Developing and evaluating a Musical Attention Control Training computer game application

Master's thesis in MSc Game and Media Technology

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Abstract

Recently, Neurologic Music Therapy (NMT) has been a prominent intervention for alleviating cognitive impairment symptoms. Specifically, Musical Attention Control Training (MACT) has been shown to alleviate attention control problems of participants, such as Parkinson's Disease (PD) patients. However, regularly attending MACT sessions can be challenging, which is further exacerbated by the current global pandemic. The question arises as to how the benefits of MACT can be more easily accessible. Serious games have proven to be a successful intervention for cognitive impairments. However, to this day, there is no serious game that is based on NMT. In this study, a novel approach was followed to research the plausibility of and develop a serious game that emulates an MACT session and is tailored to the needs of PD patients. Afterwards, an experiment was conducted to gauge the game intervention's efficacy in attention control training. Participants (n=13) were asked to play the game for three weeks and complete a questionnaire and three attention tests before and after the play sessions. Gameplay, questionnaire and attention test data were collected and analyzed in order to draw conclusions about the game's efficacy. Results indicate a positive trend in sustained and selective attention among participants. These results show that gamified MACT could be a promising supplement to conventional MACT for improving the quality of life of attention-impaired patients.

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Table of Contents

1 Introduction

Cognitive processes of the human brain are the cornerstone of functioning in our everyday life. They dictate how we think, feel and act. This is why it is important to identify when these processes are malfunctioning and intervene. Music has proven to be valuable in cognitive training (Strait & Kraus, 2011; Modi, 2018). An intervention that has been more prominent lately is *Neurologic Music Therapy* (NMT) (Thaut & Hoemberg, 2014). It is a set of standardized music therapy protocols that are used to treat and alleviate neurological symptoms. There are a multitude of groups that could benefit from NMT, including those with *Parkinson's Disease* (PD) and *Parkinsonisms*. NMT can take multiple forms. One of them is *Musical Attention Control Training* (MACT), which specifically targets the attention control systems of patients. This is specifically relevant for PD patients, since studies have shown that they display attention deficits (Crosiers et al., 2012).

MACT sessions take place in regular intervals (usually once a week), individually or in groups. However, attending an MACT session regularly can be challenging and many therapists claim that meeting once a week is not enough. The current global COVID-19 pandemic poses additional challenges due to social distancing measures in almost all countries in the world. PD typically affects people of older ages, who happen to be a high risk group when it comes to contracting COVID-19. Furthermore, the benefits of at-home training as a supplement for traditional music therapy have been highlighted (Agres, Schaefer, Volk et al., 2021).

The question that arises is how we can efficiently develop an intervention that complements MACT and which the patients can do independently at-home, that also caters to PD patients' needs and provides similar benefits to those experienced in traditional MACT sessions.

In recent years, serious games have emerged as an effective, scalable and motivating way to train cognitive functions (Boletsis & McCallum, 2016; Kueider et al., 2012). There is a plethora of games that aim to function as intervention for various cognitive deficits, including attention (Green & Bavelier, 2003; Franceschini et al., 2013; Gamito et al., 2017). Music therapy is a prime candidate for gamification, since it can benefit from the scalability and entertainment that games offer. To this day, there is no serious game that aims to interpret MACT's clinical protocols as gaming interactions.

In this thesis, we research and compile a list of requirements for a PD-tailored game intervention that emulates an MACT session. We then develop a serious game that follows the established requirements. Using the developed game intervention, we perform an experimental study that evaluates the game's efficacy of improving the attention of healthy participants, and provides some insights as to how users interacted with it. To the best of our knowledge, this game functions as the first serious game application of an NMT protocol.

This thesis is structured as follows: Section 2 lays the scientific groundwork for basing the design decisions. Section 3 presents the research questions this thesis intends to answer. Section 4 explains and illustrates the methodology followed in order to answer these questions. Section 5 presents an overview of the results. Finally, Section 6 discusses the conclusions that can be drawn based on the findings and presents the limitations and avenues for future work.

2 Literature review

In this section we provide concise scientific overviews on the topics that are relevant to this research. First of all, we cover attention, why there is a need to measure it and how it can be done. Next, there is a section about PD, in which we present the way that the disease manifests itself and what complications arise. Afterwards, we demonstrate the role of music in cognitive training before doing the same for serious games. Following that, we investigate the functions of game music and showcase a parallel between a specific video game music function and music therapy. Finally, after illustrating how *dynamic difficulty adjustment* (DDA) can be beneficial to a serious game, we conclude the literature review by highlighting the importance of UI and UX design in this context of this research. The section concludes with a table of design decisions that stem from the literature review.

2.1 Attention and its measurements

Attention is a cognitive function that humans use in their everyday life in order to perform tasks. Although researchers have a common understanding of what attention is and how it works, there is no consensus about what is the best way to model and measure it.

However, the most common framework in the literature to define attention is that of Coull (1998). Coull separates attention into four distinct sub-functions: attentional orientation, selective attention, sustained attention and divided attention.

Attentional orientation refers to the ability to focus on a specific stimulus. Selective attention refers to the ability to ignore irrelevant stimuli in order to single out the relevant one. Sustained attention is the ability to stay focused on a specific task without outside motivation. Divided attention is the process of focusing on more than one relevant stimuli simultaneously.

These functions serve as the basis for multiple tasks humans perform daily. Reading a book or driving to work require one or multiple of those subtasks in order to be performed successfully. Therefore, it is of utmost importance to be able to verify if these abilities are underfunctioning.

Multiple attention tests have been developed with that goal in mind, i.e. to measure and identify deficits in the attentional abilities of people. Below, we present a couple of those tests.

Test of everyday attention (TEA) (Robertson et al., 1994) is a collection of pen and paper tests that was developed with the goal of being able to measure all four types of attention that were listed by Coull (1998). Additionally, their format was designed so that each sub-test would resemble an everyday task, such as looking through a phone book or listening to the lottery numbers. The *d2 test of attention* (Brickenkamp, 1962) measures selective and sustained attention. The participant is presented with an extensive array of letters that have up to two straight lines above and/or below them. The letters can be either a *d* or a *p*. They are then asked to identify and mark only the entries that are the letter *d* and a total of two straight lines (hence the name d2). For example, if there is a letter d with only one straight line below it, the participant should not mark it. In an article about the validity of the d2 test, Zillmer & Kennedy (1999) compared it to other standardized tests of attention. In cases where the test results of the other standardized tests were positive, so were the d2 test results and vice versa. This proves that the d2 test is a viable option concerning measurements of sustained and selective attention.

Since attention is a cognitive task, naturally the aging process might affect it. Indeed, McKay et al. (1994) found out that the capacity to sustain attention deteriorates over time. They also found that this effect is not affected by how old the participants were at the start of the experiment. Salthouse, Rogan & Prill (1984) made a similar observation, that older participants found it more challenging to perform two tasks simultaneously, even when the task difficulty was individually adjusted to each subject.

2.2 Parkinson's disease

Parkinson's Disease is a neurological disorder that manifests mainly with motor symptoms, such as akinesia, bradykinesia, tremor, rigidity and gait control deficits (Moustafa et al., 2016) but also with *non-motor symptoms* (NMS), such as attention deficits (Crosiers et al., 2012), depression, pain or sleep disorders (Chaudhuri, Healy & Schapira, 2006). Symptoms vary from patient to patient, with almost all of the patients being of older age. Practitioners rely on rating scales to categorize the symptoms of patients, based on severity. There are three commonly used scales: Unified Parkinson's Disease Rating Scale (UPDRS) (Fahn & Elton, 1987), Hoehn and Yahr scale (H&Y) (Hoehn & Yahr, 1967) and Schwab and England ADL scale (Scwab & England, 1969).

Motor symptoms are easily noticeable and due to that, in many cases lead to the discovery of the disease. NMS, however, are not as easy to recognize. In fact, NMS can often be present even before diagnosis, are often under-reported and *"dominate the clinical picture of advanced Parkinson's disease"* (Chaudhuri, Healy & Schapira, 2006). Indeed, a large study (n=215) was conducted (Crosiers et al., 2012) in which patients were asked to identify their NMS based on the Non-Motor Symptoms Questionnaire (NMSQuest). The mean symptoms per patient was 8 out of the 30 reported NMS of PD. The study also shed light into the most prevalent self-reported NMS. Urinary urgency, nocturia, insomnia, attention problems and orthostatism were the most frequent ones. In particular, attention problems were reported by almost half (45.5%) of the study participants. Additionally, it showcased that the number of NMS increases along with the disease's Hoehn & Yahr scale. Other NMS that are reported in the literature are deficits in cognitive tasks, such as immediate recall of verbal material, language production as presented by Cooper et al. (1991) in a randomized control trial.

There is a plethora of studies that look into the disease's progression over time. The vast majority of the studies reviewed noted a deterioration of the symptoms, both motor and non-motor ones. A systematic meta analysis of studies on the progress of the disease focused on predictors for motor decline and disability among PD patients (Marras, Rochon & Lang, 2002). The authors identified that some of the important factors for predicting the decline of the symptoms were the severity of motor symptoms at onset and possibly cognitive impairments at onset. This therefore showcases a potential link between cognitive impairments at onset and deterioration of the disease. The above was also showcased by a longitudinal study that took place over an 8-year period (Alves et al., 2005). Notably, the authors claim that cognitive impairment at onset is a predictor of higher disability and Hoehn & Yahr scale. They also observed similar deterioration when measured in different scales.

Lawson et al. (2016) focused, in a longitudinal study, on the predictive powers of cognitive impairments for *quality of life* (QoL) deterioration. They observed that patients with cognitive impairments showcased three times faster decline in QoL compared to patients with normal cognition. Additionally, over the course of the 3 years of the study, they showcased how cognitive impairments predicted worsening of QoL. Attention was found to be the cognitive impairment that more accurately predicted the worsening of QoL. Based on that, they argue that "our findings have implications for clinicians as interventions targeting attention could significantly improve QoL." Indeed, a meta-analysis of studies that performed randomized control trials of cognitive training interventions for PD patients showed a statistically significant benefit in the patients' working memory, processing speed and executive function (Leung et al., 2015). Effects on other areas, including attention, were found to not be statistically significant, but showed positive trends. The authors do note the need for larger randomized control trials in order to further validate the beneficial effects.

In anticipation of the next sections of the review, it is worthwhile to investigate how music affects PD patients differently compared to healthy people. There is evidence that PD patients have impaired temporal discrimination compared to healthy controls (Rammsayer & Classen, 1997). This finding prompted Bellinger, Altenmüller & Volkmann (2017) to study how the perception of time in music functions for PD patients. They conducted a study in which PD patients and healthy controls were asked to listen to a classical melody to which they have injected short pauses and they were tasked to identify these pauses (time intervals). They noticed that patients had trouble detecting time intervals in the range of 220 to 300 milliseconds, which was in line with the findings of Rammsayer & Classen (1997). They also found a correlation between the disease's severity and failing to identify intervals in that range. However, a surprising finding was that the *just noticeable difference* (JND), which is the smallest time interval that a person could identify, was not significantly different between patients and healthy controls. The authors claim that deficits in temporal discrimination reflect an "*impairment in memory and/or attention rather than in the perception of time per se*". They claim that the patients have no problem recognizing these time intervals compared to non-patients, but fail to do so because of impairments in their attention and memory.

Another observation that was made by both the previous authors and by Rose et al. (2019) was that listening to musical structures supported entrainment better than listening to a metronome, specifically in medium and fast tempi. They define entrainment as *"[...] the general phenomenon of moving the body to the pace of regular cue [...] without specifically synchronizing each motor element to a discrete beat"*. They noticed that entrainment was not affected by the disease nor by age.

This rhythmic entrainment effect has been proven to be therapeutic in terms of gait for PD patients in numerous studies. In their systematic review of rhythmic auditory cueing studies for PD patients, Ghai et al. (2018) surmise that cueing provides positive effects on gait velocity and stride length, while also reducing the gait's cadence (the gait's tempo). Hove et al. (2012) conducted an experiment where *Rhythmic Auditory Stimulation* (RAS), a form of standardized rhythmic auditory cueing that's explained in the handbook of NMT (Thaut & Hoemberg, 2014) was tested on PD patients and healthy participants. Specifically, they were asked to walk with either no cueing, fixed-tempo RAS and sensor-controlled interactive RAS. They found that the interactive version facilitated better entrainment and therefore healthier gait dynamics. The above conclusion was also reached a year later, by Nombela et al. (2013). In their systematic review of RAS and similar rhythmic auditory studies, they conclude that when the cues are clear and entrainment is reached, the participant's gait is improved. On the contrary, when the cues are unclear there can be detrimental effects.

On another note, Arias & Cudeiro (2010) proved in their study that RAS can provide benefits even for patients with *freeze of gait* (FOG), which is when a patient is temporarily not able to continue walking. Finally, Spaulding et al. (2013) conducted a systematic review in order to compare the effectiveness of visual and auditory cues for gait improvements on PD patients. Their study concludes auditory cueing as the most effective way.

The perception of music by PD patients has also been a topic of interest in the literature. In a study with PD patients and healthy controls regarding the perceived impressions and valuations of music (Morris et al., 2019), there are a number of interesting findings. Firstly, being familiar with the music being played was more important for enjoying the music for people with PD compared to people without PD. Secondly, the authors found potential evidence that PD patients underestimate the potential enjoyment they can derive from music.

Concluding, we have a clearer picture of how PD manifests on patients, what its symptoms are and how it progresses. Regarding the effect of the disease in their perception of music, the reviewed literature shows that there is no significant difference in how patients perceive temporal intervals in music compared to healthy people. However, we have clear evidence that music can help alleviate some symptoms, specifically their gait. We also see how attention functions are affected by PD and the deterioration in QoL due to the diminished attention. Next, we will review how music can be applied in the context of cognitive training.

2.3 Music in cognitive training

Listening to music can have varied and profound effects on people, such as evoking memories and emotions. Analyzing how music affects people has been a topic researched by musicologists and neurologists alike. Especially interesting are the findings on music's effect on attention.

Strait & Kraus (2011) relied on electrophysiology to prove music's ability to affect selective auditory attention in a language context. Specifically, they mention that "musical training's power to shape neural mechanisms that underlie selective attention to speech may be of interest to individuals involved in the habilitation and remediation of attention and attention-based learning impairment". Their suggestion was validated by a study by Modi (2018), in which PD patients performed sustained and selective attention requiring tasks, while background music was playing. Their results indicate that participants that were listening to instrumental-only music performed better than those who were listening to lyrical music which is a music track with vocals. They, in turn, performed better than participants who performed the tasks with no background music present.

These beneficial effects of music on cognition have been at the centre of attention for music therapy as well. In the Handbook of Neurologic Music Therapy (Thaut & Hoemberg, 2014), an effort is made to standardize music therapy practices in order for the use of NMT to become more clinically directed. The Handbook includes several protocols targeted at various cognitive functions, including executive function and attention. NMT's validity and efficacy have been tested in multiple study environments. One of them is the study of Gardiner & Horwitz (2015) in which they combined NMT with group psychotherapy for traumatic brain injury treatment. They were able to show improvements in a variety of cognitive areas, including visual attention.

Musical Attention Control Training (MACT) is a form of NMT targeted towards attention. It is constituted of guidelines for a number of protocols that aim to improve the participants' various forms of attention. MACT has been utilized to ameliorate attention deficits of a variety of groups suffering from them, with overall positive and varying degrees of success. An example of an MACT exercise would be the following: the therapist invites the patients to play a musical instrument along with them. The patients need to recognize some predefined musical cues that the therapist plays and alter their playing. For instance, when the therapist stops playing the piano with one hand, the patient needs to do the same. Essentially, the patient needs to remain attentive to the music they play and listen to and react to some change in the music.

Abrahams & van Dooren (2018) used MACT and non-standardized music therapy in a randomized controlled pilot study, on young people in a secure psychiatric institution.

Although the participant number was low (n=6), the attendance rate was 97% and positive trends on attention were indicated in the results. Pasiali, LaGasse & Penn (2014) performed an MACT intervention on adolescents with neurodevelopmental delays. Similar to the previous study, the attendance rate was 97% and positive trends were shown in measures of attention, specifically attentional control, alternating and selective attention. Another randomized control trial study was performed by van Alphen, Stams & Hakvoort (2019) on psychotic psychiatric patients. The authors reported high attendance rates (87.1%) and the experimental group that received MACT outperformed the control group who received *treatment as usual* (TAU) in measures of selective, sustained and alternating attention. In a different randomized control trial on patients with acquired brain injury, Jones (2018) performed TAU attention process training on the control group and MACT on the experimental group. Although not statistically significant, the MACT group performed similarly and sometimes better on attention tests post-intervention. To the best of our knowledge, no empirical MACT studies performed on PD patients exist in the literature.

2.4 Serious games

In the last decades, video games have become one of the most widespread entertainment media. Naturally, they have also been used for purposes other than pure entertainment. Alvarez & Djaouti (2011) propose a definition for serious games that includes two key features. Firstly, it combines video games with one or several utility functions: broadcasting a message, providing training, facilitating the exchange of data. Secondly, it targets a market other than that of pure entertainment. For example, defence, training, learning etc.

An example of a serious game would be a *virtual reality* (VR) game designed to simulate an airplane emergency in order to facilitate learning and retention of aviation safety knowledge (Chittaro & Buttussi, 2015). When compared to the typical safety card, the serious game showed superior learning and retention, based on data collected through knowledge tests. Furthermore, subjective and psychological measurements showed that the game was more engaging and more successful in inducing fear to the participants.

Games have also proven to be useful in a cognitive health context. To give a better picture of the potential of serious games used as interventions, we provide below a few examples found in the literature. Boletsis & McCallum (2016) developed and evaluated a serious game that aimed to be used as a cognitive health screening tool for the elderly. In their study, the authors found that the screening results of the game were consistently similar to a standardized cognitive assessment test. They also noted that the participants found it to be a motivating experience. In a systematic literature review, Kueider et al. (2012) found strong evidence of serious games' capabilities of substituting traditional paper and pencil cognitive training approaches. They suggest that *"computerized training is an effective, less labor-intensive alternative*".

Exergames, which are serious games that include some form of physical exercise, have also been used to provide cognitive improvements, specifically for PD patients. In a longitudinal, controlled clinical study, PD patients showed no deficit in learning or retention when playing exergames compared to healthy age-matched controls (dos Santos Mendes et al., 2012). Notably, the authors indicated the patients' ability to transfer the trained motor skills to other similar but untrained tasks. Similar conclusions were reached by Schaeffer et al. (2019), specifically that exergames as an intervention can improve deficits in cognitive-motor dual-tasking and attention in PD. In a randomized control trial, Pompeu et al. (2012) highlighted exergaming's ability to improve daily life challenges in PD patients when the experimental group outperformed the control one in measurements on UPDRS-II (an updated version of UPDRS, a commonly used scale to measure PD symptoms - see Section 2.2). Garcia-Agundez et al. (2019) performed a meta-analysis on exergaming studies for PD patients. They deemed exergaming as safe and at least as effective as traditional rehabilitation training for PD patients.

Serious games have also incorporated musical elements in order to enhance their therapeutic capabilities. Dalla Bella et al. (2019) performed a clinical trial test using a play-at-home serious game on PD patients. The authors provided the participants with either a rhythmic video game, a non-rhythmic video game or no game to play at home. A rhythmic video game is one in which game interactions are intended to happen in a rhythmic pattern. They measured the patients pre- and post-intervention in a number of domains, such as gait and orofacial motor skills. Results indicated that improvements in orofacial and manual performance were observed solely on the group that played the rhythmic game. They argue that *"this beneficial effect was linked to an improvement of rhythm perception due to the rhythm training"*. Additionally, Agres, Schaefer, Volk et al. (2021) highlight the usefulness of serious games as an at-home supplement to music therapy sessions. Some of the mentioned benefits of serious games in this context are that they are accessible and that they enable practicing specific skills in-between sessions. In the same article, the authors also mention that serious games that incorporate music have an advantage when pursuing attention control training. Specifically, *"music's inherent alternations between expected and unexpected moments in the musical structure offer the potential to maintain attention"*.

Attention is a particularly important aspect of cognition for this thesis, as explained in Section 2.1. Serious games for attention training have proven to be an effective method for cognitive intervention. Particularly, Green & Bavelier (2003) provide strong evidence for visual attention improvement linked to playing action games with the help of a five-experiment study. Based on the above findings, Franceschini et al. (2013) conducted a study that showed action games' potential to make dyslexic children better at reading. They attributed this phenomenon to their improvement of visual attention. Additionally, they claim that games can be a fast and fun remediation for dyslexia. Gamito et al. (2017) in a randomized control trial with stroke patients were able to demonstrate improvements in memory and attention for the experimental group that played a serious game in VR. In a similar randomized control trial on stroke patients (Kim et al., 2011), the experimental group showcased improvements in attention on multiple measurements.

Despite the aforementioned benefits, Agres, Schaefer, Volk et al. (2021) mention that musical serious games that focus on a specific clinical problem are limited. Indeed, in a systematic review of serious games used on PD patients (de Oliveira et al., 2021), the authors mention that while the majority (52.63%) of studies focus on exergames for motor rehabilitation, few studies were focused on emulating an existing treatment protocol. They argue that following such a protocol would help with the evaluation of the efficacy of games designed this way.

In conclusion, the literature shows that serious games are successful in cognitive training, and specifically in attention control. At the same time, there is a shortage of serious games that follow existing treatment protocols. Given the above, the need arises for a serious game with musical aspects that target attention control for PD patients, while also following an already established treatment protocol (e.g. MACT).

2.5 Sound and music in games

The rise of multimedia in the 20th century has created an opportunity for music to be paired with visuals. This urged the former to take a supplementary role in multimedia. In a study about the cognitive roles of music in multimedia, Cohen (1999) lists the functions of music in films. Some of the functions included are the following: music directs attention to important features of the screen, induces mood, adds to the aesthetic, gives context to ambiguous situations in the narrative and enables symbolization and linking of events.

Music in video games works very similarly to music in films. Most, if not all, of the music functions in film, as explained by Cohen, work in the exact same way in video games. What differentiates a video game from a film is its ability to adjust based on interaction by the audience/user. This creates an additional layer of interactive music/sound functions that are unique to video games. Given the relatively recent rise in popularity of video games as a medium, it is not a surprise that these functions have become a topic of study.

One framework that attempts to model the possible functions of video game audio is the IEZA (Interface, Effect, Zone, Affect) model (Huiberts & van Tol, 2008). In the model, audio is categorized based on two dipoles. The first dipole is the distinction between diegetic and non-diegetic sounds. Diegetic sounds are sounds that come from the game world, whereas non-diegetic sounds are sounds that do not exist in the game world. The second dipole is the one that defines whether the audio is a result of or targets the user interaction (activity) or if it is independent of it (setting). Any kind of audio in a video game can then be described based on where they fall on these two dipoles. This creates four distinct categories of video game audio. Audio that falls in the zone (diegetic and setting) or affect (non-diegetic and setting) categories functions similarly to film music. Unique to games, however, is any kind of audio that is based on activity. Non-diegetic, activity sounds, such as sound effects of interacting with game menus, fall into the interface category. Sounds that are based on activity but are diegetic fall into the effect category, for instance the footsteps of the player character moving.

Activity audio in video games describes sound and music that serve a varied and vast amount of functions. From augmenting the feeling of immersion that is created by the enhanced cause-effect relation of the player actions to giving a competitive advantage to players that pay attention to the effect sounds of other players. Specifically for the latter, the advantage of paying attention to effect audio is so crucial that there are studies that investigate ways to train inexperienced players to do exactly that, such as the one by Johanson & Mandryk (2016).

An important function of activity audio for this thesis, however, is the function of audio cues. Audio cues are distinct patterns or changes in sound effects or music that provide information about what might be coming up in the game. An example of such an audio cue is the sound effect that plays in the commercial game Sekiro: Shadows Die Twice (From Software, 2019) when an enemy starts an attack that cannot be blocked by the player in order to warn them. The player needs to realise what is coming and react accordingly.

There is a parallel that can be drawn between audio cues in video games and music therapy, in particular MACT. In both cases the player needs to remain attentive to the audio that they are listening to, whether that is music or sound effects, and react accordingly to specific changes in it. As can be seen in previous sections, this interaction is at the core of the therapeutic mechanisms of the attention training of MACT, making video games a prime candidate for an adaptation of these mechanisms.

2.6 Dynamic Difficulty Adjustment in games

Challenges arise when adapting MACT protocols to human-computer interactions. As shown in the previous sections, PD manifests itself with a multitude of symptoms that differ from patient to patient. Consequently, a PD patient could be equally as skilled as a non-patient in a specific task. However, a non-patient could not be equally as challenged by that task as a PD patient. This means there is potentially a larger skill range among PD patients when compared to healthy people. Indeed, in a systematic literature review on exergaming for PD patients, Barry, Galna & Rochester (2014) suggest that games for rehabilitation of PD patients should be easier than commercial games. De Oliveira et al. (2021) also suggest the development of serious games targeted towards PD patients that have the "...*ability to customize the levels of difficulty according to patient health status*".

The above is already considered in MACT: the music therapist dynamically adjusts the difficulty of participating in the session according to how the participants perform. According to the Handbook of Neurologic Music Therapy (Thaut & Hoemberg, 2014, p.265), where guidelines of an MACT clinical protocol are provided, it is suggested that:

"The task difficulty should be structured around two dimensions, namely the number of change elements and the duration of the exercise".

Additionally, a popular theory about positive psychology by Csikszentmihalyi (1990) states that in performing activities there is an optimal experience with respect to the difficulty of the task. When this optimal experience is achieved, the person can become so engrossed that they lose track of time and their reflective self-consciousness. One of the mentioned prerequisites for such an experience is immediate feedback and the feeling that success is possible, showcasing the importance of task difficulty adjustment. Therefore, it would be advisable to incorporate some form of dynamic difficulty adjustment in the MACT game intervention.

Dynamic difficulty adjustment (DDA) is the online and/or offline adjustment of parameters of a video game's systems in order to tailor its difficulty to the abilities of the player. Depending on the task, the DDA implementation can differ in complexity.

An implementation proposed by Spronck, Sprinkhuizer-Kuyper & Postma (2004) is called *dynamic scripting*. They use an adaptive rule set to generate opponents at runtime. Games in which the parameter adjustment cannot give predictable results benefit from the usage of AI systems. For instance, Olese, Yannakakis & Hallam (2008) proposed such an approach to the online difficulty adjustment of real-time strategy games using neuro-evolution methodologies to train neural networks, which in turn handle the difficulty adjustment.

Several studies have examined the theoretical and empirical effects of DDA. The theoretical evidence paints a very positive outlook whereas empirical evidence is more of a mixed bag. Below we examine several of those studies and the conclusions they drew regarding the effectiveness of DDA on improving several aspects of the game, such as motivation, learning outcomes and more.

Scott (2002) mentions that "providing a challenge must apply to as broad an audience as possible, from complete novices to those who play online tournaments", exemplifying the importance of keeping a task challenging. Hocine, Gouaich & Cerri (2014) developed and evaluated a DDA system for a serious game designed for stroke patients. They conducted an experiment where participants played a serious game with either DDA, Incremental Difficulty Adjustment (IDA), or no difficulty adjustment strategy. The results showed that there the DDA version showcased an increase in the number of tasks performed, which could mean the participants felt more motivated and engaged to complete tasks.

Plass et al. (2019) conducted a study among middle- and high-school students (ages 10-17) to compare the effectiveness of using an adaptive vs non-adaptive approach for adjusting the difficulty of a serious game targeted towards training executive function skills. Based on collected user logs, the adaptive approach was successful in presenting each player with a challenge appropriate to their skills. The results also showed that the adaptive approach led to higher training outcomes in all age groups except for the 12-13 age group. Sampayo-Vargas et al. (2013) compared the learning outcomes of three educational methods on a sample of 234 secondary school students, using a quasi-experimental approach to focus on isolating the impact on motivation and learning outcomes. The three methods used were the following: a dynamic difficulty adjusted computer game, an incremental difficulty adjustment game that was non-adaptive and a written activity. While the motivation was similar among the methods, the adaptive game produced significantly better learning outcomes.

As it becomes evident from the above, there is no consensus on the potential of DDA. It appears that there are some beneficial effects but it is not clear when and how they manifest. Here, we present some studies that provide evidence as to what might be the reason for this fluctuation.

An aspect that has proven to be influential when it comes to the effectiveness of DDA is personality. Based on the findings of Bauer, Brusso & Orvis (2012), adaptive difficulty training is more efficient with participants that have *openness to experience* and *neuroticism*, which are two of the big five personality traits in the field of psychology (Digman, 1990). In the same way, participants with lower affinity in these traits performed worse in the adaptive version of the training when compared to the static one, highlighting the role of personality. A different experimental study approached the difficulty adjustment mechanisms through the lens of affective state of the player (instead of performance). They tracked the participants' state through physiological signals and adapted the game's parameters online based on that input. The results they got indicate that recognizing the affective state and basing the adjustment on that could provide enhancements to the gaming experience. Hunicke (2005), on the other hand, suggests that perceiving the effects of the online difficulty adjustment can make the player feel cheated.

Regardless of the varying evidence of DDA's success in improving performance and motivation, it is apparent that DDA is crucial to any game adaptation of MACT that is targeted towards PD patients for two main reasons. Firstly, real-time adjustment of an MACT session's difficulty is determined as a prerequisite in the NMT handbook, so it follows that an adaptation of MACT should incorporate an equivalent system. Secondly, DDA is especially significant for PD patients. As showcased in Section 2.2, PD patients cognitive functions diminish as the disease progresses, which creates a bigger spectrum of skills.

2.7 Significance of UI/UX design

As has been shown in previous sections, PD patients have unique needs and limitations compared to healthy people. Symptoms of PD, as well as those of the aging process create challenges in completing tasks. This translates to unique difficulties with handling technology.

The systematic review of exergaming studies for PD patients of Barry et al. (2014) suggests that exergaming applications for PD patients conform to some design criteria, including the following: they should provide very clear instructions and goals. Additionally, introducing cognitively demanding aspects should be done sparingly. Finally, they should not have negative feedback.

Multiple studies have shown that people of older age handle technology in a different manner. In a quasi-experiment of usability testing between younger (19-29) and older (52-73) participants (Sonderegger, Schmutz & Sauer, 2016), the participants' task completion performance was measured. The results showed there was no discrepancy between task completion measurements between the groups. Significant differences, however, were spotted when speed-related performance was measured. They conclude that while older people have no big issues completing tasks, it takes them longer than younger people. Similar conclusions were reached by the systematic review of computerized cognitive training studies by Kueider et al (2012). Specifically, they mention that older adults did not need to be familiar with technology in order to complete and benefit from training. Wirtz, Jakobs & Ziefle (2009) conducted a study in order to identify the age-specific (more prominent in older users) and the age-exclusive (prominent only in older users) issues of interface design. Surprisingly, they did not find any age-exclusive issues. They did, however, find multiple age-specific ones. Firstly, complex tasks, that are tasks that require multiple cognitive steps, seemed to be a more significant problem for older users. Secondly, there was a need for more clear feedback for older users, since subtle cues can be more easily missed and misunderstood. Additionally, inconsistency in design was more prone to create issues in the older group, which was attributed to the cognitive load they involved.

Concluding, these findings provide a solid basis to create concrete UI and UX requirements in order to tailor a computer application towards usage by PD patients.

3 Research questions

As established in the previous sections, PD patients can benefit from music therapy to alleviate some of their symptoms. However, as shown in Section 2.4, there is a lack of at-home serious games that can supplement traditional music therapy sessions for PD patients, especially ones that follow existing treatment protocols. MACT is an established NMT protocol focused on training attention control, a cognitive function that has shown to affect the QoL of PD patients. Therefore, a serious game intervention that emulates an MACT session fits all the above considerations.

The first step before attempting to design and develop an MACT game intervention tailored to PD patients is to create a comprehensive list of requirements that such a game would need to adhere to. To this effect, we define our first research question as follows:

Research question 1 (RQ1): *What are the requirements for an MACT game intervention for PD patients?*

After having determined the requirements, the next step is to explore the feasibility of a game intervention that adheres to those requirements. As such, we pose the second research question:

Research question 2 (RQ2): *To what extent can the design of a game intervention for PD patients be derived from these requirements?*

Finally, it is important to be able to measure the efficacy of the game intervention as a supplement to traditional MACT sessions. Ideally, this should be measured on PD patients. Unfortunately, due to ethical limitations, we are not able to collect data from actual PD patients. Despite this limitation, it is still possible to measure the game intervention's effect on attention in healthy people. This could function as an indication of the efficacy of the game intervention in PD patients. This leads us to the final research question, that is:

Research question 3 (RQ3): *To what extent does an implementation of the designed game intervention improve the attention of users?*

With the research questions established, we elaborate in the next section on how we approached answering each of them.

4 Method

This section describes the methodology that was followed in order to answer the research questions, as presented in Section 3. Answering RQ1 meant scouring the existing literature for insights into what a serious game that emulates MACT and is tailored for PD patients would require. In order to answer RQ2, we developed a serious computer game application which serves as an MACT intervention and follows the eight requirements previously established. To answer RQ3, we conducted an experiment using the aforementioned application. The experiment's main purpose was to measure the potential improvement in attention on the participants, caused by playing the game intervention. The experiment consisted of the following components: pre-and post-experiment questionnaire and attention tests and a number of play sessions of the game application.

Section 4.1 elaborates on the requirements for a serious game that emulates MACT for PD patients and the approach followed to establish them. Section 4.2 focuses on the effort of creating the serious game application. Section 4.3 further elaborates on the experiment conducted. Finally, Section 4.4 describes the method followed in order to process and analyse the collected data.

4.1 Requirements

We performed a literature review that aimed to provide us with insights that would help us answer RQ1. In particular, there were two main points of inquiry: first, how do you translate an MACT protocol into a serious game and, second, how do you ensure that this serious game is suitable to the needs of PD patients.

Regarding the first point of inquiry, we sought to understand the mechanisms that make NMT and in particular MACT work. We looked into studies that used MACT as an intervention and measured its results based on attention measurements. Consequently, we also needed to understand the cognitive function of attention and how it is measured. This gave us a thorough understanding of the beneficial mechanisms of MACT. The next step was to understand how those mechanisms could be adapted to a serious game. To that end, we looked into studies about serious games that have been successfully used as intervention for cognitive training. All the above gave us a clear picture of what the requirements for a serious game that emulates an MACT session should be.

While looking into studies about serious games in cognitive training, we found several serious games that have been targeted towards PD patients. This links to our second point of inquiry, which is how to adapt a game that follows the MACT-related requirements, based on our research, to the needs of PD patients. Therefore, it was important to understand PD and the way it manifests in patients. A thorough understanding of the symptoms of PD lead to a number of requirements for serious games that are targeted to be used by PD patients. Specifically, regarding the game's difficulty and human-computer interfacing (UI/UX). At the end of the literature study, we had a clear understanding of the requirements for an MACT serious game that is tailored towards the needs of PD patients. These requirements and the reasoning behind them can be found in Table 1 (see also Section 6).

Table 1. List of requirements for the game intervention based on the literature review.

Topic	**Requirement**	**Reasoning**
MACT	1. Translate an MACT protocol to a gamified version of it	This is the backbone of the research - to simulate the interactions an MACT participant would have in a gamified context
	2. Inclusion of an algorithm that generates unique gamified MACT protocols	Being able to memorize the protocols will hinder the therapeutic mechanisms of MACT due to using memory instead of attention (Thaut & Hoemberg, 2014)
Attention	3. Inclusion of a measurement of attention	This is required in order to quantify the potential beneficial effects of the intervention
DDA	4. Inclusion of dynamic difficulty adjustment	PD patients' skills are more varied than those of healthy people. DDA ensures that each user is challenged at a satisfactory level, which is something that already happens in traditional MACT (Barry, Galna & Rochester, 2014; Cooper et al., 1991)
UI/UX	5. Minimization of cognitive demanding tasks	Older people/PD patients have difficulties with more complex tasks (Wirtz, Jakobs & Ziefle, 2009; Cooper et al., 1991)
	6. Clear instructions and goals	Older people/PD patients have potential difficulties with understanding what the tasks involve (Wirtz, Jakobs & Ziefle, 2009)
	7. Clear interface feedback mechanisms	Older people/PD patients are more prone to missing subtle interface cues (Wirtz, Jakobs & Ziefle, 2009)
	8. No negative performance feedback	PD patients' symptoms worsen over time (Alves et al., 2005), (Barry et al., 2014)

4.2 Game intervention

We developed a video game intervention that emulates an MACT protocol called *Last Minute Gig*. It can be played on a PC and was developed using Unity.

In the game, the user takes the role of a guitarist whose avatar (stick figure) is on screen. Their old band will be performing in a concert. At the beginning of the game, the user is told that the band's new guitarist is sick and that they have to fill in for them. Therefore, the user will have to play along with the music and improvise since they are not familiar with the band's songs. This premise is explained in the introduction to the game. During the introduction, the only allowed interaction is to progress the dialogue.

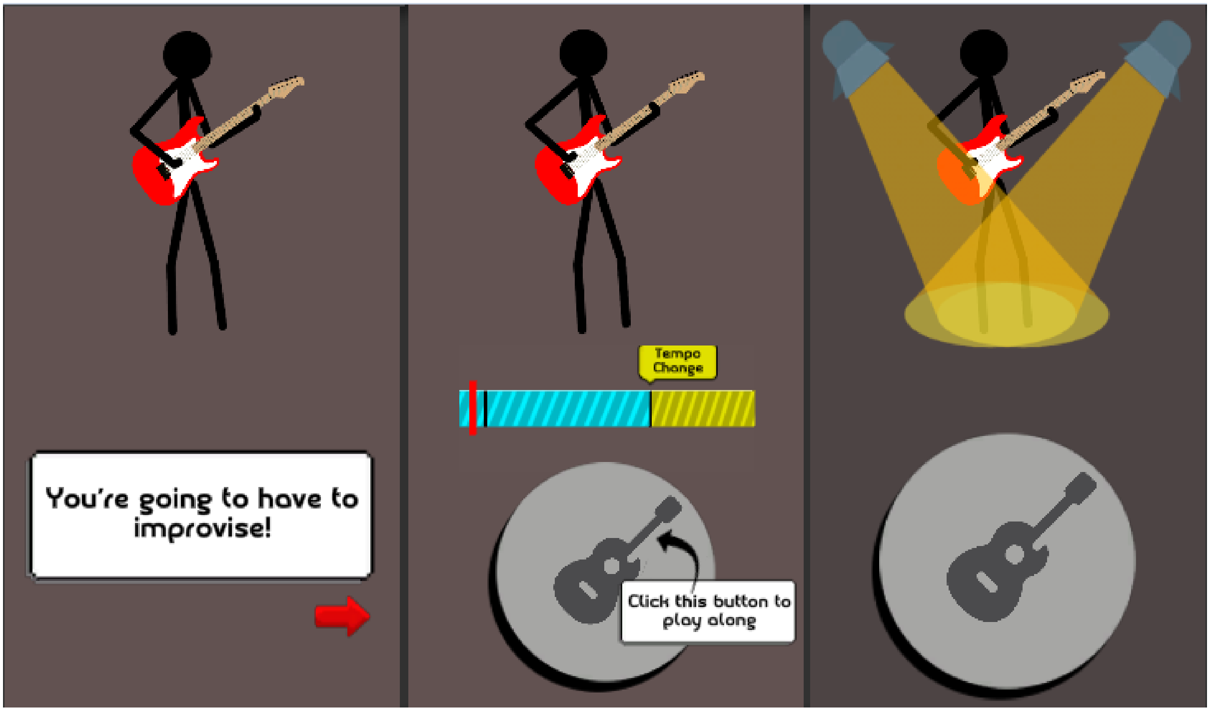

Figure 1. (From left to right) Introduction to the game, tutorial and main game screens.

Once the game starts, the user's avatar is already playing in the concert. The user can do that by pressing a button that is below the avatar (see Figure 1). When the button is pressed, the avatar plays a chord on its guitar. There are no timing constraints as to when the user can press the button and play along, it is up to the user. The only other auditory stimulation is a drum beat that plays in the background, which provides a rhythm and tempo to the user.

Each play session consists of four songs the user needs to play along to, which takes approximately fifteen minutes to complete. At the end of each song, there is an applause from the crowd, after which the next song starts. We recorded guitar audio for all major and minor chords. Each song is randomly assigned a key, chord progression, rhythm and tempo. The rhythm and tempo can be implied by the drum beat that plays in the background. The chord that plays whenever the user clicks the button is determined algorithmically, using the assigned key and chord progression. The final product of this setup is that with only one button, the user is playing along to a randomized evolving song. This eliminates the need for the user to have musical knowledge. They only need to pay attention to the rhythm and tempo. It also ensures that each play session is somewhat different. A detailed overview of this music generation process can be found in Appendix A.

After eight bars of music, the background beat changes. This musical change is randomly selected out of 3 possible options: a change in rhythm, a change in tempo, or a brief pause. This is done in order to urge the user to pay attention to the background beat and adjust their playing accordingly.

Additionally, in between the introduction and the game, there is a tutorial, which along with the introduction, only shows up during the first play session. It serves as a way to explain to the user all of the above mechanics in an interactive and comprehensive way. More specifically, there is a visualization of the music by form of a scrolling strip (see Figure 1). In it, musical bars can be visualized. Whenever a musical change is supposed to happen, there is a message bubble that serves as an indicator. Finally, in order to make sure the user understands what they need to do, if they are idle for more than 2 seconds, there is a message bubble that points to the guitar button and prompts them to play along. These visualizations only appear in the tutorial, as a means to explain the mechanics of the game to the user.

The form that this game takes has been informed by the insights that were gained by answering RQ1 as summarized in the requirements of Table 1. It is important to highlight that the main goal was to create a design that has the capacity to incorporate all of the established requirements at once. The more requirements a game has to follow, the smaller the design space becomes for a game that follows all of them. Therefore, finding a game design that incorporates all of them was a non-trivial task. This means that finding all of the possible game designs that follow these eight requirements would be completely out of scope. Consequently, our process was to find just one such design and to implement it. Below, we explain our reasoning behind the decisions we made, based on each of those requirements.

Requirement 1: Translate an MACT protocol to a gamified version of it

Since our goal is to emulate an MACT protocol as a game experience, there are a few requirements that arise. For this thesis, we decided to focus on MACT Clinical Protocol 4: Sustained Attention: Therapeutic music exercise for attention improvement (Thaut & Hoemberg, 2014). In this protocol, the users need to be able to play along however they feel like. There is no correct way of playing along - it depends on how the user perceives the music. Additionally, it is important that there are musical changes in the background music of the game. The background beat plays the role of the therapist in an MACT session. As explained in Section 2.3, the fundamental therapeutic mechanism of MACT is the following: firstly, the therapist and the user are playing their respective instruments together. At some point, the therapist changes how they play. At which point, the patient is supposed to recognize this change by paying attention to the therapist's music. The patient that understands that change is expected to change their playing accordingly. Therefore, it is of crucial importance that any emulation of MACT includes a version of this mechanism. The above points explain why the current form of the game intervention we developed allows for users to play along however they feel like and includes musical changes.

Requirement 2: Inclusion of an algorithm that generates unique gamified MACT protocols

As explained in the above requirement, the therapeutic mechanism relies on the user paying attention to the music so that they can detect possible musical changes. Additionally, we previously mentioned that the game intervention can function as a complementary therapeutic tool to MACT sessions. The benefit of the game intervention is that it is easier to access at any time and place. This means that they can possibly play the game multiple times. This might result in the users memorizing the musical patterns and stop paying attention to the music. However, that would undermine the basic therapeutic mechanisms of MACT. For this reason, it is of crucial importance that each play session is unique, which is reflected in how each song is algorithmically created in the game application. Furthermore, users' enjoyment of the music could deteriorate the more they play. A way to measure if an implementation that follows this requirement is successful is to look into users' self-reported enjoyment of the music.

Requirement 3: Inclusion of a measurement of attention

Due to the nature of how this research was conducted, a measurement of attention that would gauge whether or not the intervention was successful was not integrated in the game application, but rather was part of the experiment that is elaborated upon in the next section. However, such a test could be integrated in the game before each play session at regular intervals, for example once a week.

Requirement 4: Inclusion of dynamic difficulty adjustment

A DDA of the musical changes in the game intervention would serve as the tailoring of the sessions to each user's cognitive and/or musical skills. This function is fulfilled by the therapist in traditional MACT sessions. However, due to scoping limitations that are discussed in Section 6.2, this was not included in this game intervention. However, the game design proposed has the capacity to include online adjustments to the music generation based on the user's performance.

Requirement 5: Minimization of cognitive demanding tasks

Since this game intervention is tailored towards the needs of PD patients, some PD specific requirements need to be considered. For instance, the need to minimize cognitive demanding tasks. Therefore, any kind of playing along to music needs to be as easy and accessible as possible. This is achieved in the game application by having only one interaction that the user can perform: pressing one button to play along. Limiting the actions the user can perform minimizes the cognitive load that the user experiences while interacting with the game. It also reduces the musical experience and training a user needs to have in order to play along with the music. One button interaction mirrors percussion instruments, in the sense that the user needs to pay attention only on the rhythm and tempo and not on the pitch (notes). This also removes the cognitive demanding task of understanding and playing along with a melody.

Requirement 6: Clear instructions and goals

An additional PD-specific requirement is the need to provide clear instructions and goals, since PD patients have trouble understanding what given tasks involve. In order to combat that in our game application, we devised the concept of the concert that frames the musical task that the user needs to perform in a more comprehensive way. That is, the user has to play along by improvising, since the avatar also needs to do the same thing. Additionally, the inclusion of the tutorial serves as a way to further explain what the user is expected to be doing. The above decisions all serve the purpose of providing clarity to the user regarding what they need to achieve and how.

Requirement 7: Clear interface feedback mechanisms

As previously mentioned, the only way the user can interact with the game is by pressing the only button that is visible to them. As can be seen in Figure 1, the button is quite sizable. There are two reasons for this. Firstly, PD patients are prone to have tremors depending on their symptoms (Fahn & Elton, 1987; Hoehn & Yahr, 1967). Having a big button mitigates this issue. Secondly, it is the most prominent feature of the screen, which makes it unmissable and therefore provides clarity as to how the user can interface with the game. Additionally, pressing the button has the immediate effect of the avatar moving its hand to play a chord on the guitar, as well as the chord sounds effect being played immediately. This reinforces the link between the user and the avatar, which makes the way that the user interacts with the game explicit. This requirement, as well as the previous one, can both be measured by users' reported perception on whether having previous gaming experience influenced how much they like the game.

Requirement 8: No negative performance feedback

The last underlined requirement is that there is no negative feedback on the user's performance. Unfortunately, the symptoms of PD patients get worse over time (Alves et al., 2005). It is therefore advisable to avoid measurements of their performance. The possible deterioration of their symptoms could affect their performance, which could discourage them, regardless of whether there is a measurable improvement in their attention. However, positive feedback after each song does not run the same risk and can encourage them to keep playing.

In addition to those decisions that were based on the eight established design requirements, we also had to make some decisions based on other factors. One of them was the platform of choice. Ideally, the game would be playable on the most accessible platform, which currently is the mobile smartphone. However, due to how the experiment was set up, we had to settle on a PC application. Another decision that was influenced by the experiment was the duration of a play session. In order for sustained attention to be measured, there needs to be a task that takes place for at least 10 minutes.

In the next section we present an overview of the experiment that we conducted using the game intervention.

4.3 Experiment

In collaboration with the Music, Brain, Health & Technology Lab at Leiden University, we conducted an experiment to gauge the intervention's effect on attention. Due to ethical constraints, we were unable to include PD patients in the study. Therefore, RQ3, that is whether the developed game intervention can improve the attention of PD patients, could not be directly answered through this experiment. However, a potential improvement in attention due to the game intervention in the non-PD population could still function as an inferred answer to the question. An MACT game intervention is a novel approach to improving the QoL of PD patients, and as such, we had to work with this constraint. In total, 21 people participated in the experiment. The sample size was limited due to time constraints, but most importantly, due to the global COVID-19 pandemic and the prevention measures that were in place at the time.

As a first step, the participants were asked to fill in a questionnaire developed by Leiden University. The full questionnaire can be found in Appendix B. The questionnaire started off with questions regarding personal details of the participants, such as gender, age, educational background and possible cognitive or neurological impairments. Additionally, the participants were asked about their musical experience, formal training and habits (e.g. their ability to sing in tune, years of formal musical training), as well as gaming experience and habits.

As a second step, the participants were asked to participate in three different cognitive tests: the backwards digit-span test (Hilbert et al., 2014), a selective attention task based on the work of Woods (1992) and Rothenberger (2000) and a continuous performance task (sustained attention) based on the work of Rosvold et al. (1956) and Sanchez-Lopez, Silva-Pereyra & Fernandez (2016). All tests were performed by Leiden University. The backwards digit span test acted as a working memory gauge, while the other two tasks acted as attention gauging tests, for selective and sustained attention respectively. The attention tests were developed by Leiden University.

With the above two steps completed, the participants were asked to play 10 game intervention sessions, on 10 different days within the time span of two weeks. Finally, after this time period passed, they were asked to fill in some final questions regarding their experience of their game intervention, such as enjoyment and motivation pre- and post-playing, and they were tasked to repeat the three cognitive tests. Due to the aforementioned reasons, each participant completed the above steps from their own home in their own time.

The above set up enabled us to collect data on how the game intervention affected the participants' attention and working memory, as well as data that gave us insights into our participants' personal, musical and gaming backgrounds.

In order to bolster our understanding of how our participants played the game intervention, we included automatic gameplay data collection into the application. We set up a private server with which each instance of the application communicated and sent the collected gameplay data to. The data consisted of the users button press timings with regards to their position in the musical bars. The format was the interval in seconds between the start of the musical bar and the button press. It also contained descriptive information about the musical bar at the time when the button was pressed (rhythm and tempo).

Concluding, the experimental set up and the data that it allowed us to collect served a twofold purpose. First and foremost, using the pre- and post-attention tests, we could assess whether the game intervention had any effect on the attention of the participants. Second, using the gameplay and questionnaire data, we could get insights into which factors might have affected the potential improvement in attention. Before we could get a definitive answer to RQ3, the collected data had to be processed and analyzed. This effort is detailed in the next section.

4.4 Data processing and analysis

As it has already been mentioned, the main insight we wanted to get from the data sets was whether there was an improvement in the participants' attention after the game intervention. This is captured in the difference in their performance on the attention tests they took part in before and after the intervention, e.g. the difference between the second and the first Selective Attention tests: $SADelta = SA2 - SA1$. A positive delta would indicate an improvement in attention whereas a negative would indicate a deterioration. However, in order to further understand such a potential improvement, we wanted to include data that outlined how each participant interacted with the game intervention. In this manner, it would be possible to highlight which aspects of our designed game influenced that outcome and which did not.

To that purpose, it was crucial to find out which participants understood and participated in the typical back-and-forth that occurs in MACT, which is when someone who has been playing along with the background beat and notices a musical change should also change how they play. In order to measure this, we could use a distance metric between the participant's input before a musical change and immediately after. This makes it possible to identify participants who did not alter their playing as they would have a lower distance value compared to those who followed this back-and-forth.

In the case of the game intervention that we developed, the user's input during a musical bar does not affect the pitch of the produced music. The only varying musical aspects of the played musical bars are the rhythm and tempo of the button presses. Therefore, the distance metric needs to be able to identify different tempo and rhythms.

Firstly, a musical bar could have a shorter duration when compared to another one, due to them having a different tempo. Someone who didn't understand a musical change in tempo would not change the intervals between their button presses. Consequently, since the distance metric needs to be able to identify those instances we can't use normalized time (where $t = 0$ seconds is the start of the musical bar and $t = 1$ second is the end). In order to do this, it needs to measure the button presses in seconds from the start of the musical bar.

Secondly, the distance metric needs to be able to identify different rhythms. A rhythm is understood by the timing of beats in a musical bar. A rhythm that is almost identical to another except for not having one beat is a fundamentally different rhythm in human perception. Therefore, the distance metric needs to be able to identify differences in rhythm in terms of missing button presses. Additionally, a rhythm that is almost identical to another except in the place where there is a beat there are two beats very close in succession instead, is also a fundamentally different rhythm. This means that the distance metric needs to be able to identify these instances as well.

However, to the best of our knowledge, there is no distance metric that follows the above requirements. For this reason, we introduce a novel way of measuring distance between user button presses within a musical bar and its next. Each musical bar M can have a number of button presses b, so $M = \{b_1, b_2 ... b_n\}$. Each button press b of each bar M happened at a specific point in time. We define button time bt as the difference in seconds between the beginning of the bar M and the time when the button press b happened, $bt = |t_M - t_b|$. This way, each musical bar M can also be seen as the set of all button times, namely $M = \{bt_1, bt_2 ... bt_n\}$. Using this setup, in order to calculate the distance between a musical bar $M_1 = \{bt_{11,} bt_{12} ... bt_{1n}\}$ and a different musical bar $M_2 = \{bt_{21}, bt_{22} ... bt_{2m}\}$ we perform the five steps outlined below.

Step 1: For each bt in M_2, find the closest bt in M_1 in terms of seconds and create a pair p, e.g. $p_1 = \{bt_{11}, bt_{21}\}$.

Step 2: For each pair p, calculate the absolute value of the the pair's distance, defined as $\delta p = |bt_{11} - bt_{21}|$ (see Figure 2).

Step 3: For each pair, add a weight W to its δp if the pair contains a bt that already exists in a different pair, e.g. $p_2 = \{bt_{12}, bt_{22}\}$, $p_3 = \{bt_{12}, bt_{23}\}$.

Step 4: Calculate distance d as the sum of all δp, $d = \sum(\delta p)$.

Step 5: For each bt in M_1 that does not have a pair, add a weight E to the distance d.

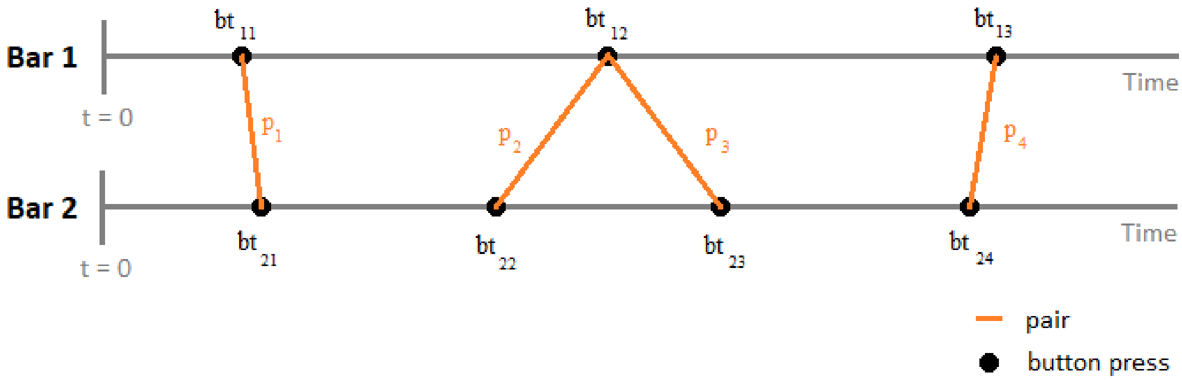

Figure 2. Pairing button presses between Bar 1 and Bar 2.

Because of the usage of non-normalized time from the start of each musical bar, we are able to identify changes in tempo. Note that the proposed metric is not a true distance metric, since it doesn't satisfy the symmetry property, e.g. $d(M_1, M_2) \neq d(M_2, M_1)$. However, that is not an issue in our use case, since its main purpose is to be able to identify (by producing a relatively high number) when the user changed their play patterns. This is the reason for the weights W and E, they allow us to identify changes in rhythm. Weight W helps to identify surplus button presses and weight E helps to identify missing ones. Using the described metric, we can calculate the distance between each musical bar and the next. We can then do this for every musical bar in a user's play session and plot the results, as shown in Figure 3. If a user was playing along with a steady rhythm and tempo, the distance between each bar should be low. Then, if a musical change happened and the user understood that change and adjusted their playing, there should be a spike in the metric between the bar before and after the musical change. We can then create metrics to identify this spike, for example the difference between the average distance after a musical change and the average distance of the whole play session.

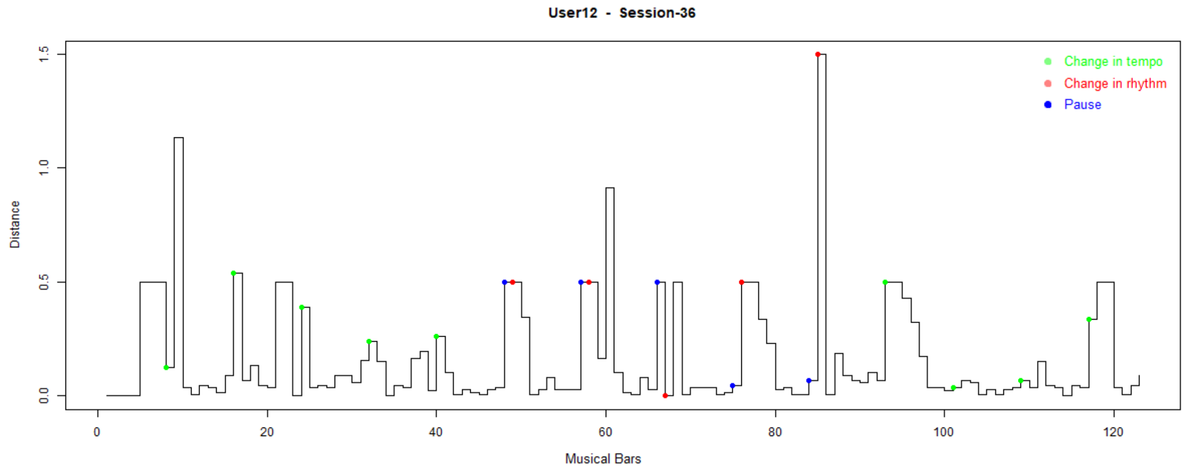

Figure 3. Plot of the distance of each musical bar of a session to its following musical bar. Dots indicate a musical change that occurred in the background music. The color corresponds to the type of musical change.

In addition to the distance metrics, other kinds of descriptive gameplay data were also extrapolated from the raw gameplay data. In total, eight different descriptive gameplay metrics were extrapolated from the button press data. For example, the average button presses per musical bar. These would serve the purpose of giving us insights into the ways that the participants interacted with the game.

Correlation analysis

All of the above metrics' purpose was to help us understand the efficacy of the game as an intervention, which is its potential effect on improving attention. Additionally, they could be used to provide further insights on the users' perception of the game, as well as how they interacted with it. To that cause, we used the Pearson coefficient formula in order to find variables that were correlated. We calculated the correlations between self-reported musical experience of users and the perceived challenge, skill increase and enjoyment of the music, based on the users' answers to the questionnaire (Appendix B). These correlations would give us insight into how users with different musical experience perceived the game and the music. Our hypothesis was that a negative correlation between experience and enjoyment/challenge would exist, indicating that more musically educated users would find the game either easier and/or the music too simplistic. Additionally, we calculated the correlations of the delta of the attention tests that the users completed and the distance gameplay metric we introduced. The assumption was that there would be a positive correlation, indicating that the distance metric was successful in identifying users that participated in the previously mentioned therapeutic mechanism. We also calculated the correlation coefficient between all other variables, which could shed light into other unforeseen correlations among our data sets.

Finally, given the research questions that we posed, it was essential that all participants complied with a set of criteria. More specifically, they had to have played a minimum number of sessions and they had to complete both pre- and post-experiment cognitive tests. The reasons for these criteria are the following: playing too few sessions ran the risk of not capturing the potential attention improvement and not having completed both attention tests meant that we would not be able to identify if there was any improvement or not. This means that participants that do not comply with these criteria would have to be excluded from the analysis (see Section 5).

In the next section, we present the results of the experiment, as extracted from the data processing and analysis that was detailed.

5 Results

This section presents the results of our experiment. In total, 21 people participated in the experiment. Of those, 13 fulfilled the criteria that were mentioned in Section 4.4, who form the final sample. Six participants did not play enough sessions and two did not complete all of the attention tests and are therefore excluded from the final sample. The average age of the 13 remaining participants was 23 years old. Seven of them were male and six of them female. None of the participants reported having any cognitive or neurological disorders. The study included a variety of nationalities, namely Dutch, Chinese, South Korean, Austrian, German and Bulgarian. The questionnaire showed a mixed level of musical experience among the participants.

The following sections are structured as follows: First, we illustrate the results of the attention tests. Second, gameplay data that outline how those participants interacted with the game intervention are showcased. Third, we exhibit the participants' self-reported experiences of the game intervention. Finally, we present the most important statistically significant correlations that we found.

5.1 Attention

As mentioned in Section 4.3, participants completed three different cognitive tests - one for working memory (DS) and two for attention (SA for selective and CPT for sustained). Table 2 shows the results of both pre- and post-experiment tests and their difference. The user base can be split into two Groups, namely A and B. The explanation for this grouping can be found in the next section.

Table 2. Attention test results for all users and Group A and B.

Test	All Users (n = 13)	Group A (n = 8)	Group B (n = 5)
DS1_score	8.92	9.00	8.80
DS2_score	9.08	9.00	9.20
DS_score_delta	0.15	0.00	0.40
SA1_hits	73.77	71.88	76.80
SA2_hits	79.77	82.13	76.00
SA_hits_delta	6.00	10.25	-0.80
CPT1_hits	60.54	61.13	59.60
CPT2_hits	60.92	60.88	61.00
CPT_hits_delta	0.38	-0.25	1.40

It can be observed that in general, for all users, there seems to be a very small improvement in the DS and CPT (0.15 and 0.38) tests and a more sizable one (6.0) for SA, as can be seen in Figure 4. When looking at the individual groups, Group A showed no improvement on DS, but showed a significantly larger improvement on SA. However, there was a deterioration in their performance on CPT. Group B on the other hand showed a small improvement on DS and CPT tests, but a deterioration on SA.

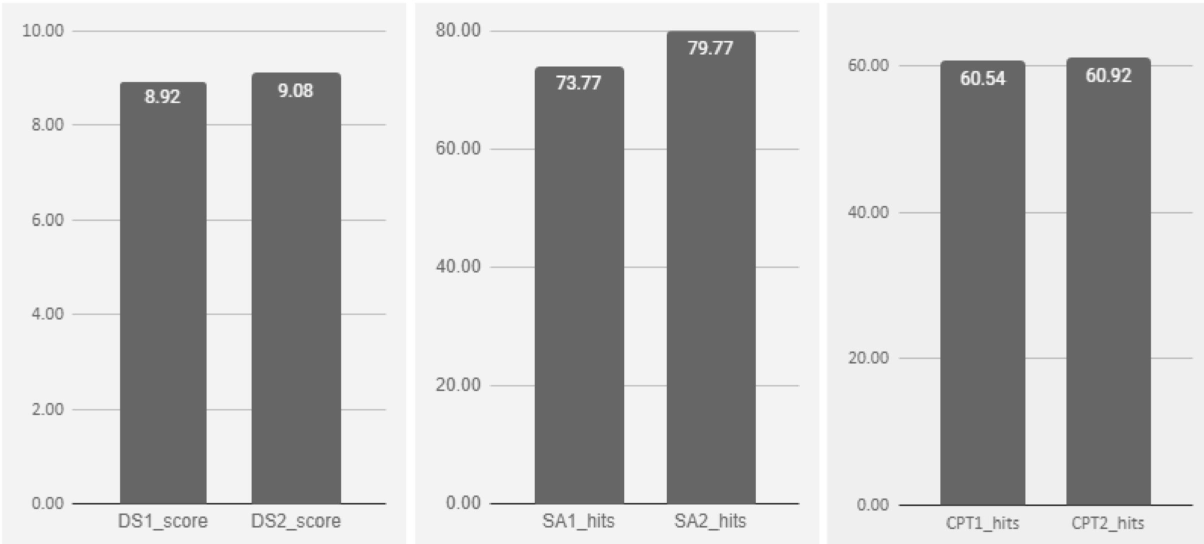

Figure 4. Pre- and post-experiment results of the three attention tests for all users.

5.2 Gameplay

As it is clear from Figure 5, the participants can be distinguished in two groups, based on their average button presses per musical bar. One group's value is very close to one button press per musical bar (Group A - 0.98 button presses), whereas the other's is significantly higher than that (Group B - 3.35 button presses). Group A interacted with the game mainly by pressing the button once at the beginning of each musical bar. Group B, on the other hand, followed a more free-form style, and seemed to press buttons on downbeats of the music.

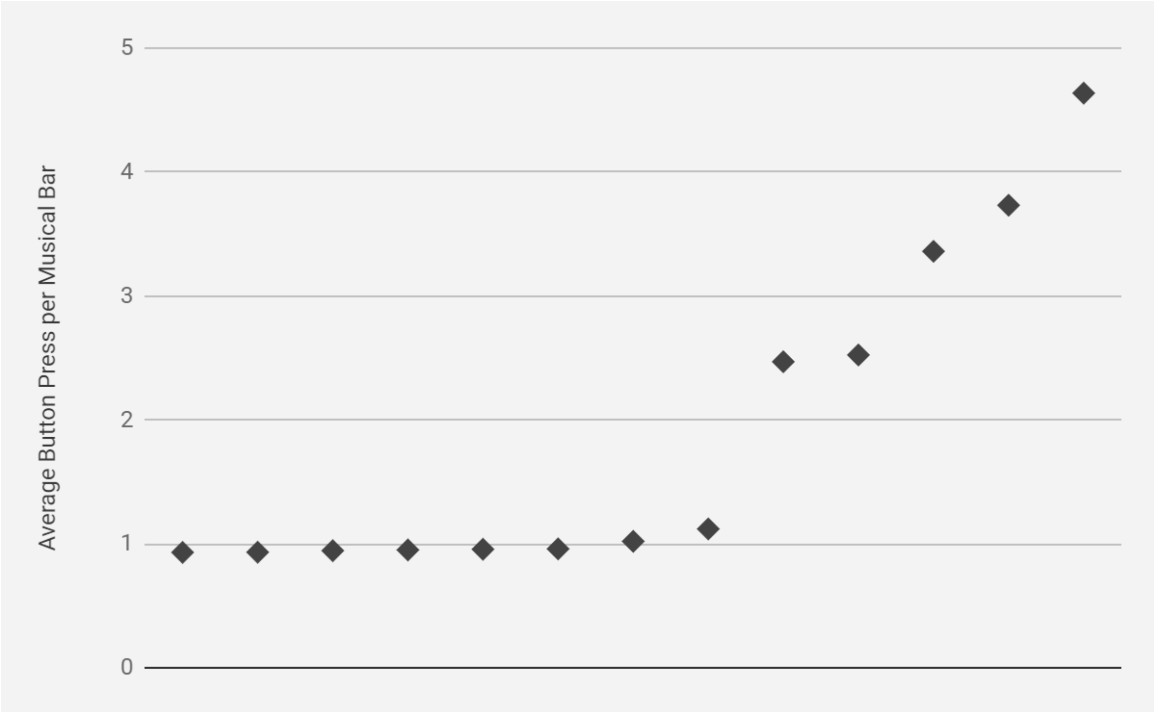

Figure 5. Average button presses per musical bars of the 13 users. Clear indication of two groups.

Table 3 shows the eight metrics that were extrapolated from the raw gameplay data. These metrics are shown for all 13 users, but also for Groups A and B separately. The results are highlighted below.

As mentioned before, the average button presses per musical bar is the defining metric that differentiates the two groups. Regarding the average distance from bar to bar, we observe that Group A had a much lower value compared to Group B (0.23 compared to 0.85). This is also noticed in the average distance after musical changes. Group B changed their playing more significantly on the first half of a musical bar after a musical change (0.92 compared to 0.25). As for the button press delta after a musical change, Group B had a more significant change compared to Group A (-0.25 compared to -0.05).

Table 3. Gameplay metrics results for all users and Group A and B.

Gameplay Metrics	All Users (n = 13)	Group A (n = 8)	Group B (n = 5)
Average Number of Sessions	15.23	17.63	11.40
Average Session Duration (s)	277.29	274.88	281.16
Average Distance Between Musical Bars	0.47	0.23	0.85
Average Button Presses	233.84	118.85	417.81
Average Button Presses Per Musical Bar	1.89	0.98	3.35

Average Button Presses Delta After Musical Change	-0.13	-0.05	-0.25
Average Distance of First Half of Musical Bar After Musical Change	0.51	0.25	0.92
Average Distance of Second Half of Musical Bar After Musical Change	0.40	0.19	0.73

5.3 User experience

Part of the questionnaire, filled in by the participants after the experiment, were a number of questions regarding their self-reported experience of the game. The average values of the participants' answers can be found in Table 4. 0 stands for "Not at all" and 10 "Very much". From the reported values, we can make several observations.

A number of questions were designed to gauge the experience of the users at the beginning and at the end of the game sessions. Some aspects of their experience increased and some declined. The biggest observed deterioration was in how challenging the participants found the game (from 5.15 to 3.78). Participants' interest in the game, as well as their motivation to perform, slightly deteriorated throughout the course of the experiment (5.43 to 4.68 and from 6.79 to 5.88 respectively). Slight improvements can be seen in the participants' enjoyment of the game, as well as their enjoyment of the music (from 4.67 to 4.78 and from 5.05 to 5.28 respectively).

There were also some questions regarding what affected their liking of the game. Users reported that their liking of the music did have some impact on their liking of the game (5.39), whereas their game experience did not have a significant impact on their liking of the game (2.58). Finally, they did experience some skill increase over the course of the play sessions (5.66).

Table 4. User experience results based on the questionnaire (0 = not at all, 10 = very much).

Questions	**Values (0-10)**
Interest in game at start	5.43
Interest in game at end	4.68
Interest in game delta	-0.75
Game was boring at start	4.78
Game was boring at end	4.69
Game was boring delta	-0.09
Game enjoyment at start	4.67
Game enjoyment at end	4.78
Game enjoyment delta	0.12

Motivation to perform at start	6.79
Motivation to perform at end	5.88
Motivation to perform delta	-0.91
Game felt challenging at start	5.15
Game felt challenging at end	3.78
Game felt challenging delta	-1.36
Liked music at start	5.05
Liked music at end	5.28
Liked music delta	0.22
Liking music affected liking game	5.39
Associations with music affected liking game	5.74
Interest in playing game outside of experiment context	2.12
Game experience influenced on liking game	2.58
Skill increased over time	5.66

5.4 Correlation analysis

We calculated Pearson correlation coefficients between self-reported musical experience of users and the perceived challenge, skill increase and enjoyment of the music, based on users' answers to the respective questions in the questionnaire. Additionally, we calculated the correlations of the delta of the attention tests and the distance gameplay metric we introduced. For further insights, we also calculated the correlation between all variables. The motive and hypotheses of this analysis is further explained in Section 4.4. All of these resulted in a very large number of correlation coefficients, of which only a small portion (~700 out of more than twenty thousand correlations, when including all possible variables) were statistically significant ($p < 0.05$). Because of the two groups that were identified in Section 5.2, we performed the correlations for all users, but also for each group individually. Below we present the most salient results, in relation to our initial hypotheses. A full table of all statistically significant correlations calculated for all groups can be found in Appendix C.

Firstly, we examine the correlations for all users ($n = 13$). The delta of the SA test results (difference between the pre- and post-experiment test results) were positively correlated with the users' self-reported ability to sing in tune ($r = 0.65$), based on the participants' answers in the musical experience section of the questionnaire (Appendix B, Block GMSI). Similarly, the delta of CPT results were positively correlated with the users' daily music listening hours ($r = 0.73$). The self-reported challenge of the game at the end of the sessions was positively correlated with the self-reported skill increase of the users (r =

0.68). No statistically significant correlation was found between the attention test deltas and the distance metrics.

Additionally, we notice a negative correlation between the participants' musical experience (years of instrument practice and/or hours of daily practice) and a number of factors: their reported motivation (r = -0.58), enjoyment of the music (r = -0.56) and perceived challenge of the game (r = -0.78), as well as their skill increase (r = -0.78).

Finally, we examine correlations for the individual groups. For Group A (n = 8), we notice a large correlation between the delta of SA tests and the gameplay metrics of average distance between musical bars, as well as the average distance of bars where a musical change happened (r = 0.93 for both). For Group B, no unique significant correlations were found.

6 Discussion

In this section, we discuss the conclusions that can be drawn from the results regarding the three research questions that we aimed to answer. Next, we present the limitations to this study and conclude by suggesting possible future work.

6.1 Conclusions

In Section 3 we listed the three research questions that this study set out to investigate and answer. Below we discuss our conclusions on the extent to which each research question was sufficiently addressed.

Research question 1 (RQ1): *What are the requirements for an MACT game intervention for PD patients?*

In the extensive literature review in Section 2, we investigated what a game intervention that aims to emulate an MACT session and is tailored to PD patients should look like. Our answer to this question can be found in Table 1, in which we list eight requirements that should be followed by any game intervention that aims to achieve this.

Research question 2 (RQ2): *To what extent can the design of a game intervention for PD patients be derived from these requirements?*

Based on the requirements, we followed an iterative process in order to develop a game intervention. This process involved taking a number of decisions regarding the design of the game, since the requirements can be translated in many different ways. The reasons for which these decisions were taken can be found in detail in Section 4.2, However, no comprehensive answer to RQ2 can be given without a materialized game in the hands of actual users. Consequently, to give a substantiated answer to the extent to which our game intervention design successfully incorporates the requirements, we take a look into the gameplay and user experience data.

We believe that, in broad terms, the game intervention manages to successfully embody most of the determined requirements. Firstly, we managed to gamify the therapeutic mechanism of MACT. The users need to pay attention to the changes and adapt their playing. Additionally, we made sure that the users will not be able to memorize the music by generating music at runtime. Generating music that sounds good and does not get boring at runtime is a non-trivial task. However, users' enjoyment of the music not only did not deteriorate throughout the sessions, but it also slightly increased (delta = 0.22). At the same time, their enjoyment of the game followed the same trend, with a comparable improvement (delta = 0.12). These observations indicate that the game was quite successful in that regard.

Regarding UI/UX design, we needed to minimize cognitive demands. This was achieved by having the interface show only relevant information about the game - the user's avatar holding a guitar and a large guitar button that when pressed made the avatar play the guitar. This setup also ensured that this button - avatar link was as clear as possible. By reducing the interface to just this setup, feedback was also minimized which meant that the button - avatar link was unmissable (i.e. pressing the button makes the avatar play guitar, which also creates music). The introduction to the game further supported this goal, introducing the context of the concert. Also, by talking about the user as the avatar, it was unambiguous what the user had to do in the game. As a matter of fact, users reported that having prior game experience was not important (average value = 2.58), indicating the game's accessibility. Additionally, by allowing the users to play along however they liked, we avoided having to include negative feedback, which would be required if the user was not playing according to a mandated pattern.

However, it is also our belief that the design of the game has room for improvement in some aspects. Since the premise was that there is no correct way to play along, there is no way of telling whether the tutorial was successful in teaching the users what they had to do when the music changed. The gameplay data clearly indicated that there were two distinct playstyles. The distance metric that we introduced gives us some kind of indication as to how the users played along, but does not provide a definitive answer.

On a similar note, as mentioned in Section 4.2, we did not include any kind of DDA in our game intervention. User experience data strongly suggest that the game intervention would benefit from an inclusion of DDA. In particular, users' musical experience had negative correlation with enjoyment, motivation, challenge and skill increase (r = -0.58, -0.56, -0.78, -0.78 respectively), which underlines the significance of adjusting the difficulty based on each user's performance. It is our speculation that users with musical experience found the game too easy or the music too simplistic for their tastes.

Research question 3 (RQ3): *To what extent does an implementation of the designed game intervention improve the attention of PD patients?*

With regards to RQ3, the results of the attention tests suggest a slight improvement in attention for the participants (0.15 for DS, 6.0 for SA and 0.38 for CPT). This is promising and might indicate the game's efficacy on non-PD patients. However, there are a number of reservations. Firstly, the sample size was too small in order to draw a definitive conclusion. Secondly, due to the circumstances under which the experiment was carried out (COVID-19 pandemic), each participant's number of sessions varied, which could affect results. Finally, as mentioned previously, whether the game intervention works for PD patients can only be extrapolated from the non-PD population. This means there is an assumption the results would be similar for PD patients.

Furthermore, there is an additional worthwhile observation regarding the game intervention's efficacy. Even though there is no conclusive evidence that the heuristic distance metric gauged whether the users' followed the emulated therapeutic mechanism, it still helps us draw some conclusions about the users' playstyle and the associated effect on attention. Specifically, for Group A's playstyle (average 1 press per musical par), the distance metric when measured on musical changes seemed to predict improvement in selective attention (r = 0.93). It was our hypothesis that users with a higher value in the distance metric we proposed would also show improvements in attention, since that would indicate that they participated in the therapeutic mechanism. Whilst that was the case for users from Group A, that wasn't the case for Group B. This shows that the approach we followed was either not successful in identifying users from all possible playstyles that changed their playing when a musical change occurred or that the initial hypothesis was incorrect.

6.2 Limitations

There are a number of limitations to this research. To start with, there are a couple of scoping limitations. As previously mentioned, we were not able to run the experiment with PD patients as participants. This has immediate repercussions on how we can interpret the results of the game interventions' efficacy on attention. Additionally, based on the user experience data, adding some form of DDA would be beneficial in keeping users with prior music training challenged and motivated. Due to time constraints, we were unable to include such a feature, though we explore future avenues on this topic in the next section.

Additionally, due to how the game design was set up, it was very difficult to measure whether the participants understood what they had to do - that is change their playing when the music changes. Having a measurement that accurately identifies when the user changes playing behaviour is important in understanding if they are participating in the therapeutic mechanism of MACT that the game tries to emulate. The proposed distance metric was the first attempt in doing this, and was ultimately unable to definitively reveal whether or not all users who followed the emulated therapeutic mechanism showed improvement in attention, since it is not clear which users did follow it and which did not. In the next section we propose several ways to improve measuring which users followed the emulated therapeutic MACT mechanism.

Finally, a limitation was the circumstances in which the experiment was performed. Due to the global COVID-19 pandemic, recruiting participants for our study was very challenging, as was setting up a controlled environment for the study. This resulted in a low number of participants that had to play the game sessions from their home in a non-monitored environment. This also prevented us from adding a control group, since that would cut our already small number of participants in half.

6.3 Future work

Based on the above limitations, we suggest several avenues that future work could focus on. The following topics are discussed in this section: improved ways to measure when participants are changing playing behaviour, inclusion of a form of DDA in the game intervention, generating more engaging music, suggestions for improving the experiment setup and suggestions for alternative explorations of MACT in a gamified context.

Firstly, we propose exploring other ways to measure when patients are changing behaviour. As previously mentioned, this is rather difficult and could be approached in a few ways. A possible future avenue is to create an algorithm that is not limited to comparing musical bars, but also takes into consideration more broad play patterns. This approach could identify when a user has settled in a play style, that could mean that they are ready for a new musical change, which isn't possible to do when focusing on the distance between one bar and the next. Another avenue that could be explored is to further explore all the possible playstyles that users have and modify the distance metric proposed in this thesis to accommodate those playstyles as accurately as possible.

A more accurate identification of situations where users are not following the desired play pattern of changing their play styles as a reaction to the music changing, makes it possible to introduce DDA in the game intervention. If a user struggles to follow the play pattern and the game intervention identifies this, a DDA implementation could reduce the difficulty so that the user is not overwhelmed by the musical changes. On the other hand, if a user never fails to follow this pattern, a DDA implementation could increase the difficulty of the game intervention. Furthermore, PD patients have a broader spectrum of skills, because of the deterioration of their symptoms as their disease progresses. Finally, gathered data show that musical experience resulted in lower game and music enjoyment, and perceived challenge as reported by the users.

For all of the above reasons, we suggest future work to investigate possible ways to include an implementation of DDA in the game intervention. Given the design of the proposed game intervention, any kind of difficulty adjustment translates to adjusting the generated music and how the music changes. A possible approach could be to include a larger array of rhythms, tempos and chord progressions, which could be ranked by how difficult they are to play along with. This ranking can happen offline, by testing it with users of a varying music and skill level, as well the severity of their symptoms. It can also happen online, by monitoring which changes are harder for each user and keeping a profile of difficulty for each of those changes. Then, when the game determines that it needs to be easier, a musical change that the profile suggests would be easier is selected and vice versa. Additionally, in terms of making playing along with the music easier or harder, less or more frequent musical changes can occur.

It might also be worthwhile to look into adjusting the music generation algorithm that is proposed in this thesis. While the current iteration of the game intervention showed that enjoyment didn't deteriorate after multiple play sessions, the value wasn't that high. The experiment that was conducted lasted for only three weeks, which is not that long of a time period to gauge a potential decrease in enjoyment. The game intervention is meant to be used as a supplement in-between music therapy sessions, which need to take place regularly over a much longer period of time, a requirement that highlights the need for the music to remain enjoyable in order to keep users engaged. Also, making the music more/less difficult means that there needs to be a wider array of musical rhythms, tempos and more/less frequent musical changes (which also means more chord progressions). The proposed version of the music generation produces music that is very simplistic in its structure when compared to popular music, mainly because it only contains a drum background beat and a guitar. This has the benefit of making it easy to distinguish musical features, such as rhythm and tempo. The downside is that it does not allow for a lot of variation, which can become monotonous, especially if played for long periods of time. In order to make the music generation more interesting, future work could explore adding more structural elements to the music, such as basslines and melodies. In this case, it is important to take into account the effect such added musical elements would have on the users' perception of the rhythm. It is very likely that playing along with the music might become more difficult as the music's features would be less easily recognizable. In this case, these new features should only appear in situations where the user's abilities are sufficient, which once again indicates the need for gauging the user's skill.

Furthermore, It would also be valuable to perform a similar study in a more controlled environment and, ideally, on PD patients. Saying with absolute confidence whether or not there is a significant improvement on attention would require a larger sample size, a specified number of sessions, as well as an experiment conducted over a longer period of time in order to explore possible retention of the attention improvement.

Finally, MACT contains a large number of protocols. In this study we investigated and tried to emulate the mechanisms behind one of those protocols. This protocol trains selective and sustained attention. Other protocols can target different aspects of attention. Future research could also look into the possibility of gamifying and emulating the therapeutic mechanisms of some of the other protocols of MACT, such as Clinical Protocol 1, Auditory Perception. In addition to this, future work could explore different game designs that follow all of the established requirements, since there is no one game design that does this.

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Appendix

Appendix A - Music generation algorithm

In this appendix we detail the nine steps the algorithm follows in order to create randomized songs for the game intervention, as mentioned in Section 4.2.

Step 1: Randomly select a **Key** from the **Key pool** (Figure A1).

Key pool

A, A#, B, C, C#, D,
D#, E, F, F#, G, G#

Figure A1. Pool of all keys the algorithm can choose from.

Step 2: Randomly select a **Chord progression** from the **Chord progression pool** (Figure A2).

Chord progression pool

I - V - vi - IV - I - V - vi - IV
I - vi - IV - V - I - vi - IV - V
I - V - IV - iii - I - V - iii - IV
I - V - vi - iii - IV - I - IV - V

Figure A2. Pool of all chord progressions the algorithm can choose from.

Step 3: Randomly select a **Rhythm** for the percussion from the **Rhythm pool** (Figure A3).

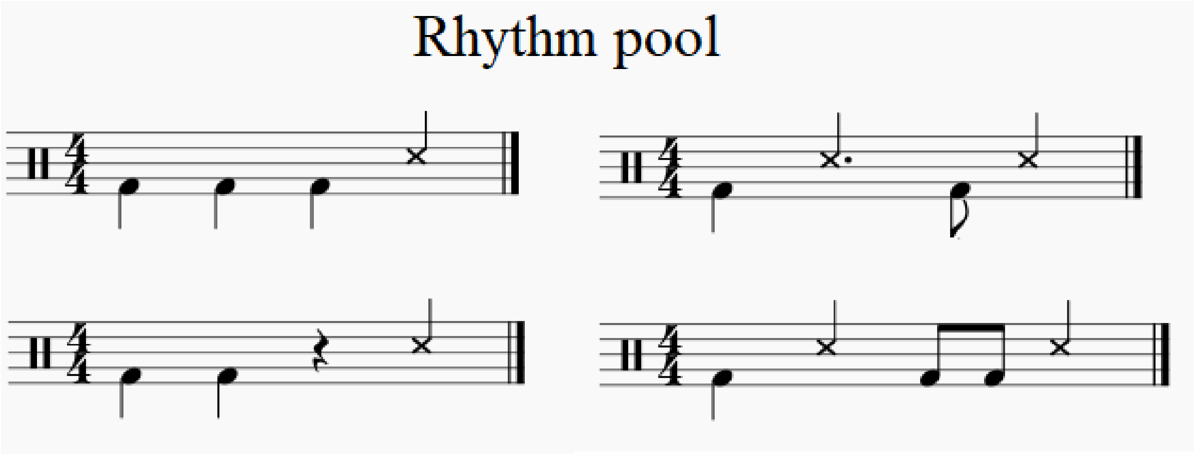


Figure A3. Pool of all rhythms the algorithm can choose from.

Step 4: Randomly select a **Tempo** from the **Tempo pool** (Figure A4).

Figure A4. Pool of all the possible tempos the algorithm can choose from.

Step 5: For 8 musical bars, play the percussion audio clip that corresponds to the selected *rhythm* and *tempo*.

Step 6: At the start of each bar, find the guitar chord audio clip that corresponds to the bar's progression. E.g. if we are in the **Key** of **C** and **Chord Progression** of **I - VI - vi - IV - I - VI - vi - IV**, in the third bar, get the minor sixth (**vi**) **chord** of the **Key** of **C**, so **Chord Am**.

Step 7: Whenever the user presses the button, play the found guitar chord audio clip.

Step 8: After 8 musical bars have passed, find a random **Musical Change** (change of **Rhythm, Tempo** or **Pause**) and apply it to the percussion.

Step 9: Go to Step 5 and repeat until the song ends (124 musical bars in total).

Appendix B - Questionnaire

This appendix includes the questionnaire used for conducting the experiment described in Section 4.3. Please note that the game "MusicRunner" mentioned in the questionnaire was a different serious game intervention and is irrelevant to this research.

Gaming AttentionBP81

Start of Block: InformedConsent

IC Thank you for your interest in this study focusing on musical computer games, carried out by Leiden University. We are looking for people without a history of neurological disorders, or (uncorrected) problems in their hearing or hand movement. It doesn't matter how much previous experience you have with music, or computer games.

In this study, we will ask you to play a computer game for 10 minutes a day on weekdays, with an online experiment at the beginning and end. If you have any questions about this study you can contact the research team at music.gaming.leiden@gmail.com, or the responsible researcher, Dr. Rebecca Schaefer, by email: r.s.schaefer@fsw.leidenuniv.nl.

In this two week period, we ask that you play a game for 10 minutes on 10 separate days. You can do this on week days, but you can also plan it yourself, for instance to catch up on a session you may have skipped. It's up to you which 10 days in these 2 weeks you choose to play, and of course you can play at any time of day that suits your schedule. You will have to download the game to play it, it will only work on Windows computers, so Mac users will not be able to take part. If you participate, we will ask for your email address in order to send you updates and reminders. This email address will only be used for the study, and will be deleted immediately afterwards.

At the beginning and ending of the two weeks, we will ask you to complete an online experiment taking about 30-45 minutes, in which we ask you questions about your previous experience with gaming or music, your opinion about musical fragments, and ask you to complete a few short tests of mental function, each taking no longer than 7 minutes. For this experiment it will help to have a good internet connection, and good sound (with stereo through headphones or earbuds). The experiments work best on a larger screen (computer or tablet).

If you are a Psychology student in Leiden, you can earn 6 sona credits for this study. If you don't need credits, you can receive a financial compensation of a €20 'VVV' voucher, to be spent in various (online) stores.

Do you have a complaint? Please contact the responsible researcher. If you prefer not to contact the researcher, you can also send an email to ethiekpsychologie@fsw.leidenuniv.nl. Questions related to privacy can be discussed with the responsible researcher or otherwise directly sent to the Leiden University Institute for Psychology's Privacy officer: privacy@bb.leidenuniv.nl

It's important to know that: All collected data will be confidential, and stored in a coded way. All participants automatically receive a code that functions as an identifier, rather than your name. The answers you will provide can not be linked to your identity. You will be asked to create a username that can link your answers to your gameplay. Your email address will only be used to send you reminders or compensation, and will be deleted when you finish the study. The collected data will only be used for scientific research and will not be shared with third parties. Only the directly involved researchers will have access to the data, conditional on their confidentiality. You are allowed to stop at any time during the study, without providing a reason - Just close the screen. You can take part on a voluntary basis, for 6 Sona-credits, or a compensation of a €20 'VVV' voucher, to be spent in various (online) stores.

o I have read the information, use a Windows computer, and agree to the use of my data for scientific research. (1)

o No, I will not take part in this study. (2)

Display This Question:

If Thank you for your interest in this study focusing on musical computer games, carried out by Leid... = I have read the information, use a Windows computer, and agree to the use of my data for scientific research.

Session Is this your starting session, or the ending session?
If this is your starting session, please choose a username that you can use to identify yourself during gameplay and for the ending session.

o Starting session, and I choose the following username: (1) ____

o Ending session, my chosen username is: (2) ____

Display This Question:

If Is this your starting session, or the ending session?If this is your starting session, please cho... = Ending session, my chosen username is:

Game Which game did you play?

- MusicRunner (1)
- LastMinuteGig (2)
- None (3)

End of Block: InformedConsent

Start of Block: Dem_InclCrit

Age What is your age?

____

Gen What is your gender?

- Male (1)
- Female (2)
- Other (3)
- Prefer not to say (4)

AttCrit Do you have any history of attention disorders?

- Yes (1)
- No (2)

NeurCrit Do you have any history of neurological disorders?

- Yes (1)
- No (2)

HearCrit Do you have any uncorrected hearing problems, or problems moving your hands?

- Yes (1)
- No (2)

End of Block: Dem_InclCrit

Start of Block: Gaming Background

Gaming_time How many hours do you spend gaming per week in your free time?

- Never (1)
- 0 - 3 hours (2)
- 3 - 5 hours (3)
- 5 - 10 hours (4)
- More than 10 hours (5)

Gaming_hist How long have you been playing videogames?

- o Not at all (1)
- o Less than 6 months (2)
- o 6 months - 3 years (3)
- o 3 - 5 years (4)
- o More than 5 years (5)

Gaming_type What type of games do you play in general? (multiple answers possible)

- ▢ Action games [Super Mario Bros, Call of Duty, Mortal Kombat, God of War, Resident Evil etc.] (1)
- ▢ Rhythm Games [Guitar Hero, Just Dance, Beat Saber etc.] (2)
- ▢ Action-adventure games [Legend of Zelda, Final Fantasy, Kingdom Hearts, Minecraft etc.] (3)
- ▢ Role-playing games [Fallout, Legend of Zelda, Final Fantasy, MMORPG, Skyrim, Dungeons and Dragons, Assassin's Creed, Genshin Impact etc.] (4)
- ▢ Simulation games [The Sims, Stardew Valley, Totally Accurate Battle Simulator, Goat Simulator, Cooking Simulator, Rollercoaster Tycoon etc.] (5)
- ▢ Strategy games [Age of Empires, Crusader Kings, SMITE, DOTA, Town of Salem, Bloons TD Battles, ShellShock, Worms etc.] (6)
- ▢ Sports games [F1, FIFA, Need for Speed, NBA, Rocket League, NHL, Madden NFL etc.] (7)
- ▢ Puzzle games [Tetris, Sudoku, Mahjong, Portal, Bejeweled, The Room, Candy Crush, Chess etc.] (8)
- ▢ I do not play any games. (9)

End of Block: Gaming Background

Start of Block: Digit Span Task

DS_instr In the next part, we will ask you to listen to a sequence of numbers, and repeat them back in reverse order. For instance, if you hear 5, 2, you type in 25. Please don't use spaces or dashes, just type the numbers. If you are unsure, you can leave it open.

As you may only listen to the sound once, please pay attention! You can only start filling in the numbers once the sound is over. This part will take about 5 minutes.

Start of Block: CPT

CPT_intro
In the next test you will see letters appear briefly on the screen.

Your task is to press the space bar whenever you see an 'X', but only when it comes after an 'A'.
If it doesn't come after an A you should not respond! Please always use the space bar.

This attention test will take about 7 minutes, please try to stay attentive for the whole video and press as quickly as you can.

Press the arrows below to go to the next screen, where you can **start the task by pressing the space bar**.

CPT_trial
Press the SPACE BAR to start the trial!
Then, press the SPACE BAR when you see an X when it comes after an A. Please press as quickly as you can!
When it's finished, press the arrows to continue.

End of Block: CPT

Start of Block: Tapping

Mettap

In the next part, we ask you only to tap along with the sound on the space bar of your keyboard. This part will take less than a minute.

Press the space bar to start the sound, and then tap along with the sound as precisely as you can!

End of Block: Tapping

Start of Block: Sel_att

Sel_att instr In the next part, we will ask you to listen to a series of beeps, and press the spacebar for only some of them. The beeps will be different in your right and left ear, and mostly be higher, and sometimes lower. We will ask you to only pay attention to one ear at a time, and only press the spacebar for the lower beeps. In total, this part will take about seven minutes.

First, let's check that you have your headphones or earbuds on correctly! This sound has two high beeps and a low beep and should play only in your right ear:

Next, here is a sound that has two high beeps and a low beep and plays only in your left ear:

This is how they will sound together, remember, you will be instructed to listen only to one ear, and only press the spacebar when you hear a low beep in that ear.
Press the arrows to do a short practice.

JS

Selatt_prac

Let's practice: press the spacebar to start the sound, and then please only press the spacebar every time you hear a lower beep in your RIGHT ear, not when you hear a lower beep in the LEFT ear.

When the sound is over, press the arrows to go to the real test, it will be one sound for each ear.

Setatt_right

Press the spacebar to begin, and then please press the spacebar every time you hear a LOWER beep in your RIGHT ear.

Selatt_left

Press the spacebar to begin, and then please press the spacebar every time you hear a LOWER beep in your LEFT ear.

Start of Block: GMSI

GMSI1-16 Now here are some more questions about your experience of music.

Please select the most appropriate answer:

	1: Completely disagree (1)	2: Strongly disagree (8)	3: Disagree (2)	4: Neither agree or disagree (3)	5: Agree (4)	6: Strongly agree (5)	7: Completely agree (6)
I spend a lot of my free time doing	o	o	o	o	o	o	o

music-related activities. (1)							
I sometimes choose music that can trigger shivers down my spine. (2)	o	o	o	o	o	o	o
I enjoy writing about music, for example on blogs and forums. (3)	o	o	o	o	o	o	o
If somebody starts singing a song I don't know, I can usually join in. (4)	o	o	o	o	o	o	o
I am able to judge whether someone is a good singer or not. (5)	o	o	o	o	o	o	o
I usually know when I'm hearing a song for the first time. (6)	o	o	o	o	o	o	o
I can sing or play music from memory. (7)	o	o	o	o	o	o	o
I'm intrigued by musical styles I'm not	o	o	o	o	o	o	o

familiar with and want to find out more. (8)							
Pieces of music rarely evoke emotions for me. (9)	o	o	o	o	o	o	o
I am able to hit the right notes when I sing along with a recording. (10)	o	o	o	o	o	o	o
I find it difficult to spot mistakes in a performance of a song even if I know the tune. (11)	o	o	o	o	o	o	o
I can compare and discuss differences between two performances or versions of the same piece of music. (12)	o	o	o	o	o	o	o
I have trouble recognizing a familiar song when played in a different way or by a	o	o	o	o	o	o	o

different performer. (13)							
I have never been complimented for my talents as a musical performer. (14)	o	o	o	o	o	o	o
I often read or search the internet for things related to music. (15)	o	o	o	o	o	o	o
I often pick certain music to motivate or excite me. (16)	o	o	o	o	o	o	o

GMS!17-31

Next, here are more questions about your musical experiences.Please indicate to what extent you agree with the following statements

	1: Completely disagree (1)	2: Strongly disagree (2)	3: Disagree (3)	4: Neither agree or disagree (4)	5: Agree (5)	6: Strongly agree (6)	7: Completely agree (7)
I am not able to sing in harmony when somebody is singing a familiar tune. (1)	o	o	o	o	o	o	o
I can tell when people sing or play out of time with the beat. (2)	o	o	o	o	o	o	o
I am able to identify what is special about a given musical piece. (3)	o	o	o	o	o	o	o
I am able to talk about the emotions that a piece	o	o	o	o	o	o	o

of music evokes for me. (4)							
I don’t spend much of my disposable income on music. (5)	o	o	o	o	o	o	o
I can tell when people sing or play out of tune. (6)	o	o	o	o	o	o	o
When I sing, I have no idea whether I’m in tune or not. (7)	o	o	o	o	o	o	o
Music is kind of an addiction for me - I couldn’t live without it. (8)	o	o	o	o	o	o	o
I don’t like singing in public because I’m afraid that I would sing wrong notes. (9)	o	o	o	o	o	o	o

When I hear a piece of music I can usually identify its genre. (10)	o	o	o	o	o	o	o
I would not consider myself a musician. (11)	o	o	o	o	o	o	o
I keep track of new music that I come across (e.g. new artists or recordings). (12)	o	o	o	o	o	o	o
After hearing a new song two or three times, I can usually sing it by myself. (13)	o	o	o	o	o	o	o
I only need to hear a new tune once and I can sing it back hours later. (14)	o	o	o	o	o	o	o

Music can evoke my memories of past people and places. (15)	o	o	o	o	o	o	o

Page Break

GMSI32
Here are some more questions about your experience with music. Please select the most appropriate answer.
I engaged in regular, daily practice of a musical instrument (including voice) for ... years.

- 0 (1)
- 1 (2)
- 2 (3)
- 3 (4)
- 4-5 (5)
- 6-9 (6)
- 10 or more (7)

GMSI33 At the peak of my interest, I practiced ... hours per day on my primary instrument.

- 0 (1)
- 0,5 (2)
- 1 (3)
- 1,5 (4)
- 2 (5)
- 3-4 (6)
- 5 or more (7)

GMSI34 I have attended ... live music events as an audience member in the past twelve months (please estimate what this would be without coronavirus prevention measures).

- 0 (1)
- 1 (2)
- 2 (3)
- 3 (4)
- 4-6 (5)
- 7-10 (6)
- 11 or more (7)

GMSI35 I have had formal training in music theory for ... years.

- 0 (1)
- 1 (2)
- 2 (3)
- 3 (4)
- 4-6 (5)
- 7-9 (6)
- 10 or more (7)

GMSI36 I have had ... years of formal training on a musical instrument (including voice) during my lifetime.

- 0 (1)
- 0,5 (2)
- 1 (3)
- 2 (4)
- 3-5 (5)
- 6-9 (6)
- 10 or more (7)

GMSI37 I can play ... musical instruments.

- 0 (1)
- 1 (2)
- 2 (3)
- 3 (4)
- 4 (5)
- 5 (6)
- 6 or more (7)

GMSI38 Per day I listen attentively to music for

- 0-15 min (1)
- 15-30 min (2)
- 30-60 min (3)
- 60-90 min (4)
- 2 hours (5)
- 2-3 hours (6)
- 4 hours or more (7)

GMSI39 The instrument I play best (including voice) is ...
if not applicable, write n/a

____

GMSI_occ
Next are some more general questions about your current situation.

Occupational status (please tick one of the following):

- Still at School (1)
- At University (2)
- In Full-time employment (3)
- In Part-time employment (4)
- Self-employed (5)
- Homemaker/full time parent (6)
- Unemployed (7)
- Retired (8)

GMSI_genre What is the musical genre you mainly listen to? (Select only one)

- Rock/Pop (1)
- Jazz (2)
- Classical (3)

GMSI_Ed What is the highest educational qualification you have attained?

- Did not complete any school qualification (1)
- Completed first school qualification at about 16 years (e.g. GCSE/Junior High School) (2)
- Completed Second qualification (e.g A levels/ High School) (3)
- Undergraduate degree or professional qualification (4)
- Postgraduate degree (5)
- I am still in education (6)

GMSI_ExpEd If you are still in education, what is the highest qualification you expect to obtain?

- First school qualification (e.g. GCSE / Junior High School) (1)
- Post-16 vocational course (2)
- Second school qualification (e.g. A-levels / High School) (3)
- Undergraduate degree or professional qualification (4)
- Postgraduate degree (5)
- Not applicable (6)

GMSI_dem Please fill in the following

- Nationality: (2) ____
- Country in which you spent the formative years of your childhood and youth: (3) ____
- Country of current residency: (4) ____

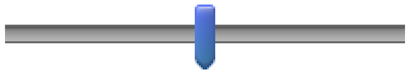
End of Block: GMSI

Start of Block: Traininginstr_game1

Mus1_assoc Use the music fragment below to set the volume properly. The intention is that you can hear the music well at a comfortable level.

When you are done, you can click on the arrow at the bottom to continue to the listening part of this survey, which takes about 10 minutes.

	Makes me think of nothing at all	Very strongly makes me think of something

Click to write Choice 1 ()	

Mus1_assoc_spec
If it makes you think of something, what does it make you think of?

TrainInstr1 This is the end of the starting session! Next, you will be given instructions on how to download the game that you will play for 10 minutes a day. You can download the game here as a zipfile or a self-extracting file, and if you need some help with getting it installed please see these instructions (for zip or self-extracting).
The idea is that you will use the username that you chose at the beginning when you enter the game, so that your gameplay is registered. We ask you to play 10 minutes every weekday, or just 5 times a week, whenever it suits you.

In the final session, to be completed in two weeks, will be a bit shorter, repeating a few things you did today, but also asking you about your experience of the game. If you are participating for credits, you will receive an invitation for the final session through your sona account.

As mentioned before, we will need your email address to send you more information and reminders, and you can always reach the research team by emailing music.gaming.leiden@gmail.com, if you have any questions or other issues.

Please leave your email address below, it will only be used to send you information about the experiment, and will be deleted once you are finished.

____

End of Block: Traininginstr_game1

Start of Block: TrainingInstr_game2

TrainInstr2 This is the end of the starting session! Next, you will be given instructions on how to download the game that you will play for 10 minutes a day. You can download the game here, and if you need some help with getting it installed please see these

instructions.
The idea is that you will use the username that you chose at the beginning when you enter the game, so that your gameplay is registered. We ask you to play 10 minutes every weekday, or just 5 times a week, whenever it suits you.

In the final session, to be completed in two weeks, will be a bit shorter, repeating a few things you did today, but also asking you about your experience of the game. If you are participating for credits, you will receive an invitation for the final session through your sona account.

As mentioned before, we will need your email address to send you more information and reminders, and you can always reach the research team by emailing music.gaming.leiden@gmail.com, if you have any questions or other issues.

Please leave your email address below, it will only be used to send you information about the experiment, and will be deleted once you are finished.

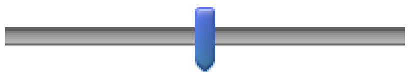
End of Block: TrainingInstr_game2

Start of Block: Musicrating_post

Display This Question:

If Which game did you play? = MusicRunner

MusicAssoc_post Use the music fragment below to set the volume properly. The intention is that you can hear the music well at a comfortable level.
When you are done, you can click on the arrow at the bottom to continue to the listening part of this survey, which takes about 10 minutes.

	Makes me think of nothing at all	Very strongly makes me think of something
()		

Display This Question:

If Which game did you play? = MusicRunner

MusicAssoc_post_spec

If it makes you think of something, what does it make you think of?

____

End of Block: Musicrating_post

Start of Block: Only post-training assessment

Postrating Now we'd like to ask some questions about your motivation in the last two weeks, and how this may have changed from the beginning to the end.

	Not at all Very much
How interesting was the game for you in the beginning? ()	
How interesting was the game for you at the end? ()	
How boring was the game for you at the beginning? ()	
How boring was the game for you at the end? ()	
How much did you enjoy the game at the beginning? ()	
How much did you enjoy the game at the end? ()	

How motivated were you to do well at the game in the beginning? ()	
How motivated were you to do well at the game in the end? ()	
How challenged did you feel at the beginning? ()	
How challenged did you feel at the end? ()	
How much did you like the music at the beginning? ()	
How much did you like the music at the end? ()	
Did how much you liked the music affect how much you liked the game? ()	
If the music made you think of something, did this affect how much you liked the game? ()	
Would you like to keep playing the game now that the study is over? ()	
Do you think your previous experience in gaming affected how much you liked the game? ()	
Do you feel like your skill increased over time? ()	

Display This Question:

If Now we'd like to ask some questions about your motivation in the last two weeks, and how this may... [Do you think your previous experience in gaming affected how much you liked the game?] > 0

Gamexp_effectdir Do you think your previous gaming experience made you like the game more or less?

- More (1)
- Not sure (2)
- Less (3)

ExtrMot Which of the following motivated you to finish the two weeks? (multiple answers possible)

- ▢ The compensation for completing the experiment (1)
- ▢ Potentially increasing your cognitive abilities (2)
- ▢ Helping science (3)
- ▢ Learning about psychological studies (4)
- ▢ Learning about musical games (5)
- ▢ Other: (6) ____

End of Block: Only post-training assessment

Start of Block: Debrief_Comp

Debrief Thank you for taking part in our study, which was intended to evaluate a newly developed music-based game to train attention. This is important because creating a game based on scientific evidence will support the rehabilitation of groups who have attentional problems, such as children with ADHD or people with Parkinson's Disease. There were two games that were evaluated, you were randomly assigned to one of them. Aspects we were interested in included specific aspects of mental functions that may have improved with playing the game, and what other aspects (such as enjoyment of the game or the music) affect this potential improvement. If you have any questions regarding this research, you can get in touch with the research team (music.gaming.leiden@gmail.com) or the responsible researcher, Dr. Rebecca Schaefer: r.s.schaefer@fsw.leidenuniv.nl   Do you have a complaint? Please contact the responsible researcher. If you prefer not to contact the researcher, you can also send an email to ethiekpsychologie@fsw.leidenuniv.nl. Questions related to privacy can be discussed with the responsible researcher or otherwise directly sent to the Leiden University Institute for Psychology's Privacy officer: privacy@bb.leidenuniv.nl   Please indicate your preferred method of compensation:

- o Voluntary (1)
- o Sona Credits, please credit my account (if you did not access the study through a sona link, please email music.gaming.leiden@gmail.com with your name and chosen username) (2)
- o Gift voucher, here is my email address (3) ____

Comments If you have any comments about the study, feel free to leave them here:

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End of Block: Debrief_Comp

Appendix C - Statistically significant correlations

In this appendix all the statistically significant correlations that were calculated can be found. Table 5 contains the coefficients for all users, Table 6 contains the coefficients for Group A (users that had an average of about 1 button press per musical bar) and Table 7 contains the coefficients for Group B (users that had an average of more than 1 button press per musical bar).

Below you can find some notes as to what each variable is, to help you read the tables:

- DS refers to the working memory test
- SA refers to the selective attention test
- CPT refers to the sustained attention test
- All of the variables containing "*GMS*" refer to specific questions that can be found in the questionnaire (see Appendix B)
- All variables that begin with "*F_...*" refer to the user experience questions that can be found in the questionnaire (see Appendix B)
- Everything else is gameplay data whose meaning should be easily extrapolated from their name

Table 5. Statistically significant (p < 0.05) correlation coefficients for all users.

Correlation	**Value**
Correlation of DS_ScoreDelta to DS1Hits	-0.62
Correlation of DS_ScoreDelta to L_GMS17_31_1	-0.73
Correlation of DS_ScoreDelta to F_Interest_start	-0.71
Correlation of DS_ScoreDelta to F_enjoy_start	-0.58
Correlation of DS_ScoreDelta to F_musiclike_start	-0.56
Correlation of SA_HitsDelta to DS2Hits	-0.57
Correlation of SA_HitsDelta to SA1Hits	-0.69
Correlation of SA_HitsDelta to L_GMS17_31_7	-0.66
Correlation of SA_HitsDelta to ED_GMSI_Ed	-0.61
Correlation of SA_HitsDelta to F_enjoy_start	0.73
Correlation of SA_HitsDelta to F_musiclike_effect	0.57
Correlation of SA_FADelta to ED_GMSI_occ	-0.57
Correlation of SA_FADelta to F_keep_playing	-0.66
Correlation of SA_RTDelta to LU_GMSI1_16_6	0.64
Correlation of SA_RTDelta to L_GMS17_31_5	0.71
Correlation of SA_RTDelta to ME_GMSI35	-0.59
Correlation of SA_RTDelta to ME_GMSI36	-0.67

Correlation of SA_RTDelta to ME_GMSI37	-0.65
Correlation of CPT_HitsDelta to CPT_FADelta	-0.58
Correlation of CPT_HitsDelta to SA1Hits	-0.57
Correlation of CPT_HitsDelta to SA2Hits	-0.71
Correlation of CPT_HitsDelta to CPT1Hits	-0.78
Correlation of CPT_HitsDelta to L_GMS17_31_3	-0.57
Correlation of CPT_HitsDelta to ME_GMSI34	0.60
Correlation of CPT_HitsDelta to ME_GMSI38	0.73
Correlation of CPT_HitsDelta to ED_GMSI_occ	-0.63
Correlation of CPT_HitsDelta to F_musiclike_effect	-0.58
Correlation of CPT_HitsDelta to F_musassoc_effect	-0.66
Correlation of CPT_FADelta to L_GMS17_31_3	0.71
Correlation of CPT_FADelta to ED_GMSI_genre	0.61
Correlation of DS1Hits to DS2Hits	0.65
Correlation of DS1Hits to LU_GMSI1_16_16	0.59
Correlation of DS1Hits to L_GMS17_31_8	0.62
Correlation of DS1Hits to L_GMS17_31_15	0.64
Correlation of DS1Hits to ME_GMSI32	0.56
Correlation of DS1Hits to F_skill_incr	-0.67
Correlation of DS2Hits to LU_GMSI1_16_1	0.69
Correlation of DS2Hits to LU_GMSI1_16_8	0.62
Correlation of DS2Hits to LU_GMSI1_16_16	0.71
Correlation of DS2Hits to L_GMS17_31_7	0.66
Correlation of DS2Hits to L_GMS17_31_8	0.82
Correlation of DS2Hits to L_GMS17_31_11	-0.68
Correlation of DS2Hits to ME_GMSI33	0.63
Correlation of DS2Hits to ME_GMSI36	0.59
Correlation of DS2Hits to ME_GMSI37	0.59
Correlation of DS2Hits to ED_GMSI_genre	0.61
Correlation of DS2Hits to F_enjoy_start	-0.64
Correlation of DS2Hits to F_challenge_start	-0.64
Correlation of DS2Hits to F_challenge_end	-0.68
Correlation of DS2Hits to F_musiclike_start	-0.60
Correlation of DS2Hits to F_skill_incr	-0.68
Correlation of SA1Hits to SA2Hits	0.90

Correlation of SA1Hits to CPT1Hits	0.74
Correlation of SA1Hits to LU_GMSI1_16_7	-0.60
Correlation of SA1Hits to LU_GMSI1_16_12	-0.62
Correlation of SA1Hits to L_GMS17_31_7	0.63
Correlation of SA1Hits to ME_GMSI34	-0.56
Correlation of SA1Hits to ME_GMSI38	-0.58
Correlation of SA2Hits to CPT1Hits	0.76
Correlation of SA2Hits to ME_GMSI34	-0.69
Correlation of CPT1Hits to ME_GMSI34	-0.62
Correlation of CPT1Hits to ME_GMSI38	-0.62
Correlation of CPT2Hits to LU_GMSI1_16_8	0.65
Correlation of CPT2Hits to L_GMS17_31_7	0.67
Correlation of CPT2Hits to F_musassoc_effect	-0.56
Correlation of CPT2Hits to AverageDuration	-0.61
Correlation of LU_GMSI1_16_1 to L_GMS17_31_8	0.75
Correlation of LU_GMSI1_16_1 to L_GMS17_31_11	-0.81
Correlation of LU_GMSI1_16_1 to ME_GMSI32	0.58
Correlation of LU_GMSI1_16_1 to ME_GMSI33	0.66
Correlation of LU_GMSI1_16_1 to ED_GMSI_genre	0.67
Correlation of LU_GMSI1_16_1 to F_skill_incr	-0.79
Correlation of LU_GMSI1_16_2 to F_challenge_start	-0.66
Correlation of LU_GMSI1_16_2 to F_skill_incr	-0.59
Correlation of LU_GMSI1_16_2 to EN_gameexp_likedir	0.73
Correlation of LU_GMSI1_16_2 to AvgButtonPressDeltaAfterMusicalChange	0.61
Correlation of LU_GMSI1_16_4 to L_GMS17_31_6	-0.58
Correlation of LU_GMSI1_16_5 to LU_GMSI1_16_6	0.71
Correlation of LU_GMSI1_16_5 to LU_GMSI1_16_15	0.84
Correlation of LU_GMSI1_16_5 to ME_GMSI38	-0.57
Correlation of LU_GMSI1_16_5 to AverageDistanceBetweenClips	0.57
Correlation of LU_GMSI1_16_5 to AvgDistanceOfSecondHalfClipsAfterMusicalChange	0.62
Correlation of LU_GMSI1_16_6 to LU_GMSI1_16_9	-0.60
Correlation of LU_GMSI1_16_6 to LU_GMSI1_16_15	0.62
Correlation of LU_GMSI1_16_6 to AverageDistanceBetweenClips	0.73
Correlation of LU_GMSI1_16_6 to AvgDistanceOfFirstHalfClipsAfterMusicalChange	0.72
Correlation of LU_GMSI1_16_6 to AvgDistanceOfSecondHalfClipsAfterMusicalChange	0.73

Correlation of LU_GMSI1_16_7 to LU_GMSI1_16_12	0.60
Correlation of LU_GMSI1_16_7 to F_interest_end	-0.57
Correlation of LU_GMSI1_16_8 to LU_GMSI1_16_9	-0.62
Correlation of LU_GMSI1_16_8 to L_GMS17_31_7	0.76
Correlation of LU_GMSI1_16_8 to ED_GMSI_occ	-0.56
Correlation of LU_GMSI1_16_8 to F_boring_start	0.70
Correlation of LU_GMSI1_16_8 to AverageDuration	-0.72
Correlation of LU_GMSI1_16_9 to LU_GMSI1_16_15	-0.64
Correlation of LU_GMSI1_16_9 to L_GMS17_31_10	-0.57
Correlation of LU_GMSI1_16_9 to ME_GMSI33	-0.61
Correlation of LU_GMSI1_16_9 to F_challenge_end	0.56
Correlation of LU_GMSI1_16_10 to L_GMS17_31_4	-0.57
Correlation of LU_GMSI1_16_10 to F_musassoc_effect	-0.77
Correlation of LU_GMSI1_16_10 to AverageDuration	-0.69
Correlation of LU_GMSI1_16_11 to LU_GMSI1_16_16	0.74
Correlation of LU_GMSI1_16_11 to L_GMS17_31_9	0.57
Correlation of LU_GMSI1_16_11 to ME_GMSI33	0.62
Correlation of LU_GMSI1_16_11 to F_keep_playing	0.58
Correlation of LU_GMSI1_16_12 to ED_GMSI_Ed	-0.76
Correlation of LU_GMSI1_16_13 to L_GMS17_31_6	-0.63
Correlation of LU_GMSI1_16_13 to F_Interest_start	-0.57
Correlation of LU_GMSI1_16_13 to F_motivate_start	-0.58
Correlation of LU_GMSI1_16_14 to ME_GMSI32	-0.66
Correlation of LU_GMSI1_16_14 to F_boring_start	-0.60
Correlation of LU_GMSI1_16_14 to F_motivate_start	0.78
Correlation of LU_GMSI1_16_15 to ED_GMSI_occ	0.62
Correlation of LU_GMSI1_16_16 to L_GMS17_31_8	0.76
Correlation of LU_GMSI1_16_16 to ME_GMSI33	0.69
Correlation of LU_GMSI1_16_16 to ED_GMSI_occ	-0.67
Correlation of LU_GMSI1_16_16 to F_musassoc_effect	-0.56
Correlation of LU_GMSI1_16_16 to F_gamexp_liking	-0.73
Correlation of L_GMS17_31_1 to L_GMS17_31_9	0.73
Correlation of L_GMS17_31_1 to L_GMS17_31_13	-0.60
Correlation of L_GMS17_31_1 to L_GMS17_31_14	-0.70
Correlation of L_GMS17_31_1 to ME_GMSI37	-0.56

Correlation of L_GMS17_31_1 to F_Interest_start	0.72
Correlation of L_GMS17_31_1 to F_motivate_end	0.70
Correlation of L_GMS17_31_3 to L_GMS17_31_6	0.61
Correlation of L_GMS17_31_3 to L_GMS17_31_10	0.72
Correlation of L_GMS17_31_3 to ME_GMSI38	-0.63
Correlation of L_GMS17_31_3 to ED_GMSI_genre	0.63
Correlation of L_GMS17_31_3 to F_enjoy_end	-0.61
Correlation of L_GMS17_31_4 to L_GMS17_31_6	0.64
Correlation of L_GMS17_31_4 to F_interest_end	-0.56
Correlation of L_GMS17_31_4 to AverageDuration	0.66
Correlation of L_GMS17_31_5 to ME_GMSI34	-0.62
Correlation of L_GMS17_31_5 to ME_GMSI37	-0.61
Correlation of L_GMS17_31_5 to F_boring_end	0.62
Correlation of L_GMS17_31_5 to F_musiclike_effect	0.63
Correlation of L_GMS17_31_5 to SessionsPlayed	-0.64
Correlation of L_GMS17_31_6 to L_GMS17_31_10	0.61
Correlation of L_GMS17_31_7 to ED_GMSI_occ	-0.58
Correlation of L_GMS17_31_7 to F_boring_start	0.59
Correlation of L_GMS17_31_7 to F_musiclike_start	-0.58
Correlation of L_GMS17_31_8 to L_GMS17_31_11	-0.59
Correlation of L_GMS17_31_8 to ME_GMSI33	0.67
Correlation of L_GMS17_31_8 to F_enjoy_start	-0.63
Correlation of L_GMS17_31_8 to F_challenge_end	-0.59
Correlation of L_GMS17_31_8 to F_skill_incr	-0.71
Correlation of L_GMS17_31_9 to L_GMS17_31_13	-0.65
Correlation of L_GMS17_31_9 to L_GMS17_31_14	-0.57
Correlation of L_GMS17_31_9 to L_GMS17_31_15	0.57
Correlation of L_GMS17_31_9 to F_motivate_end	0.59
Correlation of L_GMS17_31_9 to F_gamexp_liking	-0.72
Correlation of L_GMS17_31_10 to ED_GMSI_Ed	-0.62
Correlation of L_GMS17_31_10 to F_enjoy_end	-0.56
Correlation of L_GMS17_31_11 to ME_GMSI32	-0.67
Correlation of L_GMS17_31_11 to ME_GMSI33	-0.75
Correlation of L_GMS17_31_11 to ME_GMSI35	-0.80
Correlation of L_GMS17_31_11 to ME_GMSI36	-0.72

Correlation of L_GMS17_31_11 to ME_GMSI37	-0.70
Correlation of L_GMS17_31_11 to ED_GMSI_genre	-0.69
Correlation of L_GMS17_31_11 to F_challenge_end	0.59
Correlation of L_GMS17_31_11 to F_skill_incr	0.57
Correlation of L_GMS17_31_12 to ED_GMSI_genre	0.59
Correlation of L_GMS17_31_12 to AvgDistanceDeltaAfterMusicalChange	-0.58
Correlation of L_GMS17_31_13 to L_GMS17_31_14	0.92
Correlation of L_GMS17_31_13 to ED_GMSI_ExpEd	-0.64
Correlation of L_GMS17_31_14 to ME_GMSI37	0.56
Correlation of L_GMS17_31_14 to F_motivate_end	-0.56
Correlation of L_GMS17_31_14 to SessionsPlayed	0.59
Correlation of ME_GMSI32 to ME_GMSI35	0.62
Correlation of ME_GMSI32 to ME_GMSI36	0.65
Correlation of ME_GMSI32 to ME_GMSI37	0.58
Correlation of ME_GMSI32 to F_motivate_start	-0.58
Correlation of ME_GMSI32 to F_challenge_start	-0.65
Correlation of ME_GMSI32 to F_challenge_end	-0.69
Correlation of ME_GMSI32 to F_skill_incr	-0.78
Correlation of ME_GMSI32 to AverageDistanceBetweenClips	-0.64
Correlation of ME_GMSI32 to AverageButtonPresses	-0.58
Correlation of ME_GMSI32 to AverageClipButtonPresses	-0.57
Correlation of ME_GMSI32 to AvgDistanceOfFirstHalfClipsAfterMusicalChange	-0.66
Correlation of ME_GMSI32 to AvgDistanceOfSecondHalfClipsAfterMusicalChange	-0.61
Correlation of ME_GMSI33 to ME_GMSI35	0.60
Correlation of ME_GMSI33 to ME_GMSI36	0.58
Correlation of ME_GMSI33 to ME_GMSI37	0.72
Correlation of ME_GMSI33 to ED_GMSI_genre	0.57
Correlation of ME_GMSI33 to F_challenge_start	-0.56
Correlation of ME_GMSI33 to F_challenge_end	-0.78
Correlation of ME_GMSI33 to F_musiclike_start	-0.55
Correlation of ME_GMSI33 to F_musiclike_end	-0.56
Correlation of ME_GMSI33 to F_skill_incr	-0.58
Correlation of ME_GMSI34 to F_boring_end	-0.68
Correlation of ME_GMSI34 to F_musiclike_effect	-0.60
Correlation of ME_GMSI35 to ME_GMSI36	0.85

Correlation of ME_GMSI35 to ME_GMSI37	0.75
Correlation of ME_GMSI36 to ME_GMSI37	0.68
Correlation of ME_GMSI37 to F_challenge_end	-0.63
Correlation of ME_GMSI37 to SessionsPlayed	0.64
Correlation of ME_GMSI38 to ED_GMSI_occ	-0.59
Correlation of ED_GMSI_occ to F_motivate_end	-0.57
Correlation of ED_GMSI_occ to F_musiclike_start	0.56
Correlation of ED_GMSI_occ to F_gamexp_liking	0.71
Correlation of ED_GMSI_genre to F_interest_end	-0.61
Correlation of ED_GMSI_genre to F_challenge_start	-0.57
Correlation of ED_GMSI_genre to F_challenge_end	-0.56
Correlation of ED_GMSI_genre to F_skill_incr	-0.65
Correlation of ED_GMSI_Ed to F_enjoy_start	-0.56
Correlation of ED_GMSI_ExpEd to F_musiclike_start	-0.58
Correlation of F_Interest_start to F_enjoy_start	0.60
Correlation of F_Interest_start to AverageDistanceBetweenClips	-0.56
Correlation of F_Interest_start to AvgDistanceOfSecondHalfClipsAfterMusicalChange	-0.61
Correlation of F_interest_end to F_enjoy_end	0.91
Correlation of F_interest_end to F_motivate_end	0.76
Correlation of F_interest_end to F_challenge_start	0.67
Correlation of F_interest_end to F_challenge_end	0.74
Correlation of F_boring_start to AverageDuration	-0.56
Correlation of F_boring_end to F_musiclike_effect	0.69
Correlation of F_enjoy_start to F_motivate_start	0.76
Correlation of F_enjoy_end to F_motivate_end	0.78
Correlation of F_enjoy_end to F_challenge_end	0.59
Correlation of F_motivate_start to F_challenge_start	0.63
Correlation of F_motivate_start to F_challenge_end	0.60
Correlation of F_motivate_end to F_gamexp_liking	-0.56
Correlation of F_challenge_start to F_challenge_end	0.81
Correlation of F_challenge_start to F_skill_incr	0.68
Correlation of F_challenge_end to F_skill_incr	0.68
Correlation of F_musiclike_start to F_musiclike_end	0.85
Correlation of F_musiclike_start to F_musassoc_effect	0.56
Correlation of F_musiclike_effect to F_musassoc_effect	0.67

Correlation of F_musiclike_effect to AverageDistanceBetweenClips	-0.58
Correlation of F_musiclike_effect to AverageButtonPresses	-0.56
Correlation of F_musiclike_effect to AverageClipButtonPresses	-0.56
Correlation of F_musiclike_effect to AvgDistanceOfFirstHalfClipsAfterMusicalChange	-0.58
Correlation of F_musassoc_effect to AverageDuration	0.79
Correlation of AverageDistanceBetweenClips to AverageButtonPresses	0.85
Correlation of AverageDistanceBetweenClips to AverageClipButtonPresses	0.85
Correlation of AverageDistanceBetweenClips to AvgDistanceOfFirstHalfClipsAfterMusicalChange	0.99
Correlation of AverageDistanceBetweenClips to AvgDistanceOfSecondHalfClipsAfterMusicalChange	0.99
Correlation of AverageButtonPresses to AverageClipButtonPresses	1.00
Correlation of AverageButtonPresses to AvgDistanceOfFirstHalfClipsAfterMusicalChange	0.87
Correlation of AverageButtonPresses to AvgDistanceOfSecondHalfClipsAfterMusicalChange	0.80
Correlation of AverageButtonPresses to AvgButtonPressDeltaAfterMusicalChange	-0.87
Correlation of AverageButtonPresses to AvgDistanceDeltaAfterMusicalChange	-0.72
Correlation of AverageClipButtonPresses to AvgDistanceOfFirstHalfClipsAfterMusicalChange	0.88
Correlation of AverageClipButtonPresses to AvgDistanceOfSecondHalfClipsAfterMusicalChange	0.81
Correlation of AverageClipButtonPresses to AvgButtonPressDeltaAfterMusicalChange	-0.86
Correlation of AverageClipButtonPresses to AvgDistanceDeltaAfterMusicalChange	-0.71
Correlation of AvgDistanceOfFirstHalfClipsAfterMusicalChange to AvgDistanceOfSecondHalfClipsAfterMusicalChange	0.98
Correlation of AvgDistanceOfFirstHalfClipsAfterMusicalChange to AvgButtonPressDeltaAfterMusicalChange	-0.61
Correlation of AvgButtonPressDeltaAfterMusicalChange to AvgDistanceDeltaAfterMusicalChange	0.84

Table 6. Statistically significant ($p < 0.05$) correlation coefficients for Group A.

Correlation	**Value**
Correlation of DS_ScoreDelta to CPT_FADelta	-0.76
Correlation of SA_HitsDelta to SA1Hits	-0.84
Correlation of SA_HitsDelta to LU_GMSI1_16_1	-0.82

Correlation of SA_HitsDelta to LU_GMSI1_16_16	-0.75
Correlation of SA_HitsDelta to L_GMS17_31_9	-0.80
Correlation of SA_HitsDelta to ED_GMSI_occ	0.76
Correlation of SA_HitsDelta to F_motivate_end	-0.73
Correlation of SA_HitsDelta to F_gamexp_liking	0.90
Correlation of SA_HitsDelta to F_skill_incr	0.71
Correlation of SA_HitsDelta to AverageDistanceBetweenClips	0.93
Correlation of SA_HitsDelta to AvgDistanceOfFirstHalfClipsAfterMusicalChange	0.93
Correlation of SA_HitsDelta to AvgDistanceOfSecondHalfClipsAfterMusicalChange	0.94
Correlation of SA_FADelta to F_keep_playing	-0.97
Correlation of SA_RTDelta to SA2Hits	0.76
Correlation of SA_RTDelta to LU_GMSI1_16_6	0.78
Correlation of SA_RTDelta to L_GMS17_31_5	0.83
Correlation of CPT_HitsDelta to LU_GMSI1_16_5	-0.78
Correlation of CPT_HitsDelta to LU_GMSI1_16_10	0.76
Correlation of CPT_HitsDelta to L_GMS17_31_3	-0.71
Correlation of CPT_HitsDelta to L_GMS17_31_4	-0.84
Correlation of CPT_HitsDelta to L_GMS17_31_6	-0.92
Correlation of CPT_HitsDelta to ME_GMSI38	0.72
Correlation of CPT_HitsDelta to ED_GMSI_occ	-0.73
Correlation of CPT_HitsDelta to F_musiclike_start	-0.80
Correlation of CPT_HitsDelta to F_musiclike_effect	-0.75
Correlation of CPT_HitsDelta to F_musassoc_effect	-0.81
Correlation of CPT_HitsDelta to AverageDuration	-0.75
Correlation of CPT_FADelta to LU_GMSI1_16_10	-0.77
Correlation of CPT_FADelta to L_GMS17_31_1	0.86
Correlation of CPT_FADelta to L_GMS17_31_14	-0.72
Correlation of CPT_FADelta to F_Interest_start	0.77
Correlation of DS1Hits to DS2Hits	0.80
Correlation of DS1Hits to LU_GMSI1_16_1	0.71
Correlation of DS1Hits to L_GMS17_31_8	0.74
Correlation of DS1Hits to L_GMS17_31_15	0.73
Correlation of DS1Hits to ME_GMSI32	0.73
Correlation of DS1Hits to F_skill_incr	-0.78
Correlation of DS1Hits to AverageButtonPresses	-0.74
Correlation of DS1Hits to AverageClipButtonPresses	-0.78
Correlation of DS2Hits to LU_GMSI1_16_1	0.75
Correlation of DS2Hits to LU_GMSI1_16_8	0.72

Correlation of DS2Hits to LU_GMSI1_16_14	-0.83
Correlation of DS2Hits to LU_GMSI1_16_16	0.87
Correlation of DS2Hits to L_GMS17_31_7	0.77
Correlation of DS2Hits to L_GMS17_31_8	0.84
Correlation of DS2Hits to ME_GMSI32	0.78
Correlation of DS2Hits to ME_GMSI36	0.74
Correlation of DS2Hits to ED_GMSI_occ	-0.75
Correlation of DS2Hits to F_enjoy_start	-0.79
Correlation of DS2Hits to F_motivate_start	-0.76
Correlation of DS2Hits to F_challenge_start	-0.79
Correlation of DS2Hits to F_skill_incr	-0.73
Correlation of SA1Hits to LU_GMSI1_16_2	0.80
Correlation of SA1Hits to ED_GMSI_occ	-0.71
Correlation of SA1Hits to F_gamexp_liking	-0.71
Correlation of SA1Hits to AverageDistanceBetweenClips	-0.71
Correlation of SA1Hits to AvgDistanceOfFirstHalfClipsAfterMusicalChange	-0.71
Correlation of SA1Hits to AvgDistanceOfSecondHalfClipsAfterMusicalChange	-0.71
Correlation of SA2Hits to L_GMS17_31_5	0.77
Correlation of SA2Hits to ME_GMSI34	-0.77
Correlation of SA2Hits to EN_gameexp_likedir	0.93
Correlation of SA2Hits to SessionsPlayed	-0.73
Correlation of CPT1Hits to L_GMS17_31_2	0.93
Correlation of LU_GMSI1_16_1 to LU_GMSI1_16_16	0.76
Correlation of LU_GMSI1_16_1 to L_GMS17_31_8	0.73
Correlation of LU_GMSI1_16_1 to L_GMS17_31_9	0.75
Correlation of LU_GMSI1_16_1 to L_GMS17_31_11	-0.86
Correlation of LU_GMSI1_16_1 to ME_GMSI32	0.85
Correlation of LU_GMSI1_16_1 to F_skill_incr	-0.80
Correlation of LU_GMSI1_16_1 to AverageDistanceBetweenClips	-0.85
Correlation of LU_GMSI1_16_1 to AvgDistanceOfFirstHalfClipsAfterMusicalChange	-0.84
Correlation of LU_GMSI1_16_1 to AvgDistanceOfSecondHalfClipsAfterMusicalChange	-0.88
Correlation of LU_GMSI1_16_2 to L_GMS17_31_7	0.76
Correlation of LU_GMSI1_16_2 to L_GMS17_31_12	0.88
Correlation of LU_GMSI1_16_2 to ED_GMSI_genre	0.71
Correlation of LU_GMSI1_16_2 to F_challenge_start	-0.77
Correlation of LU_GMSI1_16_3 to L_GMS17_31_2	-0.83
Correlation of LU_GMSI1_16_3 to L_GMS17_31_4	-0.71
Correlation of LU_GMSI1_16_4 to LU_GMSI1_16_15	-0.72

Correlation of LU_GMSI1_16_4 to F_boring_start	0.73
Correlation of LU_GMSI1_16_4 to F_enjoy_end	0.80
Correlation of LU_GMSI1_16_5 to LU_GMSI1_16_15	0.77
Correlation of LU_GMSI1_16_5 to L_GMS17_31_3	0.94
Correlation of LU_GMSI1_16_5 to L_GMS17_31_4	0.87
Correlation of LU_GMSI1_16_5 to L_GMS17_31_6	0.83
Correlation of LU_GMSI1_16_5 to L_GMS17_31_10	0.78
Correlation of LU_GMSI1_16_5 to ME_GMSI38	-0.71
Correlation of LU_GMSI1_16_5 to F_enjoy_end	-0.73
Correlation of LU_GMSI1_16_6 to L_GMS17_31_5	0.83
Correlation of LU_GMSI1_16_6 to ME_GMSI34	-0.71
Correlation of LU_GMSI1_16_6 to AvgDistanceDeltaAfterMusicalChange	-0.77
Correlation of LU_GMSI1_16_7 to L_GMS17_31_12	0.75
Correlation of LU_GMSI1_16_7 to ME_GMSI34	-0.76
Correlation of LU_GMSI1_16_7 to F_interest_end	-0.87
Correlation of LU_GMSI1_16_7 to F_enjoy_end	-0.89
Correlation of LU_GMSI1_16_8 to LU_GMSI1_16_13	0.73
Correlation of LU_GMSI1_16_8 to L_GMS17_31_7	0.86
Correlation of LU_GMSI1_16_8 to ME_GMSI38	0.78
Correlation of LU_GMSI1_16_8 to ED_GMSI_occ	-0.72
Correlation of LU_GMSI1_16_8 to F_boring_start	0.84
Correlation of LU_GMSI1_16_8 to F_challenge_start	-0.77
Correlation of LU_GMSI1_16_8 to AverageDuration	-0.73
Correlation of LU_GMSI1_16_8 to AverageButtonPresses	-0.81
Correlation of LU_GMSI1_16_9 to LU_GMSI1_16_12	-0.72
Correlation of LU_GMSI1_16_10 to ME_GMSI37	0.74
Correlation of LU_GMSI1_16_10 to F_motivate_start	-0.77
Correlation of LU_GMSI1_16_10 to F_musiclike_effect	-0.77
Correlation of LU_GMSI1_16_10 to F_musassoc_effect	-0.86
Correlation of LU_GMSI1_16_11 to LU_GMSI1_16_16	0.79
Correlation of LU_GMSI1_16_11 to L_GMS17_31_8	0.75
Correlation of LU_GMSI1_16_11 to L_GMS17_31_9	0.77
Correlation of LU_GMSI1_16_11 to ME_GMSI33	0.90
Correlation of LU_GMSI1_16_11 to ED_GMSI_ExpEd	0.72
Correlation of LU_GMSI1_16_12 to L_GMS17_31_10	0.80
Correlation of LU_GMSI1_16_12 to ED_GMSI_Ed	-0.90
Correlation of LU_GMSI1_16_13 to ME_GMSI38	0.73
Correlation of LU_GMSI1_16_13 to F_Interest_start	-0.80

Correlation of LU_GMSI1_16_14 to LU_GMSI1_16_16	-0.79
Correlation of LU_GMSI1_16_14 to L_GMS17_31_8	-0.71
Correlation of LU_GMSI1_16_14 to ME_GMSI32	-0.84
Correlation of LU_GMSI1_16_14 to ME_GMSI33	-0.77
Correlation of LU_GMSI1_16_14 to ME_GMSI36	-0.73
Correlation of LU_GMSI1_16_14 to ME_GMSI37	-0.81
Correlation of LU_GMSI1_16_14 to F_enjoy_start	0.84
Correlation of LU_GMSI1_16_14 to F_motivate_start	0.84
Correlation of LU_GMSI1_16_14 to F_challenge_end	0.85
Correlation of LU_GMSI1_16_14 to F_musassoc_effect	0.76
Correlation of LU_GMSI1_16_15 to L_GMS17_31_4	0.77
Correlation of LU_GMSI1_16_15 to L_GMS17_31_6	0.71
Correlation of LU_GMSI1_16_15 to L_GMS17_31_10	0.76
Correlation of LU_GMSI1_16_15 to F_interest_end	-0.72
Correlation of LU_GMSI1_16_15 to F_enjoy_end	-0.76
Correlation of LU_GMSI1_16_16 to L_GMS17_31_7	0.72
Correlation of LU_GMSI1_16_16 to L_GMS17_31_8	0.87
Correlation of LU_GMSI1_16_16 to L_GMS17_31_9	0.74
Correlation of LU_GMSI1_16_16 to ME_GMSI33	0.84
Correlation of LU_GMSI1_16_16 to ME_GMSI36	0.78
Correlation of LU_GMSI1_16_16 to F_enjoy_start	-0.88
Correlation of LU_GMSI1_16_16 to F_motivate_start	-0.76
Correlation of LU_GMSI1_16_16 to F_gamexp_liking	-0.75
Correlation of L_GMS17_31_1 to F_Interest_start	0.71
Correlation of L_GMS17_31_1 to F_musassoc_effect	0.71
Correlation of L_GMS17_31_3 to L_GMS17_31_4	0.73
Correlation of L_GMS17_31_3 to ME_GMSI38	-0.78
Correlation of L_GMS17_31_3 to F_enjoy_end	-0.71
Correlation of L_GMS17_31_3 to F_musiclike_effect	0.72
Correlation of L_GMS17_31_3 to SessionsPlayed	-0.78
Correlation of L_GMS17_31_4 to L_GMS17_31_6	0.97
Correlation of L_GMS17_31_5 to L_GMS17_31_10	0.73
Correlation of L_GMS17_31_5 to ME_GMSI34	-0.93
Correlation of L_GMS17_31_5 to F_musiclike_effect	0.71
Correlation of L_GMS17_31_5 to SessionsPlayed	-0.76
Correlation of L_GMS17_31_6 to AvgButtonPressDeltaAfterMusicalChange	-0.76
Correlation of L_GMS17_31_7 to L_GMS17_31_13	-0.72
Correlation of L_GMS17_31_7 to ED_GMSI_occ	-0.86

Correlation of L_GMS17_31_7 to ED_GMSI_ExpEd	0.77
Correlation of L_GMS17_31_7 to F_boring_start	0.90
Correlation of L_GMS17_31_7 to F_challenge_start	-0.78
Correlation of L_GMS17_31_7 to F_musiclike_start	-0.77
Correlation of L_GMS17_31_7 to AverageDuration	-0.78
Correlation of L_GMS17_31_8 to L_GMS17_31_9	0.74
Correlation of L_GMS17_31_8 to ME_GMSI32	0.76
Correlation of L_GMS17_31_8 to F_enjoy_start	-0.90
Correlation of L_GMS17_31_8 to F_skill_incr	-0.74
Correlation of L_GMS17_31_9 to F_enjoy_start	-0.75
Correlation of L_GMS17_31_9 to F_gamexp_liking	-0.87
Correlation of L_GMS17_31_9 to F_skill_incr	-0.81
Correlation of L_GMS17_31_9 to AverageDistanceBetweenClips	-0.74
Correlation of L_GMS17_31_9 to AvgDistanceOfFirstHalfClipsAfterMusicalChange	-0.72
Correlation of L_GMS17_31_9 to AvgDistanceOfSecondHalfClipsAfterMusicalChange	-0.75
Correlation of L_GMS17_31_10 to ED_GMSI_Ed	-0.80
Correlation of L_GMS17_31_10 to F_interest_end	-0.92
Correlation of L_GMS17_31_10 to F_enjoy_end	-0.81
Correlation of L_GMS17_31_10 to F_musiclike_effect	0.77
Correlation of L_GMS17_31_11 to ME_GMSI32	-0.75
Correlation of L_GMS17_31_11 to ME_GMSI33	-0.72
Correlation of L_GMS17_31_11 to ME_GMSI35	-0.86
Correlation of L_GMS17_31_11 to ME_GMSI36	-0.82
Correlation of L_GMS17_31_12 to ED_GMSI_genre	0.88
Correlation of L_GMS17_31_12 to F_challenge_start	-0.84
Correlation of L_GMS17_31_12 to F_skill_incr	-0.73
Correlation of L_GMS17_31_13 to L_GMS17_31_14	0.94
Correlation of L_GMS17_31_13 to ED_GMSI_genre	-0.81
Correlation of L_GMS17_31_14 to ED_GMSI_genre	-0.71
Correlation of L_GMS17_31_14 to F_Interest_start	-0.82
Correlation of L_GMS17_31_15 to AverageButtonPresses	-0.85
Correlation of L_GMS17_31_15 to AverageClipButtonPresses	-0.87
Correlation of ME_GMSI32 to F_enjoy_start	-0.72
Correlation of ME_GMSI32 to F_skill_incr	-0.88
Correlation of ME_GMSI33 to F_enjoy_start	-0.77
Correlation of ME_GMSI33 to F_challenge_end	-0.78
Correlation of ME_GMSI34 to F_boring_end	-0.85
Correlation of ME_GMSI34 to SessionsPlayed	0.76

Correlation of ME_GMSI35 to ME_GMSI36	0.83
Correlation of ME_GMSI35 to ME_GMSI37	0.83
Correlation of ME_GMSI35 to F_musiclike_end	-0.73
Correlation of ME_GMSI36 to ME_GMSI37	0.79
Correlation of ME_GMSI37 to F_enjoy_start	-0.74
Correlation of ME_GMSI37 to F_musiclike_effect	-0.80
Correlation of ME_GMSI37 to F_musassoc_effect	-0.77
Correlation of ME_GMSI38 to ED_GMSI_occ	-0.74
Correlation of ED_GMSI_occ to F_boring_start	-0.80
Correlation of ED_GMSI_occ to F_musiclike_start	0.73
Correlation of ED_GMSI_occ to AverageDuration	0.72
Correlation of ED_GMSI_Ed to F_boring_end	-0.82
Correlation of ED_GMSI_Ed to F_musiclike_effect	-0.80
Correlation of F_interest_end to F_enjoy_end	0.89
Correlation of F_boring_start to AverageButtonPresses	-0.72
Correlation of F_boring_end to SessionsPlayed	-0.76
Correlation of F_enjoy_start to F_motivate_start	0.90
Correlation of F_enjoy_start to F_challenge_end	0.75
Correlation of F_enjoy_start to F_gamexp_liking	0.76
Correlation of F_motivate_start to F_challenge_end	0.77
Correlation of F_motivate_start to F_gamexp_liking	0.78
Correlation of F_motivate_end to AverageDistanceBetweenClips	-0.91
Correlation of F_motivate_end to AvgDistanceOfFirstHalfClipsAfterMusicalChange	-0.90
Correlation of F_motivate_end to AvgDistanceOfSecondHalfClipsAfterMusicalChange	-0.88
Correlation of F_challenge_start to F_challenge_end	0.79
Correlation of F_challenge_start to AverageDuration	0.87
Correlation of F_musiclike_start to F_musiclike_end	0.95
Correlation of F_musiclike_start to F_musassoc_effect	0.75
Correlation of F_musiclike_start to AverageDuration	0.93
Correlation of F_musiclike_end to F_musassoc_effect	0.75
Correlation of F_musiclike_end to AverageDuration	0.84
Correlation of F_musiclike_effect to F_musassoc_effect	0.73
Correlation of F_musassoc_effect to AverageDuration	0.78
Correlation of F_keep_playing to EN_gameexp_likedir	-0.73
Correlation of F_gamexp_liking to AverageDistanceBetweenClips	0.74
Correlation of F_gamexp_liking to AvgDistanceOfFirstHalfClipsAfterMusicalChange	0.74
Correlation of F_gamexp_liking to AvgDistanceOfSecondHalfClipsAfterMusicalChange	0.76
Correlation of EN_gameexp_likedir to AvgButtonPressDeltaAfterMusicalChange	0.88

Correlation of AverageDistanceBetweenClips to AvgDistanceOfFirstHalfClipsAfterMusicalChange	1.00
Correlation of AverageDistanceBetweenClips to AvgDistanceOfSecondHalfClipsAfterMusicalChange	1.00
Correlation of AverageButtonPresses to AverageClipButtonPresses	0.94
Correlation of AvgDistanceOfFirstHalfClipsAfterMusicalChange to AvgDistanceOfSecondHalfClipsAfterMusicalChange	0.99

Table 7. Statistically significant ($p < 0.05$) correlation coefficients for Group B.

Correlation	**Value**
Correlation of DS_ScoreDelta to ED_GMSI_occ	0.88
Correlation of DS_ScoreDelta to F_Interest_start	-0.93
Correlation of DS_ScoreDelta to F_enjoy_start	-0.95
Correlation of SA_HitsDelta to SA_FADelta	0.90
Correlation of SA_HitsDelta to CPT2Hits	-0.94
Correlation of SA_HitsDelta to ME_GMSI38	0.90
Correlation of SA_FADelta to CPT2Hits	-0.99
Correlation of SA_FADelta to LU_GMSI1_16_8	-0.92
Correlation of SA_RTDelta to ME_GMSI37	-0.91
Correlation of SA_RTDelta to F_boring_end	0.96
Correlation of SA_RTDelta to F_musiclike_end	0.88
Correlation of CPT_HitsDelta to CPT1Hits	-0.93
Correlation of CPT_FADelta to SA1Hits	0.98
Correlation of CPT_FADelta to SA2Hits	0.98
Correlation of CPT_FADelta to CPT1Hits	0.92
Correlation of CPT_FADelta to LU_GMSI1_16_12	-0.92
Correlation of CPT_FADelta to L_GMS17_31_7	0.92
Correlation of CPT_RTDelta to LU_GMSI1_16_14	0.98
Correlation of CPT_RTDelta to F_boring_start	-0.93
Correlation of CPT_RTDelta to F_enjoy_end	-0.92
Correlation of CPT_RTDelta to F_musiclike_end	-0.99
Correlation of DS1Hits to LU_GMSI1_16_13	-0.94
Correlation of DS1Hits to LU_GMSI1_16_16	0.97
Correlation of DS1Hits to L_GMS17_31_6	0.92
Correlation of DS1Hits to F_motivate_start	0.91
Correlation of DS1Hits to AverageClipButtonPresses	-0.88

Correlation of DS2Hits to LU_GMSI1_16_3	0.91
Correlation of DS2Hits to L_GMS17_31_1	-0.93
Correlation of DS2Hits to L_GMS17_31_3	0.88
Correlation of DS2Hits to L_GMS17_31_11	-0.90
Correlation of DS2Hits to ME_GMSI32	0.92
Correlation of DS2Hits to ME_GMSI35	0.92
Correlation of DS2Hits to ED_GMSI_genre	0.92
Correlation of DS2Hits to F_challenge_end	-0.88
Correlation of DS2Hits to F_musiclike_start	-0.90
Correlation of SA1Hits to SA2Hits	0.95
Correlation of SA1Hits to CPT1Hits	0.96
Correlation of SA1Hits to LU_GMSI1_16_12	-0.96
Correlation of SA1Hits to L_GMS17_31_7	0.96
Correlation of SA1Hits to ME_GMSI38	-0.90
Correlation of SA2Hits to CPT1Hits	0.90
Correlation of SA2Hits to LU_GMSI1_16_12	-0.92
Correlation of SA2Hits to L_GMS17_31_7	0.92
Correlation of CPT1Hits to LU_GMSI1_16_12	-0.96
Correlation of CPT1Hits to L_GMS17_31_7	0.96
Correlation of CPT1Hits to ME_GMSI38	-0.97
Correlation of CPT2Hits to LU_GMSI1_16_8	0.90
Correlation of LU_GMSI1_16_1 to L_GMS17_31_8	0.88
Correlation of LU_GMSI1_16_1 to F_gamexp_liking	0.97
Correlation of LU_GMSI1_16_1 to F_skill_incr	-0.94
Correlation of LU_GMSI1_16_1 to EN_gameexp_likedir	0.92
Correlation of LU_GMSI1_16_2 to L_GMS17_31_5	-0.98
Correlation of LU_GMSI1_16_2 to L_GMS17_31_13	0.92
Correlation of LU_GMSI1_16_2 to L_GMS17_31_15	-0.90
Correlation of LU_GMSI1_16_2 to ME_GMSI33	0.94
Correlation of LU_GMSI1_16_2 to F_musiclike_effect	-0.89
Correlation of LU_GMSI1_16_2 to F_skill_incr	-0.92
Correlation of LU_GMSI1_16_2 to EN_gameexp_likedir	0.98
Correlation of LU_GMSI1_16_3 to LU_GMSI1_16_9	-0.89
Correlation of LU_GMSI1_16_3 to L_GMS17_31_1	-0.96
Correlation of LU_GMSI1_16_3 to L_GMS17_31_8	0.91
Correlation of LU_GMSI1_16_3 to L_GMS17_31_9	-0.98
Correlation of LU_GMSI1_16_3 to L_GMS17_31_11	-0.98
Correlation of LU_GMSI1_16_3 to L_GMS17_31_14	0.91

Correlation of LU_GMSI1_16_3 to ME_GMSI33	0.90
Correlation of LU_GMSI1_16_3 to ME_GMSI37	0.90
Correlation of LU_GMSI1_16_3 to ED_GMSI_occ	0.90
Correlation of LU_GMSI1_16_4 to AvgDistanceDeltaAfterMusicalChange	0.95
Correlation of LU_GMSI1_16_5 to LU_GMSI1_16_6	0.97
Correlation of LU_GMSI1_16_5 to LU_GMSI1_16_15	0.98
Correlation of LU_GMSI1_16_5 to L_GMS17_31_6	-0.89
Correlation of LU_GMSI1_16_5 to ED_GMSI_Ed	0.93
Correlation of LU_GMSI1_16_5 to F_motivate_start	-0.95
Correlation of LU_GMSI1_16_5 to AverageDistanceBetweenClips	0.97
Correlation of LU_GMSI1_16_5 to AvgDistanceOfFirstHalfClipsAfterMusicalChange	0.95
Correlation of LU_GMSI1_16_5 to AvgDistanceOfSecondHalfClipsAfterMusicalChange	0.97
Correlation of LU_GMSI1_16_6 to LU_GMSI1_16_15	0.98
Correlation of LU_GMSI1_16_6 to ED_GMSI_Ed	0.96
Correlation of LU_GMSI1_16_6 to F_motivate_start	-0.90
Correlation of LU_GMSI1_16_6 to AverageDistanceBetweenClips	0.89
Correlation of LU_GMSI1_16_6 to AvgDistanceOfFirstHalfClipsAfterMusicalChange	0.88
Correlation of LU_GMSI1_16_6 to AvgDistanceOfSecondHalfClipsAfterMusicalChange	0.89
Correlation of LU_GMSI1_16_8 to AverageDuration	-0.91
Correlation of LU_GMSI1_16_9 to L_GMS17_31_1	0.90
Correlation of LU_GMSI1_16_9 to L_GMS17_31_11	0.88
Correlation of LU_GMSI1_16_10 to L_GMS17_31_12	0.90
Correlation of LU_GMSI1_16_10 to ED_GMSI_ExpEd	-0.91
Correlation of LU_GMSI1_16_11 to F_interest_end	0.90
Correlation of LU_GMSI1_16_11 to F_musassoc_effect	-0.88
Correlation of LU_GMSI1_16_11 to F_keep_playing	0.89
Correlation of LU_GMSI1_16_12 to L_GMS17_31_7	-1.00
Correlation of LU_GMSI1_16_12 to ME_GMSI38	0.93
Correlation of LU_GMSI1_16_13 to L_GMS17_31_6	-0.92
Correlation of LU_GMSI1_16_13 to F_motivate_start	-0.94
Correlation of LU_GMSI1_16_14 to ME_GMSI36	0.94
Correlation of LU_GMSI1_16_14 to F_boring_start	-0.94
Correlation of LU_GMSI1_16_14 to F_enjoy_end	-0.92
Correlation of LU_GMSI1_16_14 to F_musiclike_end	-0.94
Correlation of LU_GMSI1_16_15 to ED_GMSI_Ed	0.98
Correlation of LU_GMSI1_16_15 to F_motivate_start	-0.94
Correlation of LU_GMSI1_16_15 to AverageDistanceBetweenClips	0.93
Correlation of LU_GMSI1_16_15 to AvgDistanceOfFirstHalfClipsAfterMusicalChange	0.95

Correlation of LU_GMSI1_16_15 to AvgDistanceOfSecondHalfClipsAfterMusicalChange	0.93
Correlation of LU_GMSI1_16_16 to ED_GMSI_ExpEd	-0.91
Correlation of LU_GMSI1_16_16 to SessionsPlayed	0.90
Correlation of LU_GMSI1_16_16 to AverageButtonPresses	-0.88
Correlation of LU_GMSI1_16_16 to AverageClipButtonPresses	-0.88
Correlation of L_GMS17_31_1 to L_GMS17_31_9	0.88
Correlation of L_GMS17_31_1 to L_GMS17_31_11	0.98
Correlation of L_GMS17_31_1 to ED_GMSI_occ	-0.93
Correlation of L_GMS17_31_2 to L_GMS17_31_13	0.90
Correlation of L_GMS17_31_2 to SessionsPlayed	0.94
Correlation of L_GMS17_31_4 to F_boring_start	-0.97
Correlation of L_GMS17_31_5 to L_GMS17_31_13	-0.94
Correlation of L_GMS17_31_5 to L_GMS17_31_15	0.91
Correlation of L_GMS17_31_5 to ME_GMSI33	-0.90
Correlation of L_GMS17_31_5 to F_musiclike_effect	0.93
Correlation of L_GMS17_31_5 to EN_gameexp_likedir	-0.93
Correlation of L_GMS17_31_6 to F_motivate_start	0.95
Correlation of L_GMS17_31_6 to AverageDistanceBetweenClips	-0.91
Correlation of L_GMS17_31_6 to AvgDistanceOfSecondHalfClipsAfterMusicalChange	-0.89
Correlation of L_GMS17_31_7 to ME_GMSI38	-0.93
Correlation of L_GMS17_31_8 to L_GMS17_31_9	-0.95
Correlation of L_GMS17_31_8 to L_GMS17_31_11	-0.90
Correlation of L_GMS17_31_8 to ME_GMSI32	0.92
Correlation of L_GMS17_31_8 to ME_GMSI33	0.92
Correlation of L_GMS17_31_8 to ME_GMSI35	0.92
Correlation of L_GMS17_31_8 to ED_GMSI_genre	0.92
Correlation of L_GMS17_31_8 to F_challenge_end	-0.94
Correlation of L_GMS17_31_8 to F_musiclike_start	-0.93
Correlation of L_GMS17_31_8 to F_skill_incr	-0.98
Correlation of L_GMS17_31_9 to L_GMS17_31_11	0.92
Correlation of L_GMS17_31_9 to L_GMS17_31_14	-0.94
Correlation of L_GMS17_31_9 to ME_GMSI33	-0.97
Correlation of L_GMS17_31_9 to ME_GMSI37	-0.95
Correlation of L_GMS17_31_9 to F_skill_incr	0.91
Correlation of L_GMS17_31_10 to L_GMS17_31_12	0.90
Correlation of L_GMS17_31_10 to F_boring_end	-0.92
Correlation of L_GMS17_31_11 to ED_GMSI_occ	-0.97
Correlation of L_GMS17_31_11 to F_motivate_end	0.89

Correlation of L_GMS17_31_11 to F_challenge_end	0.90
Correlation of L_GMS17_31_12 to SessionsPlayed	0.90
Correlation of L_GMS17_31_13 to L_GMS17_31_14	0.93
Correlation of L_GMS17_31_13 to ME_GMSI33	0.95
Correlation of L_GMS17_31_13 to F_musiclike_effect	-0.91
Correlation of L_GMS17_31_14 to ME_GMSI33	0.94
Correlation of L_GMS17_31_14 to ME_GMSI37	0.95
Correlation of L_GMS17_31_14 to F_boring_end	-0.90
Correlation of L_GMS17_31_15 to EN_gameexp_likedir	-0.92
Correlation of ME_GMSI32 to ME_GMSI35	1.00
Correlation of ME_GMSI32 to ED_GMSI_genre	1.00
Correlation of ME_GMSI32 to F_motivate_end	-0.94
Correlation of ME_GMSI32 to F_challenge_end	-0.99
Correlation of ME_GMSI32 to F_musiclike_start	-1.00
Correlation of ME_GMSI33 to ME_GMSI37	0.93
Correlation of ME_GMSI33 to F_skill_incr	-0.91
Correlation of ME_GMSI33 to EN_gameexp_likedir	0.88
Correlation of ME_GMSI34 to AverageButtonPresses	-0.88
Correlation of ME_GMSI34 to AverageClipButtonPresses	-0.89
Correlation of ME_GMSI35 to ED_GMSI_genre	1.00
Correlation of ME_GMSI35 to F_motivate_end	-0.94
Correlation of ME_GMSI35 to F_challenge_end	-0.99
Correlation of ME_GMSI35 to F_musiclike_start	-1.00
Correlation of ME_GMSI36 to F_boring_start	-0.88
Correlation of ME_GMSI37 to F_boring_end	-0.97
Correlation of ME_GMSI38 to F_enjoy_start	0.90
Correlation of ED_GMSI_occ to F_Interest_start	-0.94
Correlation of ED_GMSI_occ to F_motivate_end	-0.96
Correlation of ED_GMSI_occ to F_challenge_end	-0.92
Correlation of ED_GMSI_occ to F_musiclike_start	-0.89
Correlation of ED_GMSI_genre to F_motivate_end	-0.94
Correlation of ED_GMSI_genre to F_challenge_end	-0.99
Correlation of ED_GMSI_genre to F_musiclike_start	-1.00
Correlation of ED_GMSI_Ed to F_motivate_start	-0.94
Correlation of ED_GMSI_ExpEd to F_musassoc_effect	0.92
Correlation of ED_GMSI_ExpEd to SessionsPlayed	-0.95
Correlation of F_Interest_start to F_motivate_end	0.89
Correlation of F_interest_end to F_enjoy_end	0.91

Correlation of F_interest_end to F_motivate_end	0.89
Correlation of F_boring_start to F_musiclike_end	0.91
Correlation of F_boring_start to AverageDuration	-0.89
Correlation of F_enjoy_start to AverageClipButtonPresses	-0.89
Correlation of F_enjoy_end to F_musiclike_end	0.88
Correlation of F_motivate_start to AverageDistanceBetweenClips	-0.92
Correlation of F_motivate_start to AvgDistanceOfFirstHalfClipsAfterMusicalChange	-0.90
Correlation of F_motivate_start to AvgDistanceOfSecondHalfClipsAfterMusicalChange	-0.90
Correlation of F_motivate_end to F_challenge_end	0.97
Correlation of F_motivate_end to F_musiclike_start	0.96
Correlation of F_challenge_start to F_gamexp_liking	-0.97
Correlation of F_challenge_start to F_skill_incr	0.93
Correlation of F_challenge_start to EN_gameexp_likedir	-0.90
Correlation of F_challenge_end to F_musiclike_start	0.99
Correlation of F_musassoc_effect to F_keep_playing	-0.95
Correlation of F_musassoc_effect to AverageDuration	0.90
Correlation of F_keep_playing to AverageDuration	-0.96
Correlation of F_gamexp_liking to AvgDistanceOfSecondHalfClipsAfterMusicalChange	0.88
Correlation of F_skill_incr to EN_gameexp_likedir	-0.96
Correlation of AverageDistanceBetweenClips to AvgDistanceOfFirstHalfClipsAfterMusicalChange	0.98
Correlation of AverageDistanceBetweenClips to AvgDistanceOfSecondHalfClipsAfterMusicalChange	1.00
Correlation of AverageButtonPresses to AverageClipButtonPresses	1.00
Correlation of AvgDistanceOfFirstHalfClipsAfterMusicalChange to AvgDistanceOfSecondHalfClipsAfterMusicalChange	0.99