2022 IEEE Conference on Games (CoG)
Beijing, China, August 21-24, 2022

Adaptive Game Soundtrack Tempo Based on Players' Actions

Munir Makhmutov*, Joseph Alexander Brown†, Maksim Surkov*, Anton Timchenko* and Kamilya Timchenko*
*Artificial Intelligence in Games Development Lab, Innopolis University
†Department of Computer Science, Brock University
Email: *m.makhmutov@innopolis.ru, †jb03hf@gmail.com, *m.surkov@innopolis.ru, *a.timchenko@innopolis.ru, *k.timchenko@innopolis.ru

2022 IEEE Conference on Games (CoG) | 978-1-6654-5989-1/22/$31.00 ©2022 IEEE | DOI: 10.1109/CoG51982.2022.9893604

***Abstract*—A well-designed video game soundtrack can significantly affect human game perception, especially when there is an intuitive link between musical and game features. The soundtrack intuitiveness can be increased by making it adaptive and dependent on players' actions. The tempo is one of the music characteristics, and this change is relatively easy to distinguish even for non-musicians because it is often interpreted as a speed. This work examines the existence of different correlations between players' in-game actions and soundtrack tempo. Authors suppose that results of conducted playtesting with humans can improve game development from the musical side, increasing players' engagement with the game. The playtesting is done based on a simple *runner* game called *MAK*, which was developed for scientific purposes. This research aims to find intuitive dependencies between six considered game actions and soundtrack tempo.**

***Index Terms*—playtesting, adaptive soundtrack, music tempo, music game, user-centred design, digital game**

I. Introduction

One of the first video games written for non-academic purposes called *Spacewar!* was developed in 1962. It did not include music as well as previous games written for academic purposes. However, modern games contain soundtracks, which are playing an important role in game perception. For some games developers even create virtual bands such as *K/DA* and *Pentakill* for *League of Legends* [1], *Samurai* for *Cyberpunk 2077* [2], etc. Real musicians record the music of virtual bands. Moreover, some developers create social network accounts for virtual bands to promote their games indirectly, which demonstrates the considerable impact of soundtracks on games.

Jenova Chen describes the idea of Flow Zones [3] in the field of digital games, which was also mentioned in [4]. These papers are based on the concept of Flow introduced by Mihaly Czikszentmihalyi in 1990 [5]. The Flow Zone concept is aimed to increase the pleasure and happiness of people for any activity performance. Flow Zone allows focusing on activity, with a high level of enjoyment and fulfilment based on eight components: a challenging activity requiring skill, merging of action and awareness, clear goals, direct and immediate feedback, concentration on the task at hand, a sense of control, a loss of self-consciousness and an altered sense of time. We believe that the game soundtrack also should follow this concept for a higher enjoyment of players. That is why immediate feedback from the game soundtrack responding to players' in-game actions can increase the excitement.

Nowadays, it is hard to imagine a game without soundtracks. Usually, the music is used for producing the in-game atmosphere. Besides, it sometimes emphasizes a particular moment like approaching enemies or changing locations. In some cases, special sound effects are used for this purpose, and those effects are played without changing the current soundtrack. Sound effects occur at key points to highly changes, especially in dynamic genres (*e.g. shooter*, *runner*). Repeated sound effects for routine actions are a well-known concept applied in most video games to act as signifiers to a player of an action occurring. This emphasis on the role of sound effects in games could be, in part, delegated to soundtracks.

The hypothesis is that sound effects, together with changes in the soundtrack, focus players' attention on important moments of the game. It means that soundtracks have to reflect game changes instead of sound effects or together with them. However, considering all existing game and soundtrack components is a rather difficult task for a single paper. That is why it has to be decided which game and soundtrack features have to be considered. This concept may be applied to make game soundtracks more involving in the game process. Understanding the tradeoffs on the impact on players' involvement and enjoyment during the game is measured.

Most music-based games like *Audiosurf* [6], *Guitar Hero* [7], *Crypt of the Necrodancer* [8] are rhythm-based games, and one of the reasons for it is that even for an average player it is relatively easy to hear differences in music rhythm and tempo. For example, the song key change is not necessarily that obvious to non-musicians or even some musicians. Game developers try to focus on more significant audiences to make their games more popular, explaining why rhythm-based games are the most widespread type of music-based games.

The *Audiosurf* developers claim that it is a music-adapting puzzle racer where the player uses its music to create a new experience. The chosen song determines the shape, speed, and mood of each ride. *Audiosurf* game content is dependant on the tempo of the music. *Crypt of the Necrodancer* takes fundamental elements of a roguelike dungeon exploration game and adds a beat-matching rhythm game set to a soundtrack. The movements of enemies and players are linked to the beat-matching rhythm. In *Guitar Hero*, the player simulates playing music by pressing buttons on the guitar-shaped controller in time with musical notes that scroll on the screen.

It may be unclear which dependencies of game and soundtrack components are intuitive for players. We define intuitiveness, in this case, as the ability of a player to understand the cognitive model of how a game works without trouble. It is an essential factor for game developers because it can help them get more players. The intuitiveness of design is described in [9], and the task of game developers is to avoid the so-called *Norman's doors*, which are things confusing how to use them.

So, as an initial attempt to use the described concept, this paper focuses only on one of the soundtrack features called tempo. Different features can be considered for the game side to understand what effect it can bring to soundtrack perception during the game. The results of this research should allow game developers to get a better understanding of existing correlations between the game and soundtrack tempo, which potentially can make games more intuitive and involving.

This paper has the following organization. Section II describes in detail related works in the field of an adaptive game soundtrack and other related fields. Section III describes the developed game. Section IV defines the used methodology for experiments. Section V describes the preliminary survey participants. Section VI presents an analysis of conducted experiments. Section VII reports the overall results.

II. Related Works

It was proved that the background music in games increases immersion of the players [10]. Ng and Nesbitt claim that the interest in putting additional information into sounds in games is growing [11]. Moreover, Parker and Heerema claim that sounds in games are responsible for emotions more than other parts of the game [12]. Also, the authors discuss the existing audio games, which mostly rely on the audio part during the gaming process. They concluded that the variety of ways of using sound in games is minimal. They claim that the reasons for it are limited funding and a too-visual way of thinking. Thus, game sounds and soundtracks, in particular, can affect the mood of the players and motivate them to play further.

The set of game factors affecting the soundtrack tempo has to contain general components to receive universal results. We focus on the casual game in the genre of *runner*. Therefore we consider general features related to this genre. Nevertheless, we do not state that the obtained results apply only to *runners*, the results of this research can be applied to other game genres.

Whitmore states that adaptive soundtracks in games are currently underutilized [13]. Despite this, scientific research on this subject is underway [14]–[16]. In contrast with these works in our research, we consider only soundtrack adaptation.

Some of the endless games containing many similar levels apply the concept of increasing the speed of a character movement or speed of surrounding objects. This allows adding more tension with each next level. To emphasize this tension the soundtrack tempo can also be increased for the next level. In *Untitled Goose Game* for emphasizing game tension the soundtrack becomes more intensive, which is achieved by replacing it with its more intensively played chunks. All these chunks are already composed, so real-time music modification does not happen. Brodsky states that the music listened by drivers affects their speed [17]. Utilizing PC-controlled simulation, he has proved that faster driving can be caused by a faster tempo, and vice versa lower tempo can lead to slower driving. Thus, we assume that tempo increasing linked to increasing level difficulty can allow adding even more tension.

The speed bonuses are pretty frequent in video games. Sometimes, games containing speed bonuses also include score bonuses. Hypothetically, the correlation between the soundtrack tempo and catching the score bonuses is not apparent. However, for consistency and consideration of each other's game factors, score bonuses can be considered.

We assume that each video game has a graphical representation. Therefore each image or photo can be represented by pixels in different colours. Thus, colours are common to most video games, making them a brilliant candidate for game factors consideration. Cheng, Wu and Yen claim that people feel more aroused and pleasant listening to fast music and being under warm colour conditions than those who are exposed to an environment with slow music and cool colour [18]. According to [19], gamblers risk more while listening to music with a fast tempo and surrounded by red lights. In these experiments, gamblers played games in four different conditions: red light and fast tempo, red light and slow tempo, white light and fast tempo, white light and slow tempo. Their inference explains why most casinos are painted red. In the paper of Stark, Saunders, and Wookey [20], it was concluded that gamblers within a red light environment gambled money more often and selected riskier odds than did subjects gambling under blue light. It can be assumed that under the red light illumination and fast music conditions, gamblers or gamers should be riskier than under the blue light illumination with slower music tempo conditions.

Flickering lights are usually annoying, and they can distract from the focused object [21]. It is possible to intensively change the game's illumination and apply it as a negative factor leading to higher complexity. And to increase the effect of visual distortion, soundtrack tempo can also be increased.

The percentage of life in-game defines how high is the risk of the character losing the game. Given that with the lower number of lives, a player has fewer chances to survive, the player's emotional pressure increases. That is why we claim that the number of lives can also be considered a game factor, which can correlate with soundtrack tempo.

In [22], authors highlight seven principles of interactivity in music video games: active score, rhythm action, quantisation, synaesthesia, play as performance, free-form play and sound agents. The active score music principle is the closest to the idea of a game described in the next section. It provides changes in the original music based on some randomness, which in this work is defined by player actions.

III. Game Description

The study is based on the evaluation of serious video game perception by players. An experimental video game called *MAK* was developed to control the logic in the game and

Fig. 1. MAK game process.

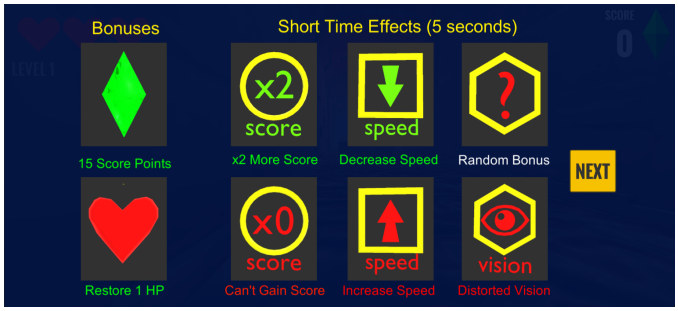

Fig. 2. MAK game bonuses shown in tutorial.

flexible data collection from participants. The game consists of two major parts - visual interactive gameplay and adaptive soundtrack. The genre of game is an *endless running platformer*, much like *Subway Surfers* [23]. While running in a mobile game, *Subway Surfers*, the player can swipe up, down, left, or right to avoid crashing into oncoming obstacles, especially moving trains, poles, tunnel walls and barriers. Also, the player can catch coins to increase the score. This game genre does not require much time for understanding the concept, which should allow players to focus on understanding dependencies between game and music.

The game is a tunnel with various obstacles on the player's path, positive and negative bonuses and diamonds that have to be collected by a player to get scores (see Fig. 1). Moving through the tunnel also increases the player's score by 1 point for each block of fixed length. Diamond catching adds 15 points to the score. With each new level, obstacles become more challenging to avoid. The obstacles represented are boxes, barrels, pits, horizontal spikes, vertical spikes and cacti. The damage received after the collision with obstacles differs. Initially, the player has the maximum number of lives equal to three. The collision with horizontal spikes, vertical spikes and cacti or fall into the pit automatically makes the number of lives equal to zero and leads to instant death. All those obstacles are unbreakable. The head-on collision with boxes and barrels leads to the loss of one life and the obstacle's destruction. However, the game's exciting feature is that side collisions can destroy boxes and barrels without a loss of any lives. The difference between boxes and barrels is their height and shape. One more type of obstacle is three boxes standing on each other, making this construction unbreakable and leading to instant death. The steps for an increase in difficulty are predefined, but the placement of obstacles is determined by the 'just-in-time' level generator, based on a probabilistic grammar model. The level generator produces acceptable levels and increases the difficulty by each new level.

Based on the discussion in the previous section *MAK* provides the next types of game bonuses shown in Fig. 2:

- Speed up, doubling the speed (5 sec)
- Slow down, decreasing the speed by two (5 sec)
- Score multiplier, doubling new collected points (5 sec)
- Score freezer, cancelling new collected points (5 sec)
- Heart, increasing life by one
- Vision distortion, distracting by flickering colours (5 sec)
- Diamond, representing points
- Unknown bonus, turning into any previous bonus

Catching of *speed up* bonus during the active *slow down* bonus neutralizes the latter's effect and vice versa. The same is true for score bonuses. All active temporary bonuses become disabled after death or transition to the next level. Sequential catching of the same type temporary bonuses does not stack their duration effect; it makes the timer equal to five seconds. All active bonuses with timers are visualized on the screen.

IV. Methodology

A. Design Experiments

The experiments' design consists of two sequential parts: a preliminary survey of candidates and further playtesting. The preliminary survey contains questions, which had to be asked in advance before playing a game. These questions are represented in Table I. Participation in this experiment was entirely voluntary, and all the responses were kept anonymous. All of the questions were mandatory. For the questions about the name, surname, contact, age and citizenship of participants, text fields were provided. The rest of the questions were single-choice. During further analysis, all names, surnames, and contacts were hidden and replaced by identification numbers. Contacts, names and surnames were collected in case of necessity to contact the participants, to clarify their answers for avoiding misunderstandings. The last question was asked only in case of an affirmative answer to the previous question about the experience of playing runner games.

Playtesting includes several games; the in-game survey for each player follows each of them. The length of each game played is three minutes. Each player has a set of non-repeating versions of the game. The whole experiment's length does not exceed one hour because the experiment can become too dull for players, which can affect the results of the experiment.

The participants were collected via announcements and invitations inside the Innopolis University (IU) and were not compensated for participation. The parents of all participants under the age of 18 were informed about this experiment and gave their oral consent. All participants gave informed consent, the study was approved under IU ethics committee, experiments were conducted under the Russian laws.

B. In-game Survey

When the participant finishes playing each game variant, they have to fill an evaluation survey. The survey consists of questions represented in Table II. The first three questions were mandatory for all participants. The fourth question was appearing only in case of an affirmative answer to the third question. By the affirmation, we mean agreement, to some degree: agree, strongly agree or slightly agree.

At the end of the last game variant, players have to answer one more additional question shown in Table II, which helps to determine if the participant is aware of the tempo term.

Question 1 about the feelings relies on Robert Plutchik's emotion classification model. The participants were allowed to choose one or more emotions from the list and even add their option. It was chosen because of its simplicity, and brevity [24]. Plutchik's model provides eight types of emotions compactly and conveniently for evaluation. Most of the later emotion classification approaches are focused on adding more complexity but are based on Plutchik's model.

C. Game Combinations

Based on the discussion in Section II it was decided to use six varying game factors, that are highly visual to the user:

1) *Speed bonus* - speed up or slow down
2) *Score multiplier* - double newly collected score points or freeze collected score points
3) *Vision distortion bonus* - player's viewport is distorted
4) *Level speed* - affects the speed of a player in the level. From level to level, the basic speed can only be increased
5) *Health points* - initially, there are three lives. When the player loses all of them, the game is over
6) *Illumination colour* - each corridor block is illuminated by red or blue light. The colour randomly changes for each next block. The player does not control the illumination colour.

For music, only soundtrack tempo can be changed. This game aims to understand which correlations between game features and the soundtrack tempo are intuitive for players. It means that it is possible to have seven game variations, considering that six of them have precisely one dependence between game and soundtrack tempo. One of the game variations does not have any dependencies. So, it has to be decided how game factors should affect the soundtrack tempo.

These game combinations have some limitations. In combinations 1, 2 and 3 players can avoid the collection of bonuses, responsible for tempo changes. In combination 4 it is possible

TABLE I
PRELIMINARY SURVEY

No	Question	Answers
1	Please leave your contact	Open answer
2	What is your name?	Open answer
3	What is your surname?	Open answer
4	What is your age?	Open answer
5	What is your gender?	Male Female Non-binary
6	What is your citizenship?	Open answer
7	What is your current status?	School student University/college student Professor/teacher PhD-student Other
8	How much do you agree with the statement: "I enjoy *indie* games"?	Strongly agree Agree Slightly agree No opinion Somewhat disagree Disagree Strongly disagree
9	How much do you agree with the statement: "I enjoy *runner* games"?	Strongly agree Agree Slightly agree No opinion Somewhat disagree Disagree Strongly disagree
10	Do you have an experience of playing *runner* games (Subway Surfers, Temple Run, etc)?	Yes No I do not remember
11	If yes, how many hours per week do you play *runner* games?	Do not play Less than 1 hour 1-5 hours 5-10 hours 10-20 hours More than 20 hours

TABLE II
IN-GAME SURVEY

No	Question	Answers
1	Which emotions did you feel while playing?	Joy Surprise Anticipation Fear Anger Sadness Disgust Trust Indifference Other
2	Did the music improve your playing experience?	Improved significantly Improved slightly Did not notice Worsened slightly Worsened significantly
3	Did the music adapt to your gameplay?	Strongly agree Agree Slightly agree No opinion Somewhat disagree Disagree Strongly disagree
4[a]	Which game action or moment affected the soundtrack? What was changed in the soundtrack and how?	Open answer
5[b]	Do you know what the tempo in music is?	Yes, I have advanced knowledge Yes, I feel confident about it Yes, I know something basic about it Almost nothing No, at all

[a]Appears only in case of positive answer to question 3.
[b]Appears only at end of the last game.

not to achieve higher levels. In combination 5 the player may fail to lose health points. In combination 6 randomness can create a tunnel illuminated by the only colour. The abovementioned cases may prevent dependencies from being found. However, these limitations can be ignored because the given time is big enough to alleviate these problems.

The experiment procedure follows the following steps:

1) before the game, the player has to see the presentation, which explains the idea of research without the revelation of used game and music factors (5 min)
2) the player using assigned unique identification number has to log in to the game (2 min)
3) the player has to pass through the tutorial (3 min)
4) the player has to pass through each of randomly-ordered seven-game variations (3 min for each)
5) each of seven in-game surveys appears after each game variation (2 min for each).

The entire experiment takes approximately 45 minutes for each player. The game soundtrack is chosen automatically from a music dataset prepared in advance. Three polyphonic MIDI files of different genres comprised the dataset[1]. So, during the game chosen soundtrack's tempo is modified in real-time based on the game factor. Thus, each participant passes through all seven-game combinations, which means that a completely randomized design is applied for experiments.

D. Soundtrack Distribution Model

The MIDI dataset used for soundtracks includes three songs. The reason for it is that it is rather dull to listen to the same song for 45 minutes. However, varying song sets for different games may negatively result game experience because different songs can change the player's opinion about the correlations. That is why it is necessary to make it mandatory to play each game with the same set of songs of the same length. Each game lasts three minutes, and songs have to be long enough to hear the tempo changes during the game. Each of the three songs plays for one minute in each game.

In the scope of all experiments, each soundtrack should be played an equal number of times, with a maximum deviation of one. That requirement was fulfilled via the synchronizing server. The latter maintains a map for all soundtracks, counting many occurrences for each track for all participants. Each time a session instance requests a new soundtrack, it also contains information about the number of previous tracks' plays. The server selects a track with a minimal number of occurrences from a subset of new tracks for a given player during the current game combination. Such a model provides a uniform distribution of tracks for the experiment.

Each of the three soundtracks has a unique constant tempo (110, 133 and 145 BPM). The time signature is 4/4 for all tracks. Each song's duration is longer than two minutes, which prevents looping the song even for the cases with increased tempo during the entire game because each song cannot last longer than one minute according to the chosen constraints. Smooth transitions occur between soundtracks. Diminuendo is applied for the end of each song. While at the beginning of the next song, crescendo is applied.

[1]https://tinyurl.com/3udnrfk8

V. Preliminary Survey

For the experiment, each participant was provided with a laptop with an installed game and headphones not to distract other participants and not be distracted by others. All laptops were applicable for a game with FPS higher than 60. Each experiment was including about 10 participants in the room.

The experiment included 75 participants from seven countries (see Fig. 3). The majority of participants are from Russia. Data received from 13 participants were excluded from consideration because of missing some data. These people refused to continue the game because of being tired. The results of the rest 62 participants were analyzed. Almost 26% of the rest 62 participants are females, and about 74% are males. The age distribution of participants is represented in Fig. 4. At the time of experiments, 29 participants were university or college students, 27 participants were school students, and six survey members were working in companies (see Table III).

The preliminary survey has shown that more than 82% of participants are, to some degree, agree with the statement that

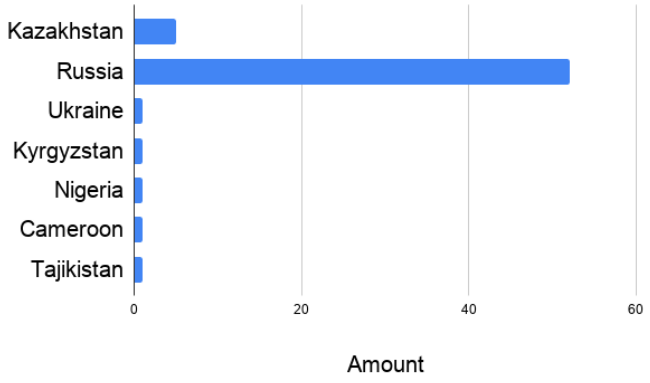

Fig. 3. Citizenship distribution.

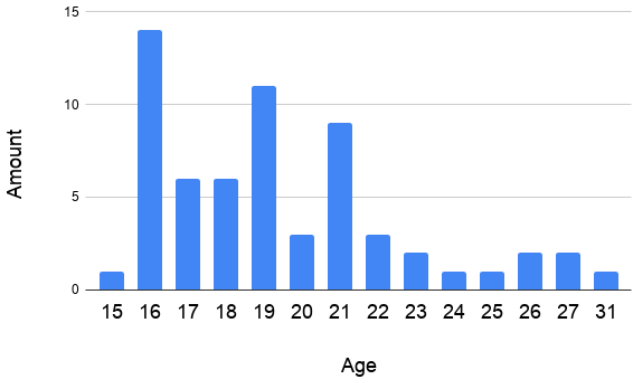

Fig. 4. Age distribution.

they enjoy indie games (see Table IV). Almost 15% did not opinion about it, and only 3.2% disagreed with this statement.

Exactly 71% of participants, to some degree, enjoy runner games (see Table V). A little bit more than 18% did not have opinions related to this question, and about 20%, to some degree, responded that they do not enjoy runner games.

About 92% of participants had an experience of playing runner games; approximately 6% did not have this experience, and almost 2% did not remember it (see Table VI).

For 57 participants, which had an experience of playing runner games, we built the distribution of the number of hours spent per week in such kinds of games (see Table VII). This distribution demonstrates that 46% of these 57 participants do not usually play runner games, about 39% play less than 1 hour per week, approximately 9% play from 1 till 5 hours per week, a little bit more than 5% play from 5 till 10 hours per week and just one person play from 10 till 20 hours.

VI. Results and Discussion

The participants were not told which game and music factors to expect. However, they knew that one type of in-game action in each given game combination affects the current soundtrack somehow. Also, they were told that none of the game combinations could be repeated more than once. Their task was to guess the dependencies between the game and their soundtrack. The more participants can think about game and music factors, the more intuitive the game combination is. However, not all of the participants were able to cope with this task. A post-game survey followed each of the seven-game combinations given to each player in random order. Also, statistics of all games were collected to estimate the performance of players in different game combinations.

Table VIII represents emotions of participants related to all game variations. Each participant had to choose at least one emotion. According to this table, game variation with vision distortion bonus linked to tempo appeared to be the most joyful for players. Game variation with health points linked to tempo became the most surprising. Level speed affecting the tempo added a sense of trust, which can be explained by prevalence in games. Many participants did not have strong emotional reactions to all settings in the game. According to the one-way ANOVA test, p-value = 0.99 and f-statistic value = 0.03.

Almost in 54% of cases among 62 players, it was claimed that music, to some degree, adapted to the gameplay. Also, this definite answer provided additional open question about describing seen correlations. Only 16% of responses to the supplementary question was correct about both musical and game factors. About 60% of answers were wrong, and almost in 24% of the cases, respondents could guess either musical or game factor. Partially correct answers can be divided into about 73% of music factor guessers and 27% of game factor guessers. Experiments demonstrated that respondents with at least some knowledge about tempo have a four-times-higher chance to guess that soundtrack tempo varied in some games.

In more than 42% of cases, players, to some degree, believe that their playing experience was improved because of the music soundtrack. The intersection between the players' answers, for whom the playing experience was enhanced because of music, and for whom the soundtrack seemed adaptive is approximately 33%. However, only in half of those responses, game and music factors were correctly identified. On the one hand, correct identification of players' factors is not the primary goal because the increase of satisfaction from the game is already a positive result. On the other hand, a better

TABLE III
Status of participants

No	Answer	Participants	%
1	University/college student	29	46.8%
2	School student	27	43.5%
3	Employee	6	9.7%

TABLE IV
How much do you agree with the statement: "I enjoy indie games"?

No	Answer	Participants	%
1	Strongly agree	11	17.7%
2	Agree	26	41.9%
3	Slightly agree	14	22.6%
4	No opinion	9	14.5%
5	Somewhat disagree	0	0%
6	Disagree	2	3.2%
7	Strongly disagree	0	0%

TABLE V
How much do you agree with the statement: "I enjoy runner games"?

No	Answer	Participants	%
1	Strongly agree	5	8.1%
2	Agree	20	32.3%
3	Slightly agree	19	30.6%
4	No opinion	11	17.7%
5	Somewhat disagree	6	9.7%
6	Disagree	1	1.6%
7	Strongly disagree	0	0%

TABLE VI
Do you have an experience of playing runner games?

No	Answer	Participants	%
1	Yes	57	91.9%
2	No	4	6.5%
3	I do not remember	1	1.6%

TABLE VII
How many hours per week do you play runner games?

No	Answer	Participants	%
1	Do not play	26	45.6%
2	Less than 1 hour	22	38.6%
3	1-5 hours	5	8.8%
4	5-10 hours	3	5.3%
5	10-20 hours	1	1.8%
6	More than 20 hours	0	0%

TABLE VIII
EMOTIONS OF PARTICIPANTS IN ALL GAME COMBINATIONS.

	Joy	Surprise	Anticipation	Fear	Anger	Sadness	Disgust	Trust	Indifference	Other
Speed Bonus	9	9	12	3	4	6	3	5	25	5
Score Bonus	11	12	13	6	3	7	3	2	18	5
Vision Distortion Bonus	14	12	12	5	4	5	1	3	19	6
Level Speed	7	17	12	5	7	6	3	9	19	2
Health Points	10	20	13	2	6	7	3	5	18	4
Illumination Colour	10	12	14	5	6	9	2	7	16	4
No Factor	10	12	10	5	7	10	3	5	18	3
Mean	10.14	13.43	12.29	4.43	5.29	7.14	2.57	5.14	19	4.14
Standard Deviation	2.12	3.74	1.25	1.4	1.6	1.77	0.79	2.34	2.83	1.35

TABLE IX
GUESSING OF GAME FACTORS BY PARTICIPANTS WHO HAVE CORRECTLY GUESSED GAME AND MUSIC FACTORS AND WHO CONSIDER THAT THE ADAPTIVE SOUNDTRACK IMPROVED THEIR EXPERIENCE.

No	Game Factor	Number	%
1	Speed Bonus	8	12.93%
2	Score Bonus	2	3.23%
3	Vision Distortion Bonus	2	3.23%
4	Level Speed	8	12.93%
5	Health Points	2	3.23%
6	Illumination Colour	0	0%
7	No Factor	1	1.62%

TABLE X
PARTICIPANTS WHICH CONSIDER THAT THE ADAPTIVE SOUNDTRACK IMPROVED THEIR PLAYING EXPERIENCE.

No	Game Factor	Number	%
1	Speed Bonus	24	38.79%
2	Score Bonus	19	30.71%
3	Vision Distortion Bonus	17	27.47%
4	Level Speed	25	40.4%
5	Health Points	19	30.71%
6	Illumination Colour	19	30.71%
7	No Factor	19	30.71%

TABLE XI
PARTICIPANTS WHICH CONSIDER THAT THE ADAPTIVE SOUNDTRACK WORSENED THEIR PLAYING EXPERIENCE.

No	Game Factor	Number	%
1	Speed Bonus	1	1.62%
2	Score Bonus	3	4.85%
3	Vision Distortion Bonus	0	0%
4	Level Speed	4	6.46%
5	Health Points	5	8.08%
6	Illumination Colour	6	9.7%
7	No Factor	1	1.62%

understanding of correlations can make the playing experience even more exciting. That is why in the further analysis, we focus on responses of players who have guessed game and music factors and have claimed that their experience was improved in games with the adaptive soundtrack.

Table IX shows the count and percentage of participants who have correctly guessed game and music factors and who consider that the adaptive soundtrack improved their playing experience. The *speed bonus* and *level speed* appeared to be the most easily recognizable game factors for the players whose playing experience was improved and who have noticed soundtrack adaptation. Both of those factors are logically close to tempo, making them more suitable to this music factor than other game factors. The same number of participants, who guessed *speed bonus* and *level speed*, does not imply that these are the same players. Their intersection is just one person out of fifteen. Identifying a game modification without a game factor affecting the soundtrack tempo was rather difficult for participants. This game version was considered a placebo for players who wanted to improve their experience by finding the soundtrack adaptability. Dependency of a soundtrack tempo on *score bonus*, *vision distortion bonus* and *health points* appeared to be unobvious for players. No one could find a correlation between *illumination colour* and tempo, making it the most difficult game factor for guessing. It is quite hard to pay attention to the background features of surroundings, and we believe that illumination colour was that type of feature.

As previously mentioned, the guessing of dependencies by players is not the main idea of this experiment. If some game combinations' soundtracks somehow affect a player's experience without the understanding of exact reasons, it is also a result. In Table X, we consider the participants which game experience was improved because of the adaptive soundtrack. Even without guessing game and music factors, players were satisfied more while playing game combinations with a speed bonus and level speed linked to music tempo.

We also need to discuss if music in some combinations can worsen the playing experience. In Table XI, we consider the participants which game experience was worsened because of the adaptive soundtrack. Almost 10% of participants claimed that their experience was further exacerbated because of music in combination with illumination colour. The music in combination with health points worsened the experience of more than 8% of participants. Surprisingly, the music combined with level speed also worsened the experience of more than 6% of participants. The combinations with a speed bonus and without linked factors caused a decline in only one player's experience. It means that the combination with speed bonus almost does not negatively affect the playing experience.

In Table XII, the average number of deaths and the average score is shown for each game combination. It can be seen that

TABLE XII
STATISTICS OF GAME COMBINATIONS' AVERAGE SCORES AND DEATHS.

	Average Deaths	Average Score
Speed Bonus	2.94	673.6
Score Bonus	2.4	659.73
Vision Distortion Bonus	2.94	665.23
Level Speed	2.34	674.65
Health Points	2.81	678.18
Illumination Colour	2.81	669.06
No Factor	2.82	684.85
Mean	2.72	672.35
Standard Deviation	0.25	8.35
***f*-statistic value**	1.18	0.17
***p*-value**	0.32	0.99

game combinations with score bonus and level speed linked to tempo helped players die less often. Surprisingly, the average score in combination without the tied game and music factors was the most significant. The least average score was achieved in game combination with score bonus linked to tempo.

It worth mentioning that correlation between gender, citizenship, age groups and the progress in guessing used game combinations were not found. However, more participants from school were not able to finish the game because of being tired. Their answers were excluded because of incompleteness.

VII. CONCLUSIONS

Several games, as a method of engaging players in the affective domain, use adaptive music techniques. Adaptive music techniques examined in the literature included [25]. However, there has been little work on linking the game elements into musical elements and showing which state is best from the player's perspective. This study has shown that players are most likely to see changes in the gameplay reflected by changes in the music's tempo, primarily when the soundtrack tempo depends on the speed of the character. This finding allows developers better to understand their player's reactions to changes in gameplay and show that many games feature a disconnect in players' perceptions of musical elements.

In future work, this linkage should move beyond just which elements should be connected but must inform the generative process for more affective music in games. Through this link, the generative model can be more focused on changes to factors that lead to playing impacts. Thus, the objective performance measure in many generation methods has a target function that has backing in objective research methods and not speculations of a developer or designer. This paper is a part of a work briefly described in [26].

It is still an open question as to if these findings link solely with the *runner* game style or if the tempo is a key to other types of games. Therefore, this study invites replication for other game elements in other game genres. Though due to the similarities between *runners* to *platformmers* and some *puzzle* games, this finding is likely transferable to some extent.

REFERENCES

[1] Riot Games, "League of legends," Video, Apr. 2009. [Online]. Available: https://na.leagueoflegends.com/

[2] CD Project Red, "Cyberpunk 2077," Video, Apr. 2020. [Online]. Available: https://www.cyberpunk.net/

[3] J. Chen, "Flow in games (and everything else)," *Communications of the ACM*, vol. 50, no. 4, pp. 31–34, 2007.

[4] P. Sweetser and P. Wyeth, "Gameflow: a model for evaluating player enjoyment in games," *Computers in Entertainment (CIE)*, vol. 3, no. 3, pp. 3–3, 2005.

[5] M. Czikszentmihalyi, "Flow: The psychology of optimal experience," 1990.

[6] Invisible Handlebar, "Audiosurf," Video, Feb. 2008. [Online]. Available: http://www.audio-surf.com/

[7] Harmonix Music Systems, "Guitar hero," Video, Feb. 2005. [Online]. Available: https://www.guitarhero.com/

[8] Brace Yourself Games, "Crypt of the necrodancer," Video, Feb. 2015. [Online]. Available: https://braceyourselfgames.com/crypt-of-the-necrodancer/

[9] D. Norman, *The design of everyday things: Revised and expanded edition*. Constellation, 2013.

[10] J. Z. X. Fu, "The influence of background music of video games on immersion," *Journal of Psychology & Psychotherapy*, vol. 5, no. 4, 2015.

[11] P. Ng and K. Nesbitt, "Informative sound design in video games," in *Proceedings of The 9th Australasian Conference on Interactive Entertainment: Matters of Life and Death*, 2013, pp. 1–9.

[12] J. R. Parker and J. Heerema, "Audio interaction in computer mediated games," *International Journal of Computer Games Technology*, vol. 2008, 2008.

[13] G. Whitmore, "Design with music in mind: A guide to adaptive audio for game designers," *Gamasutra, May*, vol. 29, 2003.

[14] M. Eladhari, R. Nieuwdorp, and M. Fridenfalk, "The soundtrack of your mind: mind music-adaptive audio for game characters," in *Proceedings of the 2006 ACM SIGCHI international conference on Advances in computer entertainment technology*, 2006, pp. 54–es.

[15] D. Williams, A. Kirke, J. Eaton, E. Miranda, I. Daly, J. Hallowell, E. Roesch, F. Hwang, and S. J. Nasuto, "Dynamic game soundtrack generation in response to a continuously varying emotional trajectory," in *Audio Engineering Society Conference: 56th International Conference: Audio for Games*. Audio Engineering Society, 2015.

[16] D. M. Young, "Adaptive game music: the evolution and future of dynamic music systems in video games," Ph.D. dissertation, Ohio University, 2012.

[17] W. Brodsky, "The effects of music tempo on simulated driving performance and vehicular control," *Transportation research part F: traffic psychology and behaviour*, vol. 4, no. 4, pp. 219–241, 2001.

[18] F.-F. Cheng, C.-S. Wu, and D. C. Yen, "The effect of online store atmosphere on consumer's emotional responses–an experimental study of music and colour," *Behaviour & Information Technology*, vol. 28, no. 4, pp. 323–334, 2009.

[19] J. Spenwyn, D. J. Barrett, and M. D. Griffiths, "The role of light and music in gambling behaviour: An empirical pilot study," *International Journal of Mental Health and Addiction*, vol. 8, no. 1, pp. 107–118, 2010.

[20] G. Stark, D. Saunders, and P. Wookey, "Differential effects of red and blue coloured lighting on gambling behaviour," *Current Psychology*, vol. 2, no. 1-3, pp. 95–99, 1982.

[21] W. P.Berg, E. D.Berglund, A. J.Strang, and M. J.Bauma, "Attention-capturing properties of high frequency luminance flicker: Implications for brake light conspicuity," *Transportation Research Part F: Traffic Psychology and Behaviour*, vol. 10, no. 1, pp. 22–32, 2007.

[22] M. Pichlmair and F. Kayali, "Levels of sound: On the principles of interactivity in music video games." in *DiGRA Conference*. Citeseer, 2007.

[23] Kiloo and SYBO Games, "Subway surfer," Video, Feb. 2010. [Online]. Available: https://www.kiloo.com/subway-surfers/

[24] R. Plutchik, *Emotions and life: Perspectives from psychology, biology, and evolution.* American Psychological Association, 2003.

[25] M. Scirea, P. Eklund, J. Togelius, and S. Risi, "Evolving in-game mood-expressive music with metacompose," in *Proceedings of the Audio Mostly 2018 on Sound in Immersion and Emotion*. ACM, 2018, p. 8.

[26] M. Makhmutov, "Adaptive game soundtrack generation based on music transcription," in *Proceedings of the AAAI Conference on Artificial Intelligence and Interactive Digital Entertainment*, vol. 15, no. 1, 2019, pp. 216–218.