Can Musical Tempo Makes Tetris Game Harder?

Hufschmitt Aline*, Cardon Stéphane†, Jacopin Éric‡
CREC, *Écoles de Saint-Cyr Coëtquidan*, Guer, France
*aline.hufschmitt@st-cyr.terre-net.defense.gouv.fr
†stephane.cardon@st-cyr.terre-net.defense.gouv.fr
‡eric.jacopin@st-cyr.terre-net.defense.gouv.fr

***Abstract*—It has been shown that music influences human behavior and that it can influence the sports endurance or cognitive performance (memory, reflexes) of individuals. However, little research exists on its influence on the performance of video game players. Music is used to create a particular atmosphere in a game but can it be used to change the difficulty of the game? In this paper, we examine the effects of musical tempo on the performance of players in the Tetris game. By experimenting with different tempo settings for the same music –perfectly synchronous with the game, gradually accelerating to prepare for speed steps, slightly out of sync or in total opposition to the tension of the game– we have shown a significant influence of tempo on the performance of novice Tetris players and even more so for those who have a neutral evaluation of the music. By increasing the tension of the game, a synchronous and increasing tempo can increase the player's stress and degrade his performance, while a tempo that is out of sync with the actions of the game or slowed down regularly can defuse this stress.**

***Index Terms*—Game difficulty, music, tempo, player performance, stress, Tetris**

I. Introduction

Interactivity is an obvious feature of video games that expect the player to act according to the instructions of the game design: the player implements the actions available to him in order to achieve a goal set by the game designers. The more difficult this implementation will be and the harder the game will be, until exasperation; and the easier this implementation will be and the easier the game will be, until boredom. In the case of online games, the level of the opponents participates in the level of difficulty of this implementation; but when the game is not online, the difficulty then stems from the ability of the game to hinder or help the player's progress towards the goal. For instance, a simple way often used to set up difficulty in First-person Shooters (FPSs) is to change the value of some constants. For example, weapons in FPSs have a more or less important effect on the elements of the game: non-player characters are more or less affected by the player's shots and the character controlled by the player can recover more or less quickly depending on the level of difficulty.

Existing research on music focuses on its impact on the immersion of the player, or tests the effect of music on performance compared to the absence of music or the total absence of sound (music and sound effects). Few researches attempt to elucidate the effect of different musical parameters (tempo, volume, timbre, harmony, etc.) on the player's performance.

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The objective of the project we report here is to use music to vary the difficulty of a video game. That is to say, we seek to use music to hinder or help the player. A player can mute the sound while playing, however. On the one hand it is a situation that can be detected, and on the other hand playing with sound can be the occasion of additional objectives, regardless of their level of difficulty, resulting in additional trophies that players may seek to acquire.

In this paper, we focus on the tempo of the music. We experiment with the effects of tempo in the game Tetris[1], which is a sensory motor task that also requires strategic thinking, in order to determine if tempo can affect the player's performance. We refer the reader to our tech. report [9] for all the technical details we could not include here due to space limitations.

The paper is organized as follows. First, we present a brief overview of the state of the art of musical tempo effects in various activities, including the Tetris game. We present our hypotheses and then describe the experiment we are currently conducting to effectively vary the game difficulty. The presentation of our first results is followed by a brief discussion.

II. Related works

Music can influence the speed of human actions [14], [15]. Fast-paced music under red light can elicit faster gambling on an online version of the roulette [16]. A fast tempo also improves stimulus evaluation and response time on a high demanding visual selective attention task, compared to music played at a slower tempo [1]. Music played at a fast tempo can also improve performance (speed, accuracy, memory) in counting or calculus tasks [6], [13]. Young tennis players consciously select music to induce emotional states as a pre-performance strategy [3], [4]. Fast tempi have a positive influence on the ability to withstand physical exertion and can significantly increase the duration of physical exercise, especially when the music is synchronous with the movements [2], [20]. Drivers tested in a simulator (which can be considered close to a video game), drive faster with fast-paced music but also commit more traffic violations [5]. Video game music

[1]"The Tetris game requires players to strategically rotate, move, and drop a procession of Tetriminos that fall into a rectangular Matrix at increasing speeds. Players attempt to clear as many lines as possible by completing horizontal rows of blocks without empty space, but if the Tetriminos surpass the Skyline the game is over." [19]

communicates important information; in [11], when playing Warcraft III after removing the sound, some players report "being left completely in the dark" or likened the experience to "losing a leg".

Nevertheless, Lawrence [12] shows that the music tempo does not significantly alter the performance of the players in the Tetris game. This study uses music whose original tempo is accelerated or slowed down very slightly by 4% or 8%. Game sessions are short (2min), the tempo remains fixed during a game session and is not related to the gameplay i.e. it is not synchronized.

Synchronizing tempo with action is important not just for athletic endurance. Studies on procedural audio solutions in video game show that the relationship between musics and gameplay is very important and plays a significant role in enhancing the immersive experience in a video game [7], [8].

III. Objectives and hypotheses

The state of the art in various fields, including video games, shows that tempo has an effect on human behavior, that it can improve both physical and cognitive performance, and that the relationship between music and gameplay is important.

We propose to experiment again with the effects of tempo on Tetris players, but this time to manage the tempo more finely in relation to the gameplay. During the different game sessions, the tempo variations must follow or not the gameplay to evaluate the effect of synchronization and the variation of the tempo must be as important as the variation of the game speed to correctly measure these effects and maintain synchronization when necessary.

Based on previous work, it is difficult to predict whether an increasing tempo can help a player think and play Tetris faster or whether speed can cause him to make fatal mistakes in this game. The aim of our experiment is to answer this question: *Do tempo variations based on synchronization with the gameplay affect the player and his performance?*

We hypothesized that in Tetris, a tempo perfectly synchronized with the gameplay would reinforce it. Since faster music tempi induce more pleasant and aroused emotional states and are used as a pre-performance strategy, we assumed that a tempo accelerating very gradually would be likely to mentally "prepare" the player for the increase in speed occurring every 10 lines of the game and help him/her to pass these levels of difficulty more easily.

On the contrary, we suppose that a tempo in contradiction with the gameplay, i.e. fast-paced music at the beginning of the game slowing down progressively as the game accelerates, would constitute a obstacle pushing the player to slow down his movements and would lead him to be overwhelmed by the speed of the tetriminos.

We also assumed that the difficulty of the game would increase with the desynchronization of the soundtrack.

IV. Experimental settings

To test our hypothesis, we designed a game of Tetris in Unity called *Sonotris*. For the selection of tetriminos, we used a variation of the original *Grab Bag algorithm* [17] allowing a fair distribution of the different tetriminos and minimizing the risks of falling on a bad draw. The next tetrimino is announced to the player. We enforced the frame rate to 60fps to implement *levels* of difficulty with tetriminos falling every 60, 40, 30, 24, 18, 15, 12, 10, 8, 7, 6 and 5 frames.

A. Tempo management

To experiment on the influence of a musical tempo synchronous with the Tetris gameplay, it was necessary to choose a music that could be accelerated without affecting its aesthetics or intelligibility. We chose an instrumental version of a traditional Russian children's song called *"Petrushka, don't cry"* which has the interesting peculiarity of starting each verse at a very slow tempo and accelerating to finish the chorus at a frantic speed (3 times faster).

As the speed of Tetris is increased tenfold between the first and the last level, we rewrote it to similarly increase the tempo without affecting the quality of the music. At the resumption of the verse, the tempo is divided by two but the beat is doubled to go from a quarter note beat, to an eighth note beat and then a sixteenth note beat. The tempo is split when it reaches a given limit (♩=150 then ♪=360) to create a sensation of continuous acceleration up to 12 times the initial tempo. To focus attention on the new beat, we modified mainly the bass with plated, split then arpeggiated chords and add some ornaments in the melodic voices. We then obtained 3 instrumental versions of a verse followed by a chorus with different beats which are linked without noticeable break by a continuously increasing tempo. We used MIDI to be able to manipulate the tempo and change dynamically the instrumental version. To avoid music degradation, we used high quality sampled piano (bass) and celesta (3 melodic voices) sounds provided to us by Sylvain Brunet from Ubisoft. To implement this dynamic music in Unity, we used *Wwise*, a professional sound engine used for AAA games which provides a callback system which allow to ensure perfect sound (de)synchronization or to re-synchronize visual with sound when necessary.

To test our hypotheses, we defined 5 STAGES i.e. 5 game *sessions* with different preset for the evolution of music tempo. Each STAGE uses the same 12 speed *level* progression. The zero STAGE is a training STAGE with no soundtrack but only some sound FX to signal forbidden moves, completed lines, etc. STAGES 1 to 5 present the following tempo presets : 1) the tempo increases at each *level* and is perfectly synchronized with game speed, 2) the tempo increases at each line and "prepares" the game speed increase of the next *level*, 3) the tempo is increased with one *level* of delay and is then slightly desynchronized, 4) the tempo is also one *level* late, desynchronized but steadily increasing, 5) the tempo is in complete contradiction with the speed of the game and is steadily decreasing.

B. Data collection

41 participants mostly male and right handed between 18 and 35 years old from the french military school of Saint-

Cyr took part of this study. Half of them practice a musical instrument or they consider themselves as music lovers. Half of them frequently play video games.

The data was collected during April 2020. To respect containment due to the COVID-19 epidemic, we packaged all the experiment in a game downloadable from the internet[2], data was automatically sent to a FTP storage after each STAGE. In the game, we invited the participants to play the training STAGE, then to play each of the 5 STAGES (each STAGE is accessible only when the previous one is completed) and to answer a small survey included in the game after each. STAGES 1 to 5 are presented in a random order to avoid effect of learning. In the survey, the player is asked about his experience with Tetris, his concentration during the game, his appreciation of the music and if he left it activated during the whole game, etc.

We finally obtained a total of 46 series of the different STAGES played in random order. At the end of the game we invite players who wish to do so to provide a free account of their experience by email: 34 participants gave us feedback and shared their impressions about the game. The results are presented in the next section.

V. First Results

A one-way ANOVA study on the final level reached by the players confirms Lawrence's [12] results: we cannot significantly differentiate the performances of the players in each of the 5 STAGES ($p = 0.809$); that is to say that one cannot significantly differentiate the performance of a player in a given STAGE according to the tempo of the music. However, a closer analysis of player performance shows that certain categories of players are affected by the tempo.

A. Musical preference

Our survey distinguishes 5 levels of appreciation of music from *"I like it very much"* to *"I don't like it at all"*. A two-way ANOVA study shows that the 5 categories of appreciation of music in terms of performance cannot be significantly separated ($p = 0.086$); however, a partition of the appreciation categories into 3 *like / neutral / dislike* categories allows to significantly separate the players' performances i.e. the final average level reached ($p = 0.021$). Players who likes the music reach globally a higher final level than players who dislike the music.

The results of a pairwise t-Test study show that the performances of players are significantly worse in only one case. The performances of players with a neutral appreciation of music (52% of the players) are worse in STAGE 2 than in STAGE 4: $p = 0.053$ for the median values and $p = 0.068$ for the mean values. Results also suggest that the mean final level in STAGE 2 for the *Neutral* group is lower than in the STAGE 1 ($p = 0,098$). All other values are far from a significant difference in performance, confirming Lawrence's [12] results overall. However, we predicted that STAGE 2 with a gradually increasing tempo synchronous with the action would help players while the desynchronization of the tempo in 4 would slightly hinder them, and our study shows the opposite.

[2]Game and survey are available on http://www.alinehuf.fr/sonotris.php.

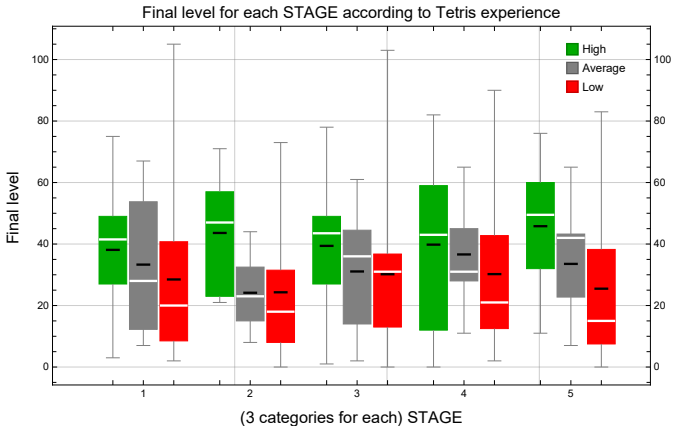

Fig. 1. Effect of Tetris knowledge on the reached final level. Horizontal black lines correspond to the mean and white lines to the median.

B. Tetris knowledge

Our survey distinguishes 5 levels of Tetris knowledge from *"I know very well"* to *"I discover"*. A two-way ANOVA study on the final level reached shows that one can significantly use the 5 categories of knowledge of the game of Tetris to differentiate the performances of the players ($p = .0092$); moreover, by grouping the categories into three categories *High / Average / Low* as we did for music, we can use these categories to even more significantly differentiate the performances of the players ($p = 0.0012$).

The results of a pairwise t-Test study show that for players in the *Average* group (28% of the players) the final level is significantly lower in STAGE 2 than in 4: $p = 0.027$ for the median values and $p = 0.015$ for the mean values. Their final level is also significantly lower in STAGE 2 than in 5: $p = 0.052$ for the median values and $p = 0.050$ for the mean values. These results confirm the reversal of performance already noted for the appreciation of music between 2 and 4. But above all, these results show the inversion of performances for STAGE 2 compared to 5; that is, everything seems to happen as if the synchronization made the task difficult for novice Tetris players and even more for those who have a neutral assessment of the music. In addition, figure 1 shows (1) compliance with the *High / Average / Low* classification, (2) that the performance of beginner players is less good (than that of experienced players: music does not even compensate for inexperience) and (3) confirms the inversion of performance 2-4 and 2-5 for the *Average* category. However, this figure also suggests the reversal of performances for 2-3 ($p = 0.133$) and 2-1 ($p = 0.100$) for the category *Average*. For the beginners (50% of the players), the median final *level* in STAGE 2 is also lower than in STAGE 3 ($p = 0,095$).

VI. Discussion

STAGES 2 and 4 both present a gradually increasing tempo,

but this tempo is delayed by one level in STAGE 4, thus causing desynchronization: the music is unrelated to the action of the game. We assumed that synchronization should help the player but the results of our tests show this is not the case. Tan *et alii* [18] hypothesized that the highest scores earned when playing *Twilight Princess* with music, that was unrelated to players' actions or events unfolding on screen, are due to the least amount of information the player has to process. They also indicate that experienced players are better able to process information conveyed by both sound and images. Among the players who sent us an email feedback, 15 said they were stressed by the acceleration of the tempo and that they made mistakes because of it, especially when the tempo increases steadily. Only 6 participants indicate that the synchronization of the sound with the fall of the tetriminos helped them to some extent to concentrate, but 4 of them indicate that from a certain speed the synchronization of the music only increased their stress. This stress felt by the players could explain the poor results obtained for STAGE 2. On the contrary, the out of sync tempo of STAGE 4 or decreasing tempo of STAGE 5 may help players relax and make fewer mistakes. Only one player mentioned the difficulty of processing game and music information at the same time but not for a particular STAGE. Therefore, the fact that better scores are obtained by non-experienced players in Tetris when the tempo is out of sync and therefore unrelated to the gameplay, seems rather due to a relaxation of the player's stress. Experienced players seems better able to stay calm and not be influenced by the music.

VII. Conclusions

The objective of the project we reported here is to use music to vary the difficulty of a video game i.e. we seek to use music to hinder or help the player. In this paper we checked if variations in the tempo based on synchronization with gameplay affect the player and his performance.

Our results confirm those of Lawrence [12] who cannot significantly differentiate the global performance of players in different tempo conditions. However, we have shown that a tempo that is synchronous with the fall of the tetriminos and gradually increasing (STAGE 2) significantly lowers the performance of novice Tetris players and even more for those who have a neutral assessment of the music compared to a slightly asynchronous tempo (STAGE 4) or a tempo in complete contradiction with the gameplay (STAGE 5). This result is surprising because, in many rhythmic games, a shifted tempo tends to disturb the player's concentration. In our experience with Tetris, player testimonials suggest that tempo synchronization focuses the player's attention on the gameplay, but since the gameplay is stressful, this focus makes the player more sensitive to the progressive increase of the tempo: the acceleration of the tempo then seems to act as an anxiety-provoking anticipation of the difficulty.

We recall the reader that the different STAGES in our experience are only distinguished by the different ways of managing the tempo of the music. Moreover the STAGES have been played in a random order to avoid the effect of learning. A study currently under review [10] shows that the tempo in a given STAGE can prepare the player positively or negatively for a given next, but the randomization of the sequences prevents this from influencing the results presented in this paper.

Our future work will focus on the development of a metric to identify player stress in relation to tempo. We will also validate the observed effects of tempo with different musics in different games including VR applications.

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