Developing and Evaluating a Musical Attention Control Training Game Application

Anja Volk, Ermis Chalkiadakis, Sander Bakkes
Utrecht University
a.volk{s.c.j.bakkes}@uu.nl, ermchalk@gmail.com

Laurien Hakvoort
ArtEZ Institute of the Arts
l.hakvoort@artez.nl

Rebecca S. Schaefer
Leiden University
r.s.schaefer@fsw.leidenuniv.nl

ABSTRACT

Musical attention control training (MACT) is a Neurologic Music Therapy (NMT) technique to strengthen attention skills for people who may have attention deficits, for instance related to ADHD or Parkinson Disease (PD), activating different parts of the brain and stimulating neural connectivity. While multiple interventions per week would enhance the effect of MACT, attending several sessions a week with a therapist can be challenging. Applied game interventions implementing MACT, which can be played at home, could offer complementary training to the limited number of therapy sessions. While applied games have been shown to facilitate successful interventions for cognitive impairments, to date no game exists based on MACT. We propose a novel approach to research the plausibility of applied games to support NMT, conclude game requirements for the specific needs of People with PD (PwPD), and introduce a game that emulates a MACT session. We carried out a pilot experiment to gauge how users interact with the game and its efficacy in attention control training with non-PD participants, letting them play 10 game intervention sessions within two weeks. Although no significant short-term attention effects were observed in this timeframe, user evaluations and metrics of game performance suggest that gamified MACT could be a promising supplement to conventional MACT for improving attention skills to optimize quality of life of PwPD.

1. INTRODUCTION

Cognitive processes of the human brain are the cornerstone of functioning in our everyday life, laying the ground for how we think, feel and act. Hence, it is important to intervene when these processes are hindered. Music has shown to be effective in cognitive training [1, 2], and Neurologic Music Therapy (NMT) [3] provides a set of standardized music therapy protocols to treat and alleviate neurological symptoms. NMT takes multiple forms, in this paper we consider Musical Attention Control Training (MACT), which specifically targets the attention control systems. It has been shown to improve attention skills [4-6], which is relevant for People with Parkinson's Disease (PwPD), since they often experience attention deficits [7].

MACT sessions take place in regular intervals (usually once a week), individually or in groups. However, attending a MACT session regularly can be challenging, while many therapists claim that even meeting once a week is not enough to effectively improve attention skills. The global COVID-19 pandemic has posed additional challenges to music therapists all over the world due to social distancing and increased the need for technological solutions for administering therapy [8]. At-home training can provide a supplement for face-to-face music therapy. Applied games (i.e., games whose chief mission is not entertainment, including entertainment games which can be reapplied to a different mission other than entertainment), have been developed to train patients' skills for rehabilitation, such as rhythmic skills of PwPD [10] (see section 2.4.1 in [9] for an overview on applied games for at-home-training).

In recent years, applied games have emerged as an effective, scalable and motivating way to train cognitive functions [11, 12]. A plethora of games aim to function as interventions for various cognitive deficits, including attention [13]. Music therapy is a prime candidate for gamification, since it can benefit from the scalability and entertainment that games offer. To our knowledge, no applied game that aims to interpret MACT's clinical protocols as gaming interactions currently exists.

This paper introduces design requirements for a PD-tailored game intervention that emulates a MACT session taking into account the specifics of Parkinson Disease. In addition, it evaluates the newly developed game "The Last Minute Gig" that follows these requirements. We performed an experimental pilot study that evaluates the game's efficacy in 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 is the first applied game application of an NMT protocol.

2. BACKGROUND

2.1 Parkinson's Disease and attention

Attention is a fundamental cognitive function that humans use in their everyday life and is typically divided into four distinct sub-functions. According to Coull [14], the most common framework to define attention consists of: attentional orientation (ability to focus on a specific stimulus while ignoring irrelevant stimuli), selective attention (ability to pick out single relevant information), sustained

attention (ability to stay focused on a specific task without outside motivation) and alternating attention (ability to focus on two or more relevant stimuli). While PD is a neurological disorder that generally manifests with motor symptoms [15], it also can include non-motor symptoms, such as attention deficits [7]. According to a longitudinal study [16], PwPD with cognitive impairments showcased three times faster decline in quality of life (QoL) compared to PwPD with unimpaired cognition. Hence, they argue that clinicians should target attention in PwPD.

2.2 MACT protocols

Musical Attention Control Training (MACT) is a NMT clinical technique for improving attention during cognitive rehabilitation, which targets music-related brain networks with structured music-making or listening exercises [3]. These exercises involve precomposed performances or improvisations in which musical elements occur to which the client is required to respond. For example, to train selective attention, each time a distinct melodic motif occurs within an improvisation carried out by the music therapist, a client needs to start/stop their own improvisation [3].

From the different existing protocols, we choose MACT Clinical Protocol 4 on Sustained Attention [3, p. 264-65] as the most fitting protocol to be transferred to a game: "The therapist and client play together on musical instruments, with the client following as closely as possible the variations introduced by the therapist." The clients play along with the therapist however they feel like. At some point, the therapist changes how they play, which the client is supposed to recognize by paying attention to the therapist's music. The client that recognized that change then adapts their playing accordingly. Examples of variation or changes by the therapist are changes between play and rest, in tempo, rhythmic patterns, note duration, dynamics etc.

2.3 Applied games for health and wellbeing

Applied games, also called *serious games* [17], have emerged as an effective, scalable and motivating way to train cognitive functions [12]. For instance, in [11] an applied game has been developed that aims to be used as a cognitive health screening tool for the elderly. The screening results of the game were consistently similar to a standardized cognitive assessment test, and participants found it to be a motivating experience. In a systematic literature review [12], strong evidence of applied games' capabilities of substituting traditional paper-and-pencil cognitive training approaches was found, suggesting that "computerized training is an effective, less labor-intensive alternative".

Exergames (applied games that include some form of physical exercise) have also been used to stimulate cognitive improvements, specifically for PwPD. In a longitudinal, controlled clinical study [18], PwPD showed no deficit in learning or retention when playing exergames compared to healthy age-matched controls. Notably, the authors indicated the patients' ability to transfer the trained motor skills to other similar but untrained tasks.

Applied games have also incorporated music to enhance their therapeutic usefulness. For instance, in a clinical trial test using a play-at-home applied game for PwPD in [19], participants were provided with either a rhythmic video game, a non-rhythmic video game or no game to play at home. Results indicated that improvements in orofacial and manual performance were observed solely in the group that played the rhythmic game. While [9] highlights the usefulness of applied games as an at-home supplement to music therapy sessions, since they are accessible and enable practicing specific skills in-between sessions, music-based applied games that focus on a specific clinical context are limited as of today. Indeed, in a systematic review of applied games used on PwPD [20], the authors conclude that the majority of studies (52.63 %) focus on exergames for motor rehabilitation, while only few studies focus on emulating an existing treatment protocol.

In conclusion, applied games have shown to be successful in cognitive training, and specifically for attention control. Yet, there are only few applied games that follow existing treatment protocols. Given the above, the need arises for an applied game with musical aspects that targets attention control for PwPD, while also following an already established treatment protocol (e.g. MACT).

3. GAME INTERVENTION

3.1 Significance of UI/UX design

To develop an applied game for PwPD with attentional deficits, their unique needs and limitations compared to people without these deficits need to be considered. Symptoms of PD, as well as those of the typical aging process, create challenges in completing tasks. This translates to unique difficulties with handling technology. A systematic review of exergaming studies for PD in [21] suggests that exergaming applications for PwPD should conform to specific design criteria, such as providing clear instructions.

Moreover, 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 [22], the participants' task completion performance was measured. The results showed that there was no discrepancy between task completion measurements between the groups. Significant differences, however, were identified when speed-related performance (or processing speed) 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 in [12]. Specifically, it was found that older adults did not need to be familiar with technology to complete and benefit from

training. In a study on potential age-specific (more prominent in older users) and age-exclusive (prominent only in older users) issues of interface design [23], no age-exclusive issues were found, while multiple age-specific ones were observed. Firstly, complex tasks that require multiple cognitive steps, seemed to be a more significant problem for older users. Secondly, there was a need for clearer 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 involved.

Taking these findings as a basis to create concrete UI and UX requirements allows us to tailor a computer application towards usage by PwPD, as listed in Table 1.

Requirement	Reasoning
(1) Translation of MACT protocol to a gamified version	Simulating the interactions a MACT participant would have in a gamified context
(2) Inclusion of 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 [3]
(3) No negative performance feedback	PwPD's symptoms worsen over time causing frustration [21, 25]
(4) Minimization of cognitively demanding tasks	Older people/PwPD may have difficulties with more complex tasks [23, 24]
(5) Clear instructions and goals	Older people/PwPD may have difficulties with understanding what the tasks involve [23]
(6) Clear interface feedback mechanisms	Older people/PwPD may more easily miss subtle interface cues [23]
(7) Inclusion of attention measures	Quantifying the potential beneficial effects of the intervention
(8) Inclusion of dynamic difficulty adjustment (DDA)	PwPD's cognitive skills vary widely. DDA ensures that users are challenged at a satisfactory level as in face-to-face MACT [21, 25]

Table 1. Game requirements concluded from literature survey on PwPD and MACT

3.2 Game development: Last Minute Gig

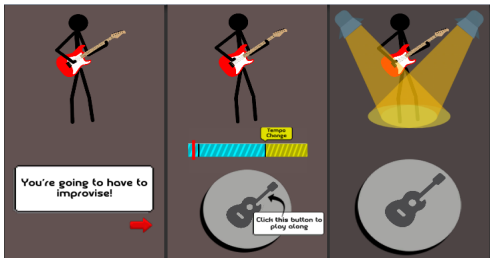

Figure 1. (From left to right) Introduction to the game, tutorial and main game screens.

We developed the video game intervention *Last Minute Gig* in Unity[1], emulating a MACT protocol, which can be played on a PC. 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 must 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.

Once the game starts, the user's avatar is already playing in the concert. The user controls the avatar 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. 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 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 (from a pool of 12 keys), a chord progression (from a pool of 4 different chord progressions, see Figure 2), a rhythm (from a pool of 4 different rhythms, see Figure 3) and tempo (96 BPM or 120 BPM). Rhythm and tempo are 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. 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, and they only need to pay attention to the rhythm and tempo of the background drum-beat. To urge the user to pay attention to the background beat and adjust their playing accordingly, the musical background changes after eight bars of music, randomly choosing one of 3 possible options: a change in rhythm, a change in tempo, or a brief pause (for the detailed overview of the music generation process, see [26]).

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 2. Chord progression pool

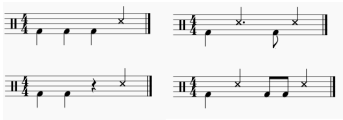

Figure 3. Rhythm pool

In between the introduction and the game, a tutorial is presented, which only appears during the first play session. It explains to the user all the game mechanics in an

[1] https://github.com/ErmisChalkiadakis/LastMinuteGig

interactive and comprehensive way. More specifically, there is a visualization of the music in form of a scrolling strip (see Figure 1, middle part), roughly visualizing musical bars. Whenever a musical change is supposed to happen, there is a message bubble that serves as an indicator. Finally, 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, to explain the mechanics of the game to the user[2].

The form that this game takes has been informed by the requirements concluded from the literature as listed in Table 1. The more requirements a game must follow, the smaller the design space. Therefore, finding a game design that incorporates all of them was out of scope. Below, we explain our reasoning behind the decisions we made.

3.3 Adherence to game requirements

Requirement 1: *Translation of MACT protocol to a gamified version.* The background drumbeat plays the role of the therapist in a MACT session, following the fundamental therapeutic mechanism of MACT: firstly, the therapist and the user are playing their respective musical parts together. At some point, the therapist changes how they play, at which point the user is supposed to recognize this change and to change their playing accordingly. Our current form of the game intervention allows for users to play along however they feel like to the drumbeat, following clinical protocol 4 for sustained attention [3].

Requirement 2: *Inclusion of an algorithm that generates unique gamified MACT protocols*. While the benefit of the game intervention is that it is easier to access at any time and place and can be played multiple times, this might result in the users memorizing the musical patterns and stop paying attention to the music. This would undermine the basic therapeutic mechanisms of MACT. For this reason, each play session needs to be unique, which is reflected in how each song is algorithmically created in the game application as described in Section 3.2.

Requirement 3: *No negative performance feedback.* Since the symptoms of PwPD get worse over time [25], no feedback on the user's performance is given in the game. The possible deterioration of their symptoms could affect their performance, which could discourage them when receiving negative feedback, regardless of whether there is a measurable improvement in their attention.

Requirement 4: *Minimization of cognitively demanding tasks*. Any kind of playing along to music needs to be as easy and accessible as possible for PwPD. This is achieved in the game application by having only one interaction that the user can perform: pressing one button to play along, and the user needs to pay attention only to the rhythm and tempo. This also removes the cognitively demanding task of understanding and playing along with a melody.

Requirement 5: *Clear instructions and goals.* We devised the concept of the concert that frames the musical task the user needs to perform in a comprehensive way. The user has to play along by improvising, and the tutorial serves to further explain what the user is expected to be doing with instructions on what and how needs to be achieved.

Requirement 6: *Clear interface feedback mechanisms*. The only way the user can interact with the game is by pressing the big button that is visible to them. As can be seen in Figure 1, the button is quite sizable to mitigate the issue that PwPD are prone to have tremors depending on their symptoms [27].

Requirement 7: *Inclusion of a measurement of attention*. A measurement of attention that would gauge whether or not the intervention was successful was not integrated in the game application but was part of the experiment as described in the next section.

Requirement 8: *Inclusion of dynamic difficulty adjustment (DDA)*. A DDA of the musical changes in the game intervention would serve as the tailoring of the sessions to each user's cognitive and musical skills. This function is fulfilled by the therapist in traditional MACT sessions. Due to scoping limitations, it was not included in the current game version. The game design proposed has the capacity to include online adjustments to the music generation based on the user's performance in the future.

4. EVALUATION OF THE GAME

4.1 Experiment

We conducted an online longitudinal study to gauge the intervention's effect on attention with 21 participants in the spring of 2021. We did not yet include PwPD in this pilot; however, information on ease of use as well as potential evidence of improvement in attention after the game intervention in the non-PD population would provide an iterative step in the design process for PwPD. Participants with a history of hearing deficits, attention deficits, or neurological disorders were excluded in the current study.

Participants were asked to fill in a questionnaire regarding their personal background, such as gender, age, educational background, and their musical experience, formal training and habits (e.g. their ability to sing in tune, years of formal musical training) according to [27], as well as gaming experience and habits (for the full questionnaire, see Appendix of [26]). Participants were then asked to participate in three different cognitive tests: the backwards digit-span test from the Wechsler Adult Intelligence Scale [28], which requires repeating digit sequences backwards, an auditory selective attention task created based on [29, 30], which requires responses to one ear while ignoring the other, and a continuous performance task (sustained attention) based on [31, 32], which requires responses to specific combinations of visual cues (and not others). The

[2] see https://www.youtube.com/watch?v=OfIUofmjJF4 for a short video

backwards digit span test acted as an index of working memory, the other two tasks tested attention function, namely selective and sustained attention, respectively.

The participants were asked to play 10 game-intervention sessions, on 10 different days within two weeks. Afterwards, they filled in questions regarding their experience of the game intervention, such as enjoyment and motivation pre- and post-playing (all on sliders with values from 1-10), and they repeated the three cognitive tests.

To bolster our understanding of how our participants played the game, we included automatic gameplay data collection into the application. The data consisted of the user's button press timings regarding their position in the musical bars, measured as the interval in seconds between the start of the musical bar and the button press. This way we measured in units of musical bars, how consistently participants played along, and whether they adapted their play after a change had occurred in the background drumbeat. It also contained descriptive information about the musical bar at the time when the button was pressed (rhythm and tempo).

To provide a comparison group, the pre- and post measures were also administered two weeks apart to a control group who did not play the game, to assess possible training effects on the cognitive measures. Here, the measurement procedure was identical, except for the questionnaire that evaluated the game.

4.2 Data processing and analysis

Through our experiment, we wanted to gain insights into potential improvement in the participants' attention after the game intervention, and into the aspects of our designed game that might have influenced the outcome. Potential changes in attention function were captured as a difference score in their performance on the attention tests before and after the intervention. Moreover, we developed a distance gameplay metric (distance between musical bars) measuring the participant's button presses in the game before a musical change and immediately after, for measuring whether or not a participant changed their playing and hence followed the therapeutic mechanism. We extrapolated several gameplay metrics from the button press data, for an overview on all metrics we refer to [26].

Correlation analysis. We calculated the Pearson coefficient correlations between self-reported musical experience of users and the perceived challenge, skill increase and enjoyment of the music. We hypothesized 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 change in the pre- and post-attention tests that the users completed with 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 showed more pronounced attention effects.

4.3 Results

13 out of 21 participants played a minimum of four sessions and completed both pre- and post-experiment questionnaires and cognitive tests. Six participants did not play enough sessions and two did not complete all the attention tests and are therefore excluded from the final sample. The average age of the 13 remaining participants was 23.6 (sd = 3.4) years, seven of them were male and six were female. A control group of 22 people was recruited, of whom 15 were retained who maximally matched the gamer group in terms of age and gender balance (23.2 (sd = 3.7) years; 7 male). The questionnaire showed a mixed level of musical experience among the participants.

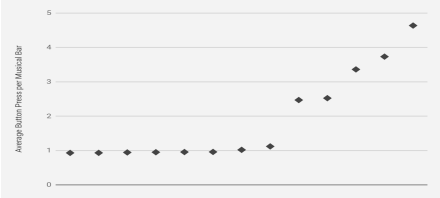

Figure 4. Average button presses per musical bar of all 13 participants.

Gameplay. Participants can be categorized into two groups based on their average button presses per musical bar (see Figure 4) using manual clustering. One group's value is close to one button press per musical bar (Group A - 0.98 button presses), whereas the other's is much higher than that (Group B - 3.35 button presses). Hence, group A interacted with the game mainly by pressing the button once at the beginning of each musical bar, Group B followed a more free-form style, and seemed to press buttons on the downbeats. Table 2 shows gameplay metrics that were extrapolated from the raw gameplay data for all users, and for Groups A and B separately.

Gameplay Metrics (Average)	all users (n = 13)	group A (n = 8)	group B (n = 5)	p-value
Distance Between Musical Bars	0.47	0.23	0.85	.001
Button Presses	233.84	118.85	417.81	.0001
Button Presses Per Musical Bar	1.89	0.98	3.35	.0001
Button Presses Change After Musical Change	-0.13	-0.05	-0.25	.0014
Distance of First Half of Musical Bar After Musical Change	0.51	0.25	0.92	.0005
Distance of Second Half of Musical Bar After Musical Change	0.40	0.19	0.73	.0044

Table 2. Averages of Gameplay Metrics and T-test results for differences between 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 vs 0.85, $p<0.00$). This is also seen 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 vs 0.25, $p<0.00$). As for the button press change after a musical change, Group B had a more significant change compared to Group A (-0.25 vs -0.05, $p<0.00$).

Attention. Participants completed three cognitive tests - one for working memory and two for attention (selective and sustained attention). As this is the only set of measures for which a control group was present, we will here distinguish the 'gamer group' and the 'control group'. Figure 5 shows the results of both group's pre- and post-experiment cognitive tests. Using a Wilcoxon-rank test due to mostly non-normally distributed data, no statistically significant differences were found in any pre- to post-measure for either group. In terms of absolute differences, some qualitatively different tendencies can be observed between the gamer group and control group, namely that the gamer group appears to more consistently make small improvements, but this effect is not large enough to warrant any significant interactions.

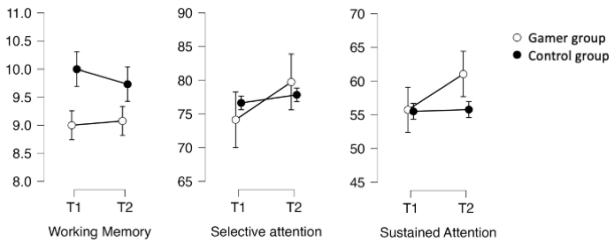

Figure 5. Pre- and post-experiment results of the cognitive tests for the gamer and control groups. T1 and T2 denote pre- and post-test time points. None of the differences are statistically significant, error bars signify standard error.

User experience. Average values of the participants' slider answers to questions about their self-reported experience of the game can be found in Table 3 (0 stands for "Not at all" and 10 "Very much"). The first six questions were asked at the beginning and end of the game sessions, for which the statistical differences are shown. As can be seen, in terms of absolute values, some aspects of their experience increased, and some declined. The only significant change was in how challenging the participants found the game (lowering from 5.15 to 3.78, $p=.01$). The non-significant directional differences in absolute values indicate that participants' interest in the game and their motivation to perform, appeared to slightly deteriorate throughout the course of the experiment (from 5.43 to 4.68 and from 6.79 to 5.88 respectively). Similarly, slight improvements can be seen in the participants' enjoyment of the game, and their enjoyment of the music (from 4.67 to 4.78 and from 5.05 to 5.28 respectively).

Questions	At start	At end	p-value
Interest in game	5.43	4.68	.88
Game was boring	4.78	4.69	.40
Game enjoyment	4.67	4.78	.20
Motivation to perform	6.79	5.88	.90
Game felt challenging	5.15	3.78	.01
Liked music	5.05	5.28	.36
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	

Table 3. Mean values of user experience indices (0 = not at all, 10 = very much) and pre-post differences as tested with a T-test (all normally distributed) for questions which were answered at the start and end of the gaming period.

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). They did experience some skill increase over the course of the play sessions (5.66).

Correlation analysis. The full table of all statistically significant correlations calculated for all groups can be found in the Appendix of [26]; here we discuss the most salient results relating to game experience. A negative correlation is seen between participants' musical experience with 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). For Group A we notice a large correlation between the change of Selective Attention 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.

5. DISCUSSION

In broad terms, the game intervention manages to successfully embody most of the determined requirements for a MACT game. For instance, participants reported that having prior game experience did not influence their liking of the game, indicating the game's general appeal. At the same time, this first MACT game prototype has room for improvement, to raise liking ratings further, that are currently moderate. By allowing the users to play along however they liked, in accordance with the MACT protocol, we avoided having to include negative feedback. However, the lack of informative feedback during game play points to a crucial challenge of telerehabilitation, namely when a clinician cannot provide informative feedback on the spot, and even informal feedback is missing which is part of every in-person musical collaboration. 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. The 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, which underlines the significance of adjusting the difficulty based on each user's performance. We assume that users with musical experience found the game too easy or the music too simplistic.

The results of the attention tests show no significant changes at all, either for the gamer group or a matched control group, but this was to be expected using healthy participants and only a short testing time. To better understand the potential for PwPD, several aspects of the study can be improved in follow-up work. Firstly, the sample size was too small to draw a definitive conclusion. Secondly, each participant's number of sessions varied, which could affect results. Furthermore, for Group A's playstyle, the ability to adapt their behavior to changing rhythms seemed to predict improvement in selective attention. It was our hypothesis that more adaptability would lead to improvements in attention, since that would indicate that they participated in the therapeutic mechanism. Whilst that was the case for users from Group A, who tapped in a stable manner, it was not the case for Group B, who produced more freestyle responses. 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 (perhaps by not quantifying this adaptability correctly) or that the initial hypothesis was incorrect.

Game limitations. It was 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 and to provide informative feedback. Our distance metric was not able to definitively reveal whether users who followed the emulated therapeutic mechanism improved their attention.

6. CONCLUSIONS

This paper introduced design requirements for a PD-tailored game intervention that emulates a MACT session, and tested the newly developed game "The Last Minute Gig" in a pilot study with healthy young participants. The game meets most of the determined requirements, and a positive trend in scores of user experience could be observed. Due to the small size of the study, the results need to be taken with caution and call for follow-up research. We identify several avenues for future work. Metrics to measure whether participants are changing their playing behavior after a musical change happened in the game need to be improved, and positive and informative feedback based on these metrics needs to be provided to players. According to the specific MACT protocol we emulated, no "correct" way of playing along is defined; yet this left participants in a quandary whether they were playing as required, since no feedback was given. To increase the participants' engagement in the game, future work needs to include a form of DDA in the game intervention, for instance by incorporating rhythms with different complexity, and to generate more engaging music. The improved version of the game finally needs to be evaluated with PwPD to gauge its effectiveness for the target group.

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