pitches and velocities of the notes in the database.

Hand Separation

When two notes are played simultaneously, we check the number of notes between them. We wanted something to measure the hand separation, to measure the difficulty, so we decided to identify the difference between the lowest note and the highest note. A bigger number would mean that the hands were very far away from each other, while a small number could either mean that the hands were close together or that only one hand was playing multiple notes. For this calculation, we decided not to consider this, given that the hand-eye independence and how much a hand is stretched also play a role in the difficulty, somewhat aligning with our scale.

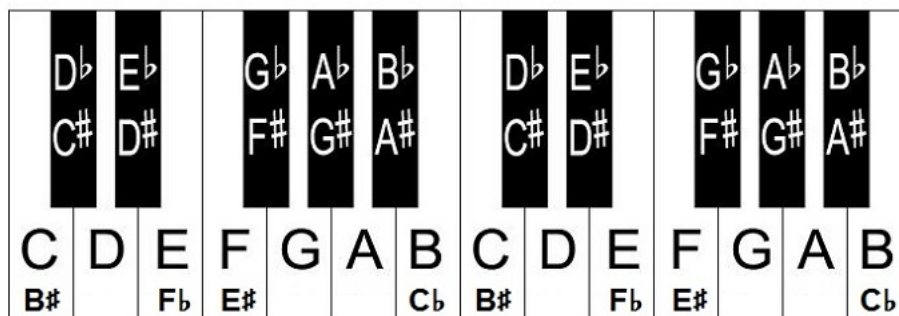


Figure 4.1: Keyboard with keys labeled [8]

Chords

A chord is when 3 or more notes are being played simultaneously and can be categorised into many types according to the intervals between the notes. For simplicity purposes, we chose to detect the five most common chord types: Major, Minor, Major Seventh, Minor Seventh and Dominant Seventh. Chords are constructed using intervals. An interval refers to the pitch distance between two notes, being measured in terms of the number of notes and additional accidentals (sharps \sharp or flats \flat) they encompass. For example, a minor third spans three notes with a lowered third note, while a perfect fifth spans five notes.

Major and minor are chords composed of three notes: the tonic, the note that gives the chord its name, a third above it and a perfect fifth above it. The difference between a major and a minor chord is the quality of the third that in major chords is a major third and in minor chords is a minor third. Using the tonic as C, the C major chord would be composed of C, E and G, and the minor chord would be composed of C, E^b and G. Major, minor and dominant seventh are four-note chords. In a major seventh, a major seventh interval to the tonic is added to a major chord. In a minor seventh, a minor seventh interval to the tonic is added to a minor chord. In a dominant seventh, a minor seventh interval to the tonic is added to a major chord. Using the tonic as C, the C major seventh chord would be composed of C, E, G and B, the minor seventh chord would be composed of C, E^b, G and B^b and the dominant seventh would be composed of C, E, G and B^b. The notes can be played in any order, sometimes doubled, sometimes even suppressed. As these categories can be subjective and vary immensely, especially when analysing the chords according to the context that they are played in, we decided to detect chords if all of the notes are present at least once and considering the tonic of the chord is the root note, i.e. the lowest note that's being played. This means that for a C major seventh to be detected we could play, for instance, C E G B or C G B G E E, but we could not play B C E G, as the root would then be B instead of C. In the Midis plugin, notes have a short display name (e.g. A4, pitch A, fourth octave) and a note number, corresponding to the MIDI number of the note, from 0 to 127. As an octave contains 12 different pitches and a piano is made of many octaves, we can ignore the octave, to detect the intervals between the notes, like they were played in the same octave. Every time that three or more notes

are being played, the application tries to detect a chord, using the active notes array, that is sorted from lowest to highest pitched note. First, we calculated the modulo 12 of the notes, to abstract the octave, and store all the different notes in a different array, eliminating the duplicate notes. The initial array was sorted, but by applying the modulo 12 to the notes, we could end up with a note that's higher than the root being lower than the tonic. For instance, a B minor chord, comprised of the notes B4 D5 F#5, with corresponding note numbers 71, 74, 78, when applying the modulo 12 we would get 11, 2, 6, which would mean that the tonic would be higher in pitch than the rest of the notes. To avoid this we ensure that, in the modulo array, the notes are crescendoing, if not we add 12 to the note that breaks the crescendoing pattern. In the same example, we would check if $2 > 11$, and because it is not, we would add 12 to 2, and then check if $6 > 12 + 2$. The final array would then be 11, 14, 18. We then simply subtract the tonic number from the notes and get the interval numbers 0, 3, and 7, which we find in a dictionary containing the chords and necessary intervals, corresponding to a minor chord. When a chord is detected, we save its type to the database and we set a recording to start.

Recordings

The recordings are triggered when a chord is detected. When a recording is set to start, the app waits for a note to be played. Then for a total of 3 seconds, notes with their velocity, duration and timestamp are stored in an array. After the recording is done, it's uploaded to the database under a timestamp

4.4 Flow of Information

As said before, the data collected from the piano companion application is sent and stored in a Firebase real-time database. This data is structured as follows: Each player has an entry to the database consisting of the player ID, as the root, and below there's the last session, old sessions, game sessions, game logs and the player save. Most importantly, the last session contains what will affect the next game: the date and time, the location, the weather, a list of recordings, that are each a list of notes played in that time frame, a list of chord types played, the duration of the session, a list of hand intervals, a list of the note velocities and a list of the notes with pitch, timestamp and velocity. When the game is played, a "Played Since" boolean is added to the last session, to prevent the same session from being used multiple times. The old sessions store the past sessions. When a new session is started, the last session is added to the old sessions under the timestamp of the moment it's moved. Regarding the game information, the player save stores the player's skill levels: dexterity, health and strength. The game logs store information regarding games played, for instance, when the game was played, for how long and which bosses were defeated, so we were able to extrapolate which path the player took in each game. The game sessions store how many games were played in total. When the player completes the first 2 sessions, a toggle is added to the root, to alter what would be the effects in the game. To summarise, the database's structure can be seen in table 4.1.

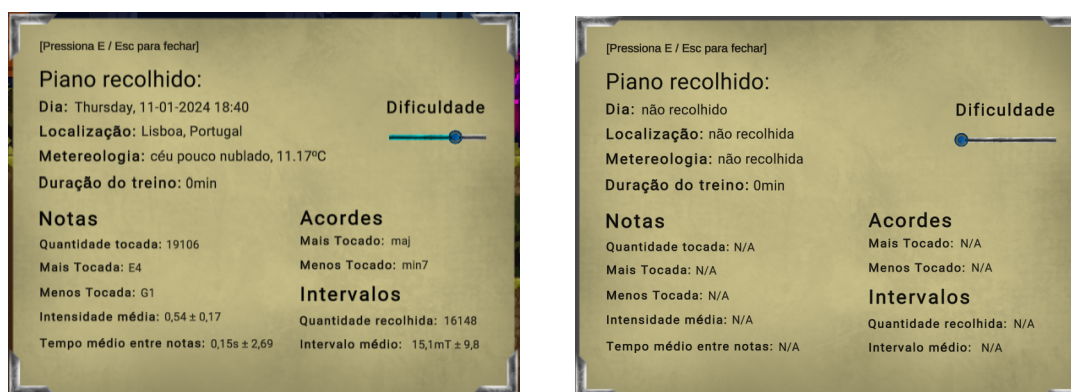
PlayerID	Toggle - toggled after two sessions, to change the pattern of effects	
	Last Session	Date And Time - time of the last session
		Location - location of the last session
		Weather - weather at the time and location of the last session
		Chords -list of chord types played in the last session
		Duration - duration, in minutes, of the last session
		Hand Intervals - list of all intervals from the last session
		Notes - list of all notes from the last session
		Velocities - list of all velocities from the last session
	Played Since - if the player played the game after this session	
	Old Sessions	Timestamps - list of past sessions
	Player Save	Dexterity - the player's dexterity skill value
		Health - the player's health skill value
		Strength - the player's strength skill value
	Game Sessions - total number of game sessions	
Game Logs	Timestamp	Duration - list of game sessions with durations
	Timestamp	Boss name - list of bosses killed

Table 4.1: Database's Structure

4.5 The Game

As for the game that would be fed by these metrics, we decided on a platformer game consisting of 4 zones with enemies and 3 zones with bosses, the objective is to fight the last boss in the least amount of time, being able to take a few different routes. The player has 3 skills, dexterity, which controls their walk and run speed, and strength, affecting their damage and health, affecting how much damage they can withstand before dying.

The game was implemented in Unity, using the Corgi Engine plugin and went through testing and iteration with other game researchers, to detect and fix bugs, and ensure the game was appropriately balanced and the harvesting was noticeable. When the same starts, a board containing statistics from the last piano session is displayed. This board, shown in figure 4.2, can be consulted in every zone, by interacting with a computer sprite.



(a) Data affecting

(b) No data affecting

Figure 4.2: Session statistics panel with:

Below is described how the harvested data brought effects to areas of the game.

4.5.1 Session Stats

In addition to the metrics that we directly collect, described above, the game does some calculations to affect the gameplay. These are the average velocity and the standard deviation of the velocity, the number of notes and the most played and the least played note and chord type, the number of intervals played, the average interval and the standard deviation of the intervals, the average time between two notes and the standard deviation of the time between notes and the difficulty.

As the difficulty of a piece is mostly subjective, since what is difficult to an experienced player varies greatly from what is considered difficult to a beginner, and it's hard to determine using calculations instead of human evaluation, we try to calculate somewhat of a complexity measure, using set criteria. Again, these criteria aren't and cannot be perfect indicators of difficulty, but the goal of this project is not to evaluate the player, instead, we want the measurements to affect the game in a vague way that can be noticed but not pinpointed. The chosen criteria are the complexity of the chords played, the time between notes and the hand separation.

To get the complexity of the chords, first, we retrieve all chord types played and assign them a number based on a complexity scale. We assume the following progression of chord complexity from least to most complex: major, equaling complexity 1, minor, major 7th, minor 7th, dominant 7th, equaling complexity 5. After all complexities are summed, we normalise the parameter, dividing it by the maximum complexity possible, which is the total number of chords played times complexity 5. Then, the complexity is expressed from 0 to 1, with being 0 the easiest.

For the time between notes, we retrieve the timestamps of all notes and store the difference between each note and the preceding one. Then, we calculate the average of the time between notes, by dividing this sum by the number of notes minus 1. The timestamps used have a millisecond precision, so the difference in timing between two notes is expressed in milliseconds. We assume the easiest tempo is 60 beats per minute, meaning one note played per second. Considering this, we normalise the average time between notes by dividing it by 1000, essentially converting it to seconds. The threshold is defined at 1 second so if the average was above 1 second, the normalised average time between notes is still 1. So, the time is expressed from 0 to 1, with being 1 the easiest.

For the hand separation, we take into account which intervals (separation between two notes played at the same time) were played. As stated above, in this calculation we also take into consideration intervals played with only one hand, as we have no way of telling which hand played which note, but we can generally say that a small interval is the easiest to play while a very large interval, only being physically possible to play with two hands is harder, because of the eye coordination. The only exceptions are intervals that can be played with two hands and with one hand, that require more hand flexibility, possibly considered harder. So, instead of using the average of the intervals, we chose to use the standard deviation. Considering that a smaller standard deviation means the player did not change their hand separation much, otherwise, we can



Figure 4.3: Evolution of the armour's sprites, level 1 does not have armour.



Figure 4.4: Evolution of the boot's sprites, level 1 does not have boots.

assume that the piece that was played varies in hand separation. So, to normalise the standard deviation from 0 to 1, with being 1 the easiest, let's assume the easiest piece to have a standard deviation of 1, and divide 1 by the calculated standard deviation.

Then for the calculation of difficulty, we invert the normalised average time between notes and the normalised standard deviation of hand separation, to make 0 the easiest for all 3 parameters. The difficulty is then calculated by the average of the parameters, with being 0 the easiest and 1 being the hardest. In every area of the game, there is a computer object where the player can go and see the practice statistics. This panel displays what we collected from the piano, along with some additional metrics that are not used to affect the game.

4.5.2 Player Skills

As stated above, the player has 3 skills: dexterity, health and strength, levelling from 1 to 8. When the player plays the tutorial, using the piano session from before, the player gets a level up in two random categories. Afterwards, each time the game is played while fed by the piano, the player gets a level up in a random skill, provided it is not maxed out. The progression of the skills is indicated visually:

- With increasing health, the health bar goes from a red colour to a blue colour and the player's armour evolves to a different sprite, shown in figure 4.3.
- With increasing dexterity, the players' trail when walking or running gets faster and bigger, respectively, and their boots evolve into different sprites, shown in figure 4.4.
- With increasing strength, the body of the player evolves into a different sprite, shown in figure 4.5.



Figure 4.5: Evolution of body's sprites.

4.5.3 Background and Music

There are 3 backgrounds and 3 background songs, 2 of them are fed by the piano and a default one. In the first week, this is influenced by the music intensity, and in the second week by the music difficulty. These backgrounds can be seen in figure 4.6: the default background displayed when no data is affecting the game is sub-figure 4.6a. For lower intensities/difficulties, the background seen in sub-figure 4.6b is shown and for higher ones, the background in sub-figure 4.6c is shown.

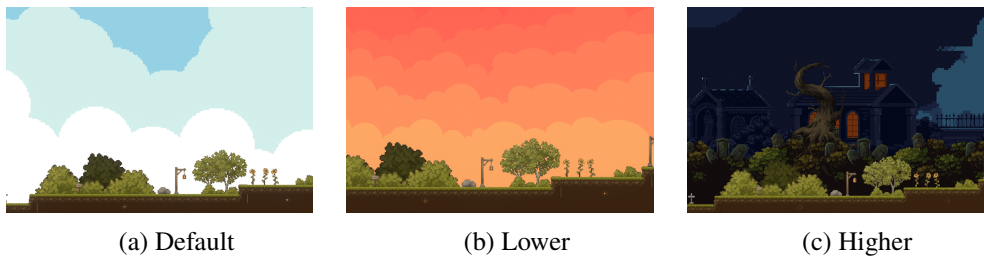


Figure 4.6: Different backgrounds in the game, based on harvested data

4.5.4 Enemies

We implemented 5 enemies for the game:

- A slime enemy that follows the player, randomly stopping, seen in sub-figure 4.7a.
- A rat enemy patrolling a section quickly, that when hit, gets temporarily stunned, seen in sub-figure 4.7b.
- A flying enemy that chases the player, when hit, becomes temporarily invulnerable, seen in sub-figure 4.7c.
- A floor creep enemy that does not move, but has a wide-ranged attack, seen in sub-figure 4.7d.
- An archer enemy that tries to shoot the player down, seen in sub-figure 4.7e.

Enemies' health is determined by the piano playing and each health tier gets a different colour in every enemy. The health tiers are as follows:

- **Tier 0** - 100% of base health

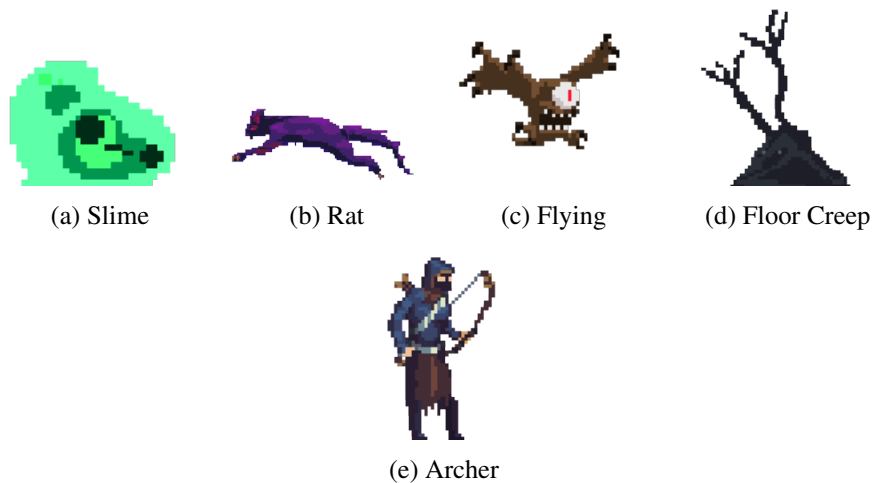


Figure 4.7: Enemies

- **Tier 1** - 120% of base health
- **Tier 2** - 200% of base health
- **Tier 3** - 250% of base health

4.5.5 Bosses

We designed 3 bosses, each with 3 attack patterns, determined by piano playing. Like the enemies, the bosses' health is also affected. The first boss, shown in figure 4.8, is a melee boss with the following patterns:

- **Pattern 1:** Patrol the area. When the player is close, attack.
- **Pattern 2:** Follow the player. When the player is close, attack. Randomly, dash into the player.
- **Pattern 3:** Follow the player. When the player is close, attack and jump. Randomly, double in size.



Figure 4.8: Melee Boss

The second boss, shown in figure 4.9, is a ranged boss with the following patterns;

- **Pattern 1:** Patrol the area. When the player is close, shoot. Randomly, shoot a semi-circle shape.
- **Pattern 2:** Follow the player. When the player is close, shoot. Randomly, shoot in rapid bursts.
- **Pattern 3:** Follow the player. When the player is close, attack and jump. Randomly, shoot in a wave shape.

The third boss, shown in figure 4.10, is a contact boss with the following patterns:

- **Pattern 1:** Idle. When the player is facing away, chase the player. Randomly, spikes appear under the player.
- **Pattern 2:** Idle and chase, timed. Randomly, double in speed
- **Pattern 3:** Chase and fly away, timed. Randomly, spawn 3 small ghosts.



Figure 4.9: Ranged Boss



Figure 4.10: Contact Boss

The bosses are affected in the first week by the music's difficulty, and in the second week by the music's intensity. When the metric is below 0.33, the first pattern is activated and the health is 80% of the original. If above 0.33 but below 0.66, the second pattern is activated and the health is 120%. When above 0.66, the third pattern is activated and the health is 150%. If no piano was played since the last game, the first pattern is activated, but health remains at 100%.

The criteria for this is the note that was most played during the last piano session. If no practice

occurred since the last game or the most played note was C, C \sharp or D, tier 0 is selected. If the most played note was D \sharp , E or F, then tier 1 is selected. If the note was F \sharp , G or G \sharp , then tier 2 is selected. Finally, if the most played note was A A \sharp or B, then tier 3 is selected. As tiers 1 through 3 change the enemy's health, the sprite colour is changed, while tier 0 stays with the original colour. The most played chord types also affect the probability of mobs spawning. Each chord type is associated with a specific enemy and the 3 most played chord types make the corresponding enemies more probable to spawn. When an enemy is killed a piano recording is played, if there is any, and then deleted from the database. This was done using the Maestro - Midi Player Tool Kit - Free Unity plugin, with a simple piano instrument playing the MIDI notes from the database.

Chapter 5

Exploring the Effects of Harvesting Activities

We conducted a qualitative study with 5 participants, with a duration of 2 weeks. Our goal was to understand how intertwining the gaming and musical experience could change either experience and how and if this harvesting could motivate participants to practise their instrument more. We sought to understand this by adding to their routine a game influenced by their practice sessions.

5.1 Participants

We recruited participants based on some requirements. One was that they played a keyboard instrument and enjoyed and had some sort of familiarity with playing video games. Another was having a digital keyboard with at least a MIDI out port or a USB port capable of transmitting MIDI. Recruitment to this study was done through friends and shared on a Discord group with researchers from the faculty. The recruitment survey included demographic questions as well as questions regarding their experience with the piano and their gaming habits. These questions were:

1. For how long have you been playing the piano?
2. How frequent are your practice sessions?
3. On average, how long are your practice sessions?
4. On average, how much time do you spend playing the piano in a week?
5. On average, how much time do you spend playing games in a week?
6. Which platforms do you usually play on?
7. What type of gamer do you consider yourself to be?

Table 5.1 summarises participants' demographics and answers.

Participants were 4 college students and 1 recent graduate, aged from 23 to 28. Participants ranged in experience and how frequently and how long they practise. In terms of gaming, all

	P1	P2	P3	P4	P5
Age	23	28	23	23	23
Gender	M	M	M	F	F
Q1	>10 y	<6 mo	1 to 5 y	>10 y	5 to 10 y
Q2	O	O	AE	FM	FM
Q3	30 min to 1h	<30min	<30min	30 min to 1h	<30min
Q4	<1 h	1 to 3h	>5h	1 to 3h	<1 h
Q5	3 to 5h	4 to 5h	3 to 5h	<1 h	<1 h
Q6	CPU, CNS	CPU	CPU, CNS	CNS	CNS
Q7	C-H	C-H	C	C	C

Table 5.1: Study participants' demographics

M - Male; F - Female; O - Occasionally; AE - Almost Everyday; FM - A Few Times a Month; CPU - Computer, CNS - Console; C - Casual Gamer; H - Hardcore Gamer;

participants play console games, and 2 also play computer games. No participant considered themselves hardcore gamers, while 2 considered themselves somewhere between hardcore and casual gamers.

5.2 Procedure

Having recruited the participants, we scheduled a one-on-one remote session with each participant. In these sessions, we collected more data regarding their practice routines and motivation for the instrument and walked the participants through the setup and procedure.

We asked the participants to fill out a questionnaire with questions directed at understanding how players felt regarding their mastery of the instrument and their habits of playing. These questions circled around the players' feelings about the practice sessions, for instance, if they felt like they needed to play more, or they felt like their sessions lacked in quality. This questionnaire can be seen in the appendix. We also tried to understand their current goals and rituals associated with the instrument, as well as what's motivating them to play currently.

To our questions, we added the Deliberate Practice in Music Inventory's (DPMI) questions [31]. DPMI is a self-report questionnaire, based on data from 1,558 musicians, ranging from amateurs to world-renowned soloists, measuring the deliberate practice in four subscales: Process improvement, Practice competencies, Mindless practice, and Task decomposition. We included these questions to better understand their playing habits, for instance, how they handle their mistakes or how they deal with a bigger goal.

Then, we briefly explained our study and walked the participants through the setup, explaining how to connect the cables and use the applications. After the setup was done, participants were asked to play the piano for around 3 minutes, so they had some data for the first game. They were given the freedom to mute themselves or leave the call so that they would feel the most comfortable while playing.

The participants played the walkthrough and completed one run of the game. They were

instructed to practice 3 more times and play 3 more games, after playing. Each session needed to be on different days. Each time they completed a game after playing the piano, players filled out a survey where they would rate how much they enjoyed their piano session and their game run and detailed what was different from the past games, guessing what was collected from the piano.

Due to technical difficulties, one participant only completed 2 full sessions. When players completed the required sessions, we scheduled a remote interview where we tried to understand if our approach had any effect in motivating them to play the piano and if either the gaming experience or the playing experience suffered changes in comparison. We also tried to understand if the harvesting was noticeable and which game elements were better for it.

5.3 Analysis

After all interviews were conducted, the recordings were transcribed, coded, and analysed leading to three themes. The themes we focused on were as follows:

- **Piano Experience was affected** - if the player's experience with the piano session changed because of the harvesting or setup, be it in how they played, habits or performance
- **Gaming Experience was affected** - if the player's experience with the game was different to other games because of the harvesting or setup, be it in strategy, habits or performance
- **Motivation to play the instrument was changed** - if the player's motivation to play their instrument changed because of the harvesting or setup

Throughout the analysis, new codes were created that could inform relevant ideas that were not yet captured by the initial codes. This codification was enriched with the short surveys players filled out after each session, to obtain information that may have not been stated in the interview. The data from the initial questionnaires with the data we gathered from the piano and game sessions was also analysed. The findings we obtained from this analysis can be seen below, in chapter 5.4.

5.4 Findings

In this chapter, we discuss our findings from the analysis of the interviews and data collected throughout the study.

Given that we did not explicitly say how the harvesting was being done, not all features were noticed in the gameplay. The most noticeable effect was the **recordings** because people could easily understand that it was a snippet from their session, even if they did not know what triggered the snippet to be recorded or what triggered it to play in the game. The **background change** was also noticed and one player even understood that it was from the intensity of their playing.

"I noticed right away that, instead of being nighttime and everything being scary and hard, it was much easier and calmer. And, as I played [the game] immediately after [playing the piano], I liked to [see the difference]" - P5

In general, players noticed the **bosses' different patterns**, but none remembered experiencing all of them, possibly for not having enough sessions, or their practice sessions being similar.

"I noticed that in one [game, the boss] started to jump suddenly and in one there would be spikes and in the other it would spawn the smaller ghosts and it wouldn't happen at the same time" - P2

Only one player noticed that the **enemies' colours** changed between sessions, possibly because their most played note was in the same tier through all the sessions and one player had a hunch that the **enemies health points** were changing. Players did not notice they were getting **skill upgrades**, much less feel its connection to the piano, even though they noticed the different clothes in their character. One player even thought they would lose skills if they practised more piano, possibly because the bosses and enemies were harder.

"[The skill upgrades] are not noticeable during the game session, because it's not a thing that was explicitly stated. Normally, there's some kind of obvious feedback, so, I was also not expecting that to happen without me being informed, in some way" - P1

In general, while the players would normally take the longest route to finish the game, they felt like the game was easy, however, too easy and with little variety for the more experienced players. Players enjoyed the possibility to choose their route, and with that, the duration of gameplay, but felt like the routes were not explicit enough in-game and they would not have known they existed if we had not talked about them. Regarding the genre of the game for this approach, it was well suited and almost every player compared it to Super Mario, so it was a game they could easily understand and how it's played. Other genres were suggested such as MMO, to leverage the social benefits and competition, and RPGs or a relaxing game, like Stardew Valley, after playing a hard session. This strategy could also be implemented in a strategy game, but if the piano was part of the strategy, it could alter the practice a lot.

"I think that with more variety I would do this gladly. I would always have the piano connected to the game. And better yet if it was a relaxing game, like Stardew Valley." - P3

Below we expand upon our findings on the impact our approach had in motivation to play as well as the differences in musical or gaming experience and the improvements we think are needed.

5.4.1 Impact on Motivation to Play

Regarding motivation to play, no player noticed a tangible difference. If they had more will to play, it was mostly out of curiosity about what would happen and the novelty effect. To understand this, we need the context of why they are playing in the first place. Our participants were mostly playing the piano for years, or they were just playing as a hobby because they enjoyed it as it was. As studies show, external motivation does not work when the player is already intrinsically motivated. Another point is how much they enjoy playing. One player stated that they were inconsistent with their study but that the game would not help them that much, for they don't care for gaming enough to motivate them. For instance, this participant is already intrinsically motivated to play the piano:

"I play the piano as a hobby [...]. So, it's a thing that in itself, I like to play [the piano], because I enjoy playing [the piano], just as I like to play [games] because I like to play [games]. But I didn't feel the need to play [the piano] just because I wanted to play [the game]." - P2

Additionally, as much as we wanted to keep the musical experience intact, the setup and requirements of the study negatively impacted the motivation to play. Players felt there was too much friction between the moment they decided to play and finishing their practice session. This was for multiple reasons, mainly because the approach involved connecting the computer to the piano and not all participants had them close together, so it would require moving one of the components, connecting the cables and making sure that it was properly collecting the notes. Another reason was that only the last session played would have an impact, so players felt the necessity to have a session without breaks, which meant that they would delay it until they had more uninterrupted time, while normally they would play, even if it was just for a couple of minutes. One player had a piano they were not accustomed to, given that we required a digital piano with a port capable of transmitting MIDI messages, this also negatively impacted their motivation to play, as they did not feel comfortable with the hardware, and had to work around a lot of technical difficulties. Overall, we can see how the logistics and requirements of the setup and harvesting negatively impacted the motivation to play the instrument, best illustrated by this participant:

"[...] bringing the computer [...] and the charger and the iPad [...] and I have to connect all of that to the keyboard and then bring everything back up. [...] it's just the logistics around that that make it complicated." - P4

To summarise this approach would work best with someone who was not intrinsically motivated, most likely a beginner, who enjoyed playing games enough to be a good reward for their effort in the piano, and the harvesting would have to be expanded upon and improved, to keep their practice as close as possible as what they are used to.

5.4.2 Differences in Musical Experience

Regarding the differences, there were some noticeable ones. We define musical experience as what players feel during the practice session and the way they interact with the instrument. In general, players felt intrigued by the harvesting, so they would play differently, try to play differently each session to try to understand their effect on the game. Playing the recordings back influenced a player to try to play the song better each time, as they did not want to listen to their mistakes:

"It affected my playing because I was curious about what going to happen. [...] it affected the songs I would play [...] and my will to play [the song] right, because I did not like it when the game played a recording and it was horrible. [...] The better I played, maybe it would play a snippet of when I played something well." - P5

Capturing a snippet of their playing and playing it back to the players later seemed to be a good way to provide the players with feedback and encourage their practice. This could extend to other areas. In this case, we played the snippet back in the game, but we could play them, for instance, as their phone or computer's notification sound, or embedded in other game mechanics and explore how that would affect the player's motivation to play.

Yet, the harvesting being hidden can lead to mixed results. On one hand, it encouraged players to explore, and play differently and prevented the exploitation of the game, as we can see with this participant:

"[...] when I realized that [the game] was always playing the first song I played, I changed the first song I played [in each session] - P1

On the other hand, it allowed players to incorrectly guess the changes made, for instance, one player thought that they would be stronger in the game if they played less:

"[...] if I played too much it would affect how the game was played and I wanted a smoother, easier game. So, I would shorten my piano playing, because I did not want it to make my game harder." - P2

Obviously, this is not ideal. Possibly, this could be bettered by stating the effects the session had in the game explicitly but without mentioning what accounted for these effects. Still, it could give room for incorrect guesses. This is not necessarily a bad thing, but it depends on the change (i.e. playing more time versus playing less) and how different of a practice session it would lead to. Overall, a positive small change in the musical experience would be good, but we don't want to interfere with players' long-term goals for the instrument, so we don't want players to guess and act on harvesting algorithms that would go against these goals.

5.4.3 Differences in Gaming Experience

Given that a game influenced by a real-life activity is not something you play every day, we expected it to affect the way players experienced the game, compared to other titles. However, by

analyzing the participants' interviews, we concluded that most participants did not feel like their experience was any different. This was mostly because the differences the piano would bring into the game did not bring new experiences or widely different strategies, so players did not experience a gameplay that would morph according to their music but more of a normal game with an RNG dictated by some hidden criteria collected from playing the piano. Participants were expecting a different gameplay or a more noticeable effect on the piano, like generating the map procedurally, by the data collected.

"I didn't think [the changes] made the gaming experience that different because they didn't change the strategy, or difficulty, or something like that, but it brought a different vibe" - P1

"In terms of actually playing the game, [the changes] didn't affect [the gaming experience]" - P2

Moreover, there were no clear indicators of what the piano was doing to the game, this was done so that players could not exploit the game and alter their practice sessions, however, it also meant that they were not generally able to create a correlation between what they had played and the game changes. Player progression was the most confusing effect, as it lacked indicators for how strong the character was and it was hard to tell the difference between games. The players didn't realize they were getting stronger every time because they played the piano, so they thought they were only clearing the game faster because they had gotten better at it, reducing the harvestings' usefulness and leaving the game as a normal platformer. While we want the game to be more of a side activity to motivate people to play the piano, if the game is not interesting enough or if the effect on the piano is not noticeable, then we will not achieve that motivation. The most noticeable aspect was playing records of their playing, and even that, was merely aesthetical. Moreover, if the gameplay was changing it would stimulate their curiosity and eventually motivate them more. Another point is that the game progression is distinct from the player's musical growth, if these were more connected, the game could serve more of a tracker for progress, as it's easier to notice progression with skills and levels in a game than with knowledge and learning in real life.

"Ideally, as a player would make mistakes in their practice session, maybe [the game character] would be weaker" - P3

"Instead of being random, I think [the skill upgrades] should be influenced more directly. Some criteria to define which skill would be incremented." - P3

Additionally, it's important to note that the difficulty (or fairness) is important to their motivation. If, for instance, the player likes a calmer game after a harder practice session, then the harvesting should not give them a hard game, as it could have a negative effect. In our approach, the difficulty changes between sessions, given the enemies' health and patterns being variable, with this in mind, it's important either to have settings where players can choose their difficulty or

a game that could adapt the difficulty to the players' gaming style. Ultimately, we should consider the musical and gamer needs, to create a strong relation between them and leverage one another. Unfortunately, in our approach, the game was just too separate from the game to affect motivation.

5.4.4 Improvements

Upon the analysis of the participants' interviews and data collected, we've concluded that improvements in various areas of our approach are needed.

Internet Connection

Throughout the study, some technical issues compromised the immersion of some players. Most commonly, a lack of internet connectivity meant that the levels were not loading correctly right away, with the effect of their piano playing. Although this did not happen in our study, it could also be a problem if the user did not have stable internet connectivity while collecting data, as it could result in a loss of data. Even though the data is sent in individual blocks after being played, the system only checks for internet connectivity at the start and warns the player if it's not able to connect to the database, but if the connectivity is lost during the session, it does not warn the player their data was not sent. Then again, the system should not require the player to constantly check the UI for errors, as it would negatively influence their piano-playing experience. A possible solution would be to cache the session data internally, so both applications could run offline.

Equipment

As stated previously, this study relied on the MIDI protocol, meaning players needed to perform on a digital keyboard with MIDI OUT ports (USB B or MIDI ports). This created two issues. One is that not everyone played on a digital keyboard. For instance, one participant is accustomed to playing an upright piano. This participant had a keyboard, but, being notably cheaper, it was smaller (fewer notes), the keys were not weighted and the sound was completely different to an acoustic piano. This can, and did, negatively impact this participant, because they had to play in a different way they would normally do. As this participant states:

"It was very hard to do anything that's even a little bit more complex from a technical standpoint, in that keyboard." - P5

Another issue is with the MIDI ports. To be able to connect a MIDI port on the keyboard to a USB port on the computer, we need a MIDI interface. These interfaces range in price and quality. Two participants had a MIDI port and we used a MIDI to USB cable, which is cheaper and lower quality. Unfortunately, this cable was faulty and interfered with the notes collected (in this case it treated the use of a sustain pedal as an E4 note). One of the participants noticed this and tried to limit their use of the pedal, ultimately interfering with the piano-playing experience.

For our approach to have an effect without disturbing the piano playing, the players should play the way they normally do, with their accustomed setup and without having to think if the

cables are working. This could be improved with an additional audio recognition software that automatically recognized and collected the notes.

Routine Integration

After analysing the data, we can see how some of the harvesting features were not compatible or fully supported by the harvesting and it did not take into account the player's already existing routine. For instance, it assumes a session is uninterrupted. As an example, it would not support a Pomodoro Technique (play for 25 minutes, rest for 5) and if the player wishes to interrupt the practice for a couple of minutes, the first half is completely discarded. One participant found having to play right after each small session to go against their routine, stating:

"That's what I usually do, I play for a bit and then I leave." - P2

The mechanics associated with chords are also at fault because not all players focus on or play chords at all. This can cause players to have little to no recordings and less distribution of enemy types. While one player had this experience:

"There was not enough game to be able to listen to all of the recordings." - P5

Others had this experience:

"I only heard the recordings in the first zone." - P2

This approach should also take into account the player's goals for the instrument and support them in achieving them. The player may be trying to improve their session quality and not quantity, for instance. As best put by this participant:

"This ideally would be tailor-made to what the player wants. Their objectives, right? If you aim to learn a song and you're playing it for 3 weeks, maybe a game that's always going to have the same changes would not motivate you." - P4

The differences in the player's practice routines, rituals and goals should be taken into account and be highly customizable. The effect on the game should try to maximise the goals and leverage or potentially better the already existing routines.

Piano and Game Dynamic

In this study, we required the player to play the piano before playing the game. This tried to make the piano more important and use playing the game as motivational fuel for playing the piano and we also did not want the game to influence the piano. Yet, some players felt limited by this rule:

"I felt a bit constrained for having to play the piano first and then play the game. [...] I couldn't just play the game without the practice session. So there's a formula that needs to be followed, to enjoy the game as it was supposed" - P3

Instead, the piano and the game could have a more symbiotic dynamic, as long as the plans the players made for the piano practice are altered as little as possible. Another limitation is that the game is only influenced by the last piano session. A couple of issues arise from this. One is only regarding the last uninterrupted session. This was a source of frustration for some players, as we should not discard sessions if we want to motivate people to play more piano.

The other issue is that it doesn't support the tracking of progress. Progress is hard to track from memory, yet if we are collecting data, we should be able to illustrate the player's progression, either through statistics or game mechanics, as some players were expecting.

"It would be great to be able to see my progress with the instrument, with some statistic" - P1

Additionally, it doesn't allow room for error, if the player accidentally quits the game or tracking app, or if the app loses connection to the internet of the piano.

Harvesting

There were some issues with the way data was harvested and the related effect on the game. Firstly, the way the recordings were taken did not take into account how the players practised the piano. We collected a recording of 3 seconds after a player played a chord. As already stated before, the amount of played chords can drastically change between players. Some players play a lot of chords and, hence have a lot of recordings that would never even be played. Players who started a session with a repetitive song or a song full of chords never got to hear the second song they played, often ending up with repetitive recordings. On the other hand, players who don't use a lot of chords in their playing barely got any recordings at all, one player even stated that they would only play in the first room, meaning they got only about 5 recordings. This leads to a very unbalanced experience. Furthermore, associating the chord type with an enemy may not be the best way to balance the gameplay. The most common chord is the major chord, the majority of songs would have a major chord, while a diminished chord is rarely used. Even though the chord type only influences the probability of spawning, this makes some players rarely encounter the enemy associated with the diminished chord, and have an abundance of enemies associated with the major chord.

It ties in again with the differences in the way players practise their instrument, for instance, if a player is practising the same piece for a long time, the enemies that would spawn would be similar and the recordings would be the same. We can see how having the same experience every game wouldn't motivate the player to play the piano the way they intended to.

The way the harvesting was implemented, players could technically play the piano for 1 minute and play the entire game once. In terms of motivation, a 1-minute session and a 3-hour session are not created equal. Right now, it can have the reverse effect of what we wanted, encouraging the pianist to play less. To guarantee the game supports playing the piano and not the inverse, we need to achieve a healthier balance in play times.

"I would focus on encouraging the person to be more healthy [...] It does not need to give points just for playing, maybe if you played [the piano] for 15 minutes, you could play [the game] for 15 minutes. [...] Because playing [a game] can be healthy, but not that healthy. So I think playing [the piano] is more important than anything"
- P2

As best said by the participant above, this could be leveraged by proper player progression. The way we've implemented it, if the player played the game after a practice session, of any duration, they'd receive a level up in a random skill, between strength, speed and health. To encourage the player to play more, we could, for instance, tie the health of the player to the duration of the practice session, or add a different stamina skill, something that encourages players to perform for a longer period. Another solution would be to allow playing the game for only as much time as the piano was played, since the last game was played, essentially accumulating piano sessions.

The main idea is that the effort put into playing the piano should be proportional to the rewards the players get in the game. This is not happening right now, for a player is equally rewarded for playing a little or a lot. The increase in skills instead of one level at a time, should happen by increasing a percentage of the skill. A participant pointed out that players were not punished for lack of commitment to playing the piano, for instance, if a player stopped playing for a month, they would have the same skills. They suggested the skills should fade out slowly, mimicking the way people lose a skill in real life if they don't practise it.

"I would increase the skills linearly.[...] However, maybe I would add a mechanic that if I did not play for some time, I would slowly lose skills [...] as in real-life" - P2

Lastly, even though participants could tell some differences, and some even figured out what was being harvested and the effect on the game, this was not enough, as the gameplay was never really different. Enemies were virtually the same, with the same strategies to defeat, the player's skills did not alter the players' strategies and while the bosses did require different strategies depending on the pattern, we needed to ensure different patterns would be triggered and these strategies were different only in small details. The rest of the effects, like the background and music, were inconsequential to the gameplay.

"I think the gameplay should be more diverse [...] I think the gameplay never changes according to the session. It's unchanged." - P3

Game Mechanics

In terms of game mechanics and features, some players felt like the difficulty of the game rooms did not progress smoothly. They thought that the regular enemies were too easy to defeat, in terms of strategy, compared to the bosses.

"I felt like the enemies were too basic" - P1

Regarding the bosses, P2 thought that the second boss was harder than the last one and that *"it would make sense that the last boss should be the hardest, so either we could switch those two bosses, or make the last one harder"*. That being said, these opinions varied, being more prominent among more self-proclaimed hardcore gamers who dedicated more time to playing video games. The other, more casual and less experienced, players thought the game was easy enough for them and, while the first time they played was hard, they found it easy to learn the controls and strategy. For our approach to work, we need to appropriately support the gamer's skill level and desired difficulty level.

One thing that should be improved upon is the spawning of enemies, as they sometimes spawned, or fell into the same platform, making it harder to kill them, as P5 said: *"It was too hard when [the enemies] would go close to each other"*. The recordings were reported to be too quiet, and hard to hear with the background music playing. The game should have a way to control the volume of all the individual elements, however, because we wanted the user to experience the changes in background music, this was not implemented.

In general, the players wished the game was more complete, having more levels and different enemies and strategies to defeat them, with an overarching progression between sessions, basically a polished game with more variety.

Supporting the player's needs

As already mentioned before, when mentioning routine integration, to successfully motivate someone, it's important to support their needs, goals and plans. This was not regarded in this approach, be it in the way harvesting was done or in the setup itself. This means that for this to work, it needs to be highly customizable, from the piano they are using to how much of the game they can play from a single practice session.

The quality of the piano is important to the player's performance. Hence, we should support every keyboard, from small digital keyboards to acoustic ones, to reach the most people possible. This would require software with note detection from audio. It's also important to support the player's existing skill. How should the harvesting be different for a beginner and an experienced player?

Chapter 6

Conclusion and Future Work

While gamification has been increasing in popularity, it only scratches the surface of connecting a game to an activity. In this project, we expanded on this broad concept of motivating action through game elements. We proposed a new way, harvesting data from an activity, without changing it, and leveraging this data in a game separate from the activity. To achieve this, we set out to build an application that could harvest data from an activity, and a game using algorithms that could leverage this data. This concept was applied to playing an instrument, in this case, the piano, as it is easily connected to a computer, but we believe the concept could be applied to any activity, provided there are ways to efficiently harvest the activity without interfering with it. To inform our decisions, the state-of-the-art was reviewed and two design workshops were conducted, one with game researchers and another with musicians. Then, a data collection application and a platformer game were designed and implemented, through an iterative process. Our hypothesis was this would increase their motivation and engagement with their instrument.

A study was conducted with 5 participants, aged 23 to 28, who tested our approach for 2 weeks. Analysis of the data revealed some potential for the harvesting, yet, the game elements that brought the piano into the game did not help the approach reach its full potential. This was due to multiple reasons, for instance, players not seeing the changes from game to game, or if they did, they could not correlate them to the piano sessions. While this approach may not be the best at helping players who already are intrinsically motivated to play the piano more consistently, it's still not clear if harvesting can help people who are just starting out, or who are not as motivated.

Using snippets from the participants' practice sessions was the most noticed feature by the players and it showed potential in moulding the players' practice, leading a participant to try and improve their performance each session. Future work may include these snippets in other contexts and figure out how to maximise their potential. Our study also showed that participants were more inclined to features that would change the gameplay and strategy entirely, instead of the aesthetic, like the backgrounds and music. Using that knowledge as guidance, it's needed to correlate which effects on the game would maximise the motivation levels.

Above all, further research needs to be conducted to figure out the harvesting's place in motivation, according to their skill level, current habits, consistency, goals and motivations for the instrument.

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Appendix A

Study Initial Questionnaire

1. "I feel like I should play..." (1- less, 5- more)
2. "I feel satisfied with the quality of my practice sessions" (1- Completely disagree, 5- Completely agree)
3. What would make you more satisfied with your practice sessions?
4. Do you have an objective or goal you aim to achieve when you play? If so, which?
5. What motivates you to play currently? (Choose one or more)
 - (a) Parents
 - (b) Friends
 - (c) Teachers
 - (d) Gamified Application (ex: Simply Piano, Yousician, Rocksmith, etc.)
 - (e) Personal objectives and goals
 - (f) Habit or routine of playing the instrument
 - (g) Other option...
6. Do you ever feel like you should play and don't? Why? (Choose one or more)
 - (a) Tiredness
 - (b) I don't feel good enough
 - (c) It's too hard
 - (d) I feel overworked or stressed
 - (e) I struggle to create or maintain a habit
 - (f) I can't find the point of playing my instrument at that moment
 - (g) Don't know/ Not applicable
 - (h) Other option...

7. How do you feel regarding your mastery of the instrument?
8. Do you have any technique or personal ritual associated with the practice of the piano? If so, which?

Appendix B

Recurrent Questionnaire

1. How satisfactory was the last game session(s)? (1- very unsatisfactory, 5- very satisfactory)
2. How satisfactory was the last piano session(s)? (1- very unsatisfactory, 5- very satisfactory)
3. How do you think the piano affected your game session? Did you notice any differences compared to the last session?
4. Any opinion or comment?

Appendix C

Interview Script

1. General questions about the game:

(a) What did you think of the game? Which parts did you enjoy more and which did you enjoy less?

(b) Did you find the game hard? Was any part of the game confusing?

2. Game experience:

(a) Did you feel any difference in your experience of playing the game? If so, which?

(b) Did the game affect your motivation, in any way?

3. Piano experience:

(a) Did you feel any difference in your experience of playing the piano, for the game? If so, which?

4. Piano experience:

(a) Did you feel any difference in your experience of playing the piano, for the game? If so, which?

5. Explanation of the differences:

(a) Did you reach any conclusion about what the piano was changing in the game?

(b) Skill Progression:

i. What did you think about the progression of your character? Do you think you were getting stronger, or faster?

ii. What if the piano was affecting it, how do you imagine it?

iii. There were 3 stats: Dexterity (speed), Strength (damage), and health (health bar). When you played for the first time, according to the intensity of your playing, you received a couple of random boosts. Whenever you would play the piano and then play the game, you would receive a random skill increase.

Did you notice it? What do you think about this interaction?

(c) Music and Backgrounds:

- i. What did you think about the aesthetic of the game? Did you notice anything in the music or the ambient?
- ii. What if the piano was affecting it, how do you imagine it?
- iii. In the first 2 times, when you played the piano and then you played the game, the background and music would change according to the intensity of your playing. Then, we switched to the complexity of your playing. Did you notice it? What do you think about this interaction?

(d) Enemies and bosses:

- i. What did you think about the enemies and bosses?
- ii. What if the piano was affecting them, how do you imagine it?
- iii. In the enemies, when you played, the type of chords you played the most influenced the probability of certain enemies spawning. Your most played note would give them a different color and change their health bars.
In the bosses, what we harvested was the complexity, and after 2 sessions, the intensity. The effect was also their health bars and according to the collected data, the boss had a different pattern of behaviour.
Did you notice it? What do you think about this interaction?

(e) Recordings:

- i. Regarding the recordings that would play, did you figure out when they were played? Did you reach a conclusion about what was the criteria for recording a snippet?
- ii. When you played a chord, we recorded a 3-second snippet. And then they were played when you would kill an enemy.
What do you think about this interaction? Would you do it differently?

6. General Questions:

- (a) Did you enjoy the genre of the game?
- (b) During this study, you've experienced a possible example of a game affected by the practice of an instrument. What is your opinion about the games that include this type of interaction?
- (c) Is there a future for these types of games? How do you see it evolving? What would you like to happen? In what way?

Appendix D

Workshop and Study Recruitment Survey

1. Do you play any instrument?
 - (a) Which instruments do you play?
 - (b) How long have you played your instrument?
 - Less than 6 months
 - 6 months to a year
 - 1 to 5 years
 - 5 to 10 years
 - More than 10 years
 - (c) How many times per week do you practice your instrument?
 - (d) On average, how long are your practice sessions?
 - Less than 30 minutes
 - 30 minutes to an hour
 - 1 hour to 2 hours
 - More than 2 hours
2. Do you usually play games?
 - (a) What types of games do you play?
 - Board games
 - Casual games (mobile)
 - Console or computer videogames
 - Other option...
 - (b) On average, how much time do you spend playing games in a week?
 - Under 1 hour
 - Between 1 and 3 hours

- Between 3 and 5 hours
- More than 5 hours

3. "In digital games, I consider myself..."

- A casual gamer
- Between a casual and a hardcore gamer
- A hardcore gamer
- I don't know

Appendix E

Ideas for Game Mechanics List

E.1 Initial Ideas

Table E.1: N- Novelty, R- Resources, U- Unlocks game, D- Difficulty

Upon playing the piano...	Effect on Game
Unlocks avatar costumization	N
Snippets of the performance are played back in the game	N
Changes the narrative of the game	N
Unlocks new part of a map	N
Unlocks rooms	N
Unlocks biomes/areas	N
Unlocks new weapons	N
New blocks/objects	N
New enemies	N
New challenges	N
New rewards (with different effects)	N, R
New Secrets (pickables or subareas)	N, R
New debuffs (poison, fire,...)	N
Unlocks ability	N
Unlocks class	N
Unlocks research	N
Generates a resource	R
Loses a resource	R
Unlocks a recurring item	U
Unlocks # of jumps/steps	U
Revives character/ heals	U
# of tries	U
Time based change	U
Changes a puzzle	D
Changes enemy spawns	D
Game gets easier from being nearly impossible	D

E.2 After Workshop with Game Researchers

Table E.2: N- Novelty, R- Resources, U- Unlocks game, D- Difficulty, M- Mood, C- Control of the Character, Ru- Rules

Upon playing the piano...	Effect on Game
Enemy wave density	D
Mob variety	D
Spawn rare enemies	D, Ru
Dexterity	C
Player Speed	C
Stamina	C
Health	U
# Lives	U
Unlocks # of movements	U
New areas	N
Level time limit	U
Level size	D
Mood of the areas	N, M
New NPCs	N
Changes world creation	Ru
Played back in the world music	N, M
Played back in mob sounds	N, M
Changes the narrative of the game	N, M
Visual Effects	N, M
Changes Dialogue	N, M
Quality of abilities/debuffs	C
Unlocks class	N
New debuffs	N
Unlocks ability	N
Boost specific abilities	C
Changes player stats	C
Pickup speed	Ru
Task speed	Ru
New weapons	N
New rewards	N
New Collectibles	N
Resource generation	R
Loses resource	R
Changes stocks	R
Share resource	R
Unlocks avatar customization	N, M
New playable characters	N
Unlocks research	N
Shop with redeems	R

E.3 After Workshop With Musicians

Table E.3: N- Novelty, R- Resources, U- Unlocks game, D- Difficulty, M- Mood, C- Control of the Character, Ru- Rules

Upon playing the piano...	Effect on Game
Enemy wave density	D
Mob variety	D
Spawn rare enemies	D
Enemy difficulty	D
Enemy loot variety	R
Dexterity	C
Player Speed	C
Stamina	C
Health	U
# Lives	U
Unlocks # of movements	U
New areas	N
Level time limit	U
Level size	D
Mood of the areas	N, M
New NPCs	N
Changes world creation	Ru
Hand Coordination Challenges	D
Obstacle count	D
Game/event velocity	Ru
Played back in the world music	N, M
Played back in mob sounds	N, M
Changes the narrative of the game	N, M
Visual Effects	N, M
Changes Dialogue	N, M
Weather	M
Color palette & OST	M
Quality of abilities/debuffs	C
Unlocks class	N
Pickup speed	Ru
Task speed	Ru
New weapons	N
EXP multiplier	Ru
Skill tree	C
Character resistance	C
Character physical capacity	C
New rewards	N
New Collectibles	N
Resource generation	R
Loses resource	R
Changes stocks	R
Share resource	R
Unlocks avatar costumization	N, M
New playable characters	N
Unlocks research	N
Shop with redeems	R
Get reward items	R
Get healing items	R