Applied Computer Science, vol. 18, no. 4, pp. 28–52
doi: 10.35784/acs-2022-27

Submitted: 2022-06-27 | Revised: 2022-12-09 | Accepted: 2022-12-11

Keywords: EEG, Eye Tracker, engagement, IGA, Advergaming

Konrad BIERCEWICZ [0000-0003-1635-4527]*,
Mariusz BORAWSKI [0000-0001-8470-8329]*,
Anna BORAWSKA [0000-0001-6680-1052]*, *Jarosław DUDA* [0000-0001-9971-3075]*

DETERMINING THE DEGREE OF PLAYER ENGAGEMENT IN A COMPUTER GAME WITH ELEMENTS OF A SOCIAL CAMPAIGN USING COGNITIVE NEUROSCIENCE TECHNIQUES

Abstract

Due to the popularity of video games in various applications, including both commercial and social marketing, there is a need to assess their content in terms of player satisfaction, already at the production stage. For this purpose, the indices used in EEG tests can be used. In this publication, a formula has been created based on the player's commitment to determining which elements in the game should be improved and for which graphic emblems connected with social campaigns were more memorable and whether this was related to commitment. The survey was conducted using a 2D platform game created in Unity based on observations of 28 recipients. To evaluate the elements occurring in the game at which we obtain a higher memory for graphic characters, a corresponding pattern was created based on player involvement. The optimal Index for moving and static objects and the Index for destruction were then selected based on the feedback. Referring to the issue of graphic emblems depicting social campaigns should be placed in a place where other activities such as fighting will not be distracted, everyone will be able to reach the level where the recently placed advertisement is. This study present the developed method to determine the degree of player's engagement in particular elements in the game using the EEG and to explore the relationship between the visibility of social advertising and engagement in a 2D platform game where the player has to collect three keys and defeat the ultimate opponent.

1. INTRODUCTION

Since the time of the mass market entry, computer games have been used as an advertising tool. In the 1980s, they were based on modifications of available games and served to entertain a small, limited group of people. In those days, product placement in computer games was limited by technological possibilities. However, over time, the attractiveness of games, their quantity, the graphic possibilities have improved and the

* Finance and Management Faculty of Economics, University of Szczecin, Szczecin, Poland, konrad.biercewicz@usz.edu.pl, mariusz.borawski@usz.edu.pl, anna.borawska@usz.edu.pl, jaroslaw.duda@usz.edu.pl

number of players around the world has increased, which has attracted potential advertisers. Initially, computer games were aimed mainly at computer enthusiasts, but now they have become a mass product, aimed at different types of players, in different age ranges, with different interests. A breakthrough product that changed the player's profile was The Sims, launched in 2000, which attracted women and girls. This has opened up a new space for advertising activities (*Lokowanie produktów w grach komputerowych – Prawo własności intelektualnej*, b.d.).

In 2015, profits from game advertising alone amounted to $2.75 billion. Profits are expected to increase to $5.05 trillion in 2020. (Statista, 2017). We distinguish two groups of promotion tools that can be used in computer games (Gałuszka, 2016):

- IGA (in-game advertising) means using the game as an advertising medium;
- Advergaming (advertising + games) are advertising games created specifically to advertise a particular product or service.

There are different ways of using the game as a means of advertising. The easiest way is to place advertising billboards. In 3D games, advertising billboards are placed according to the same rules as in the real world. An example is the 2008 advertising campaign of President Barack Obama, which used 18 games, including Need for Speed: Carbon. In the game, the player drives a car and the presidential candidate's ads are displayed on large billboards along the road (Yenigun, 2012).

Advergaming, on the other hand, is a custom-made game that aims to advertise certain goods or services. In 2006 Burger King launched the Sneak King game created by Blitz Games. The game was sold with a meal at a special price of 3.99$. In total, three games were created, which were not well received by critics, but generated huge revenues. They made a significant contribution to the company's sales growth. The main character of the game was the royal toy Burger King, and his task was to deliver burgers to hungry people (Hyman, 2007).

The discussed ways of presenting content in games also apply to social campaigns. Advergaming is a more common method used because among the benefits of this approach we can mention (The motion monkey, 2017):

- combining advertising and entertainment,
- interactivity – the recipient of an advertising message is a participant, not a passive viewer,
- creating positive associations,
- long life of the computer game (compared to standard advertising).

Besides, it is important that all the elements in the game are associated with the goal of the campaign. As a result, the recipient can memorize most of the presented material in a shorter time. An example of such a game created for a social campaign is Food Force. It was published by the UN World Food Programme (WFP) in 2006. Players take part in hunger prevention missions. In this way, they learn about the problems associated with hunger and WFP activities (United Nations World Food Programme, 2017).

A campaign does not always have to involve spectacular ventures like the Food Force game – sometimes even a small element, if well prepared, can make a difference. Regardless of the scale of the actions taken, the overriding goal of each campaign is to change attitudes or behaviour among its recipients. To achieve this goal, it is extremely important to prepare the visual identification of the campaign. One of the important elements of such identification

may be the campaign emblem – a simple image (sign or graphic), clearly linked to the promoted views or behaviours, which will be easy to remember. This method is used in in-game advertising.

Therefore, in the case of the in-game advertising method, it is necessary to place static ads appropriately and the player should reach such a level of commitment to the game that he plays it for as long as possible. Playing the game longer will give us a higher probability that social advertising will be noticed and thus remembered. The situation is similar in the case of TV commercials - once displayed, an advertisement will be remembered by a handful of people, but if it is repeated several dozen times, the number of recipients who will remember it will increase. What matters in the game is "its life expectancy". The number of views of the advertisement depends on the player's engagement, because the more the player gets involved, the longer he plays it, and consequently, the longer he plays it, the more often he watches the advertisement (Hofman-Kohlmeyer, 2017). The second aspect is the location of advertising (Gałuszka, 2016). It should be placed in such a way that it is well visible and at the same time does not affect the game. Besides, social campaign placement in the game attracts attention and makes the virtual space closer to reality - the game is more realistic (Kiedy reklama flirtuje z gamingiem..., 2015). The research presented in the article concerns the player's engagement, while the second problem concerning the placement of advertisements requires separate research.

1.1. Measuring Engagement

Player engagement is one of the dimensions of gaming experience and can be associated with many concepts, such as (Filsecker & Kerres, 2014; Schoenau-Fog, 2011): flow (Chen, 2007; Csikszentmihalyi, 1990), gameflow (Sweetser & Wyeth, 2005), presence (Lombard & Ditton, 1997; Tamborini & Skalski, 2006), immersion (Brown & Cairns, 2004; Jennett et al.., 2008; Mcmahan, 2003), pleasure (Costello & Edmonds, 2009), motivation (Iacovides et al., 2011; Przybylski, Scott Rigby & Ryan, 2010; Yee, 2006), enjoyment (Ijsselsteijn et al., 2008), arousal (Ravaja et al., 2006) and fun (Koster & Wright, 2004). Therefore, for the recipient to feel as many positive emotions as possible, it is necessary to maintain the player's commitment and concentration at a certain level, e.g. by introducing unexpected action phrases that will encourage him to continue exploring further areas of the game. First of all, to assess whether the game does not discourage the participant, it is necessary to conduct research on the participant's engagement in the game. Also, the growing community of video players creates demand among game developers or researchers for examining player engagement.

It may seem that evaluating a player's engagement in a video game is quite an easy task. We can think that, because there are ready-made tools on the market, such as Unity Analytics (Unity - Analytics, b.d.) and Game Analytics (GameAnalytics, b.d.), that analyze players behaviour. Thanks to them we are able to monitor, among others:

- Onboarding – whether players use mechanisms such as tutorials or initial levels?
- Progression – whether players pass the game levels?
- Economics – does the game economy work as expected?
- Design accuracy – does the designed game work the right way?
- Application accuracy – are all areas of the application used as expected? Are there elements that players ignore or do not notice?
- Earnings – are the strategies for making money optimal?

However, they are not able to check in real-time e.g. what the player is looking at and what emotions accompany him.

It is necessary to look for such methods of engagement research that will allow determining the level of engagement at any time in the game, while not being dependent on other factors. This would be possible with the use of cognitive neuroscience techniques. They are becoming more and more useful because they allow us to get to know the current state of the brain. This task is facilitated by the indexes calculated based on the recorded signals. In the literature on the subject, numerous indices of engagement can be found, which will be presented later in this chapter. They allow us to know the level of human engagement in a given activity in a given moment.

New developments in Brain-Computer Interfaces (BCI) using wireless electroencephalographic systems (EEG) provide recording and access to neuronal activity, enabling the computer to retrieve and analyse information from brain waves. It has been demonstrated that EEG has the ability to determine the engagement of the user. The frequency bands are determined from the EEG signal using the spectral method. Besides, the EEG can be used to change the game scenario for the player (Hondrou & Caridakis, 2012). For example, the detection of boredom will cause changes in the game to make it more challenging whereas the detection of anxiety will cause the game to slow down or decrease the levels of difficulty.

Using the EEG and eye tracker device we can determine the preferences of the player, as well as the moment of the game which is not very interesting, and we can improve it to make the player fully active in the game. New EEG devices are increasingly being used outside of medicine and are finding more and more new applications.

1.2. Related works

Using the EEG to measure the commitment of tasks is not a new concept. Pope (Pope, Bogart & Bartolome, 1995) built a system to control the level of automation of tasks based on whether the operator had increased or decreased his engagement. Freeman (Freeman et al., 1999) extended this system by evaluating the performance of each task with the use of absolute values of commitment. Berk (Berka et al., 2007) has invented a more accurate and effective method for people to interact with technology, with the ability to develop more productive work environments that increase motivation and productivity. The results suggest that the commitment measured using the EEG reflects information gathering, visual processing, and attention allocation. Smith and Gevins (Smith & Gevins, 2005) used a flight simulator to study the reactions of the human brain to low, medium, and high difficulty exercises. Studies have shown increased activity of the frontal lobe waves together with decreased activity of parietal lobe alpha waves during demanding tasks. In turn, Yamada (Yamada, 1998) measured the activity of theta waves along with blinking of the eye and discovered that children playing video games had higher activity of theta waves during more frequent blinking. These results suggest that interesting tasks cause higher activity of theta waves, while the task inhibits the activity of blinking eyes. Kamzanova (Kamzanova et al., 2011) compared the sensitivity of a series of EEG engagement indices by examining time pressure individuals performing tasks of varying degrees of stress to determine which one was most effective. McMahan (McMahan, Parberry & Parsons, 2015) investigated in Super Meat Boy game whether there is a connection between engagement and arousal in events of death and general entertainment. The results of their research suggest that by combining engagement data with arousal data, we can establish

thresholds indicating when a player has left the flow state. On the other hand, Ewing (Ewing, Fairclough & Gilleade, 2016) investigated the sensitivity of EEG power in the (front) theta and (parietal) alpha bands to changing levels of demand for play. Besides, he also conducted a study that assessed the adaptive performance of Tetris in terms of system behavior and user experience. Vourvopoulos's (Vourvopoulos i in., 2017) research focuses on the impact of how gaming experience has on modulating brain activity, as an attempt to systematically identify elements that contribute to high BCI control and that can be used in the design of a neurogame.

The above-mentioned research (McMahan, Parberry & Parsons, 2015; Vourvopoulos et al., 2017) is examining player engagement, but it focuses on topics related to dependencies or BCI. Therefore, the article attempts to solve the following problems:

- to examine which elements in the game should be modified on the basis of the developed method based on the engagement index
- whether placing banners next to engaging elements affects their memorization

The aim of the article is to present the developed method to determine the degree of player's engagement in particular elements in the game using the EEG (engagement indexes) and to explore the relationship between the visibility (an Eye Tracker was used to check visibility) of social advertising and engagement in a 2D platform game where the player has to collect three keys and defeat the ultimate opponent. This will allow determining at which obstacles the advertisement was more memorable and what should be improved in the game so that the player can spend more time in it.

2. MATERIALS AND METHODS

The experiment was attended by 32 people, but only 28 people joined the main survey. Four people were not taken into account because the specified target group had to be mainly occasional players and those who liked 2D platform games. The results of survey are presented in Tab. 1. In addition, respondents had to list three things that they like in playing games (story – about 70%, collecting items – about 40%), and also whether they like 2D platform games – everyone answered positively.

Tab. 1. Results of the survey

Question	Answers	Number of people
How often do you play computer games?	Every weekend	8
	Occasionally	7
	Rarely	13
What player would you describe yourself?	Commonly known gamer	3
	Reactional player	25
What's your preference for the way you play?	Single Player	21
	Multiplayer	7

2.1. Description of game

The game was downloaded from the Unity Asset Store ("2D Game Kit") (2D Platformer - Asset Store, b.d.) and adapted for testing in the Unity engine. Before the start of the game, there were instructions on how to move (using arrows or WASD and key space for jumping) and on the goal that need to be achieved, i.e. three keys had to be collected, which guaranteed the entrance to the room where the last opponent was located, the so-called the boss (Fig. 1).

Fig. 1. A screenshot of the game showing the fight with the boss

In addition, the game also features emblems that show the various real situations to be prevented (see

Tab. ***2***). The emblems were in the background, so the player did not have to avoid them. They were used in the experiment because often in computer games, due to the resolution of the graphics, very complex advertisements are not clear enough to be noticed properly (Chang et al., 2010; Yang et al., 2006). There are also social campaigns, using simple symbols to promote their activities (Rubin, b.d.).

The purpose of the emblems' placement is to examine whether such signs in a typical game are noticeable and whether this type of advertising is effective for use in a social campaign.

Tab. 2. Description of signs

Name of sign	Emblem	Description
Pregnant woman		Prohibition of drinking alcohol during pregnancy
Key		No driving on alcohol
Alcohol		Prohibition of drinking alcohol
Stop		Shows the inability to drive under the influence of alcohol
Bottle		Ban on drinking alcohol
Syringe		Ban on using drugs
Tap		Ban on drinking tap water
Drug		Ban on using drugs
Key2		Prohibiting drinking when driving
Selfie		Prohibiting taking pictures

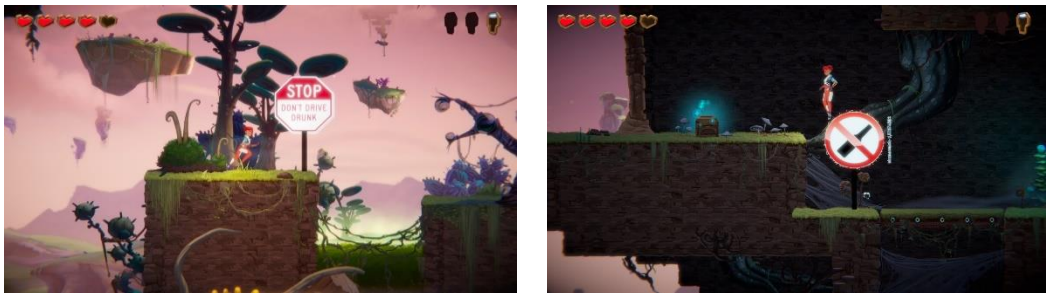
On the first level (Zone 1) there is a sign – “pregnant woman” (Fig. 2) when moving on to the next level.

Fig. 2. Social advertisements on level 1 – Zone 1

On the second level, there are two graphic emblems (Fig. 3): the "key" and "alcohol" – at the doorway to the last level of Zone5 where the boss is waiting to be defeated. You have to collect three keys to getting there. Each key collected is followed by a close-up on the door.

Fig. 3. Social advertisements on level 2 – Zone2

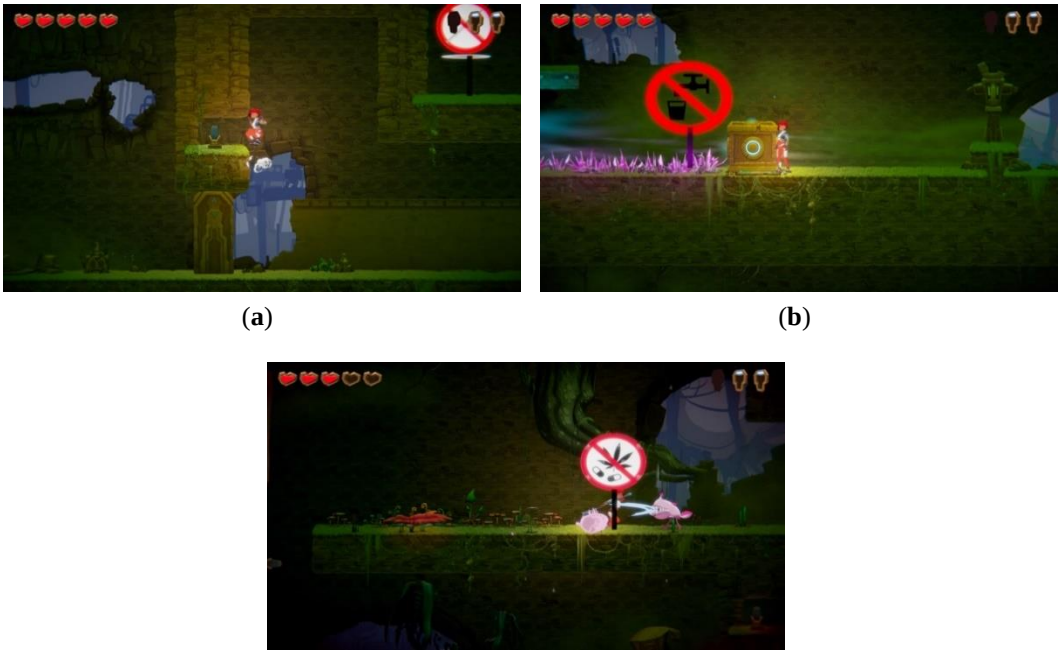
On the third level, there are two signs – "stop" and "bottle" (Fig. 4) – the first one (a) was located near water and the second one (b) near column destruction.



(**a**) (**b**)

Fig. 4. Social advertisements on level 3 – Zone 3

On the fourth level, there are three graphics (Fig. 5). The first one – "syringe" was placed in a safe place when opening the door (a), the second – "tap" in the danger of spikes (b), and the third – "drug" when fighting the Chomper monsters (c).



(**a**) (**b**)

(c)

Fig. 5. Social advertisements on level 4 – Zone4

Two prohibitions have been placed on the last level – "selfie" and "key2" immediately after entering the level (Fig. 6).

Fig. 6. Social advertisements on level 5 – Zone5

2.2. Test procedure of the experiment

EEG data were collected from 28 healthy people (4=female, 24=male), the average age was 23 years. The persons were informed about the course of the examination. They then signed their consent to participate in the study and were seated in a comfortable chair with access to the keyboard and mouse. The next step was to put on the cap and connect the electrodes to the participant's scalp and connect them to the data recorder of the participant's brain.

The cap (g.Nautilus Research Wearable EEG Headset) with 24 electrodes placed in AF3, AF4, F3, F4, F7, F8, FC5, FC6, P7, P8, T7, T8, O1, O2, P3, C3, C4, Pz, Fz, Cz, FPz, Fp1 P4, POz, and 3 reference electrodes: AFz, FCz, CPz was used (see: Fig. 7). The channels have been distributed according to the 10–10 system, the international EEG electrode distribution system (Jurcak, Tsuzuki & Dan, 2007). The electrodes required a dampened socket to improve conductivity. In order to check whether the EEG electrodes are in good contact with the scalp, impedance values were measured with the g.Recorder program. The sampling frequency was 500 Hz.

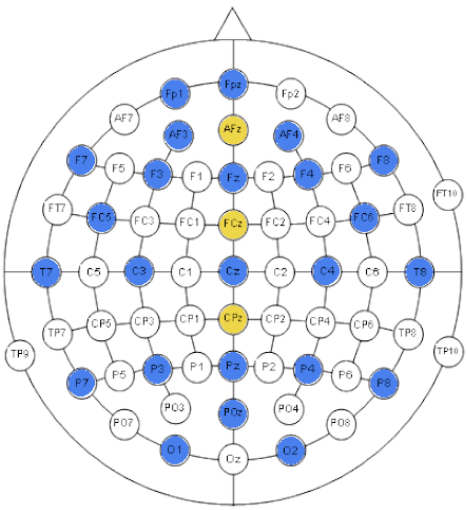


Fig. 7. Sensor location on headsets

After the above steps have been taken, a study was started. Before the game, there was information shown what the game will be about, its goal, and how to move around. Then, after clicking the “Play” button, a black screen appeared, lasting 60 seconds, during which the participant silenced himself (see: Fig. 8). The recorded signals during the play were used to calculate the EEG indicators. On the basis of the respondent's engagement, concentration, and response (in relation to the game and the remembered ads), a comparison of responses and indicators was made. This made it possible to create a pattern based on engagement, more precisely specifying the relationship between engagement for a given element and the engagement that accompanied the whole level. The difficulty in defeating monsters or obstacles) in the game needs to be improved to keep the engagement in the game at a certain level. Also, it made it possible to investigate which social advertisements have been remembered and whether this is related to engagement. the effectiveness of social advertising placed.

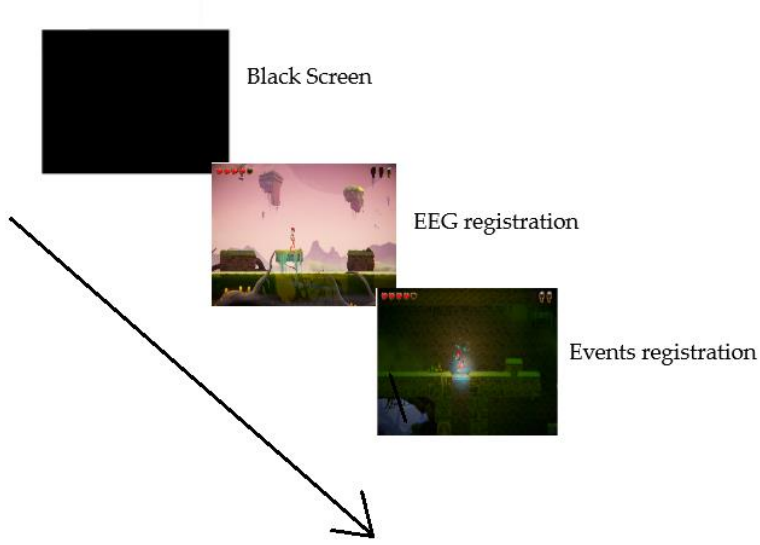


Fig. 8. Chronological order of events while playing a computer game

Each participant's game was recorded at a resolution of 1920×1080 using programmed in-game registration. During the game, screenshots were taken at a frequency of 3 shots per seconds. Each screenshot generated a timestamp for the EEG data to determine the start and end position of each section. Screenshots were saved for later use during the data analysis phase. In addition to the EEG, the study used the Eye Tracker (Eyetribe eye-tracker with a frequency of 30 points per second) to track image elements that were particularly important to the respondent.

2.3. Game survey

After the game was finished, an interview was conducted about the impressions of playing the game, which stage in the game was the hardest, which elements should be improved, what was the engagement during the levels and the fight. The last questions focused on remembering the social advertisements emblems.

2.4. Measures

Measuring the level of engagement and memory of a player is one of the elements determining their experience while playing a computer game. In particular, it can be used to determine player preferences. For this purpose, the relevant indicators have been calculated, as indicated in Tab. 3. These indices were selected for the study because they were used by their developers to study player engagement in computer games or simulations. They were then normalized against the reference image - the black screen, and the spider that appeared on the screen.

Tab. 3. Description of the indices used in the test

Index number	Formula	Counting method
Index 1 (McMahan et al., 2015)	Beta-3 / (Alpha-2 + Theta)	Average registration value of all electrodes on the head.
Index 2 (McMahan et al., 2015)	Theta / Alpha-2	Average registration value from electrodes placed on the frontal lobe of Theta and parietal lobe of Alpha.
Index 3 (McMahan et al., 2015)	Theta	The average value of registration from electrodes placed on the frontal lobe of Theta.
Index 4 (Kamzanova et al., 2011)	Beta-4 / (Alpha-3 + Theta)	Average registration value from electrodes: F3, F4, F7, F8, Cz, P3, Pz, P4.
Index 5 (Kamzanova et al., 2011)	Beta-5 / (Alpha-4 + Theta)	Average registration value from electrodes: F3, F4, F7, F8, Cz, P3, Pz, P4.
Index 6 (Chaouachi & Frasson, 2012)	Beta-6 / (Alpha-5 + Theta)	Average registration value from electrodes: P3, C3, Pz, Fz, Cz, FPz.
Index 7 (Lee et al., 2010)	(SMR + Mid Beta) / Theta	Power index from electrode Fp1.

3. RESULTS

All data were analysed using Matlab R2019a. The analysis of the EEG signal started with filtering the bandwidth removing the disturbances of the power network, i.e. frequencies above 50 Hz. In addition, the signal was detrended and filtered using the Fieldtrip library. The EEG spectral signal was then analysed using a Morse wave, which calculated an average peak frequency of half a second in a frame (Lilly & Olhede, 2010, 2012; Wachowiak et al., 2018). However, in order to calculate the Alpha, Beta and Theta frequencies, the signal has been divided into appropriate bands (Tsipouras, 2019), see Tab. 4.

Tab. 4. Representation of frequency bands Alpha, Beta, Theta

Bandwidth	Frequency [Hz]
theta	4–8
alpha2	7–13
alpha3	8–13
alpha4	8–10.9
alpha5	11–13.9
SMR	12–15
Mid beta	15–20
beta3	13–25
beta4	13–22
beta5	14–19.9
beta6	20–29.9

The next step was to analyse the variance to see if there is a significant difference between player engagement and concentration. The ANOVA statistical test was used for this purpose. The engagement was divided into seven subgroups - Index1, Index2, up to Index7. This creates different conditions and allows to use repeated ANOVA. The results of repeated ANOVA measurements using the indicator as an object factor for the general concentration-dependent variable showed a significant difference between the engagement indices ($F(6,580)=18.37$; $p= 1.42*10^{-19}$; $p < 0.05$). The Turkey-Kramer statistical test was used to investigate between them. The test showed that there is a statistically significant difference between all groups (Tab. 5).

Tab. 5. Results of Tukey-Kramer statistical test

Index Number	Index Number	Lower limit for the 95% confidence interval of the true difference in average	The difference between the estimated averages	Upper limit for the 95% confidence interval of the true difference in average	Value of p
1	7	0.1234	0.2980	0.4725	1.0058e-05
2	7	0.1755	0.3501	0.5247	1.0565e-07
3	7	0.0637	0.2383	0.4129	0.0011
4	7	0.1498	0.3244	0.4989	9.2470e-07
5	7	0.3331	0.5077	0.6822	3.7064e-08
6	7	0.3635	0.5380	0.7126	3.7064e-08

In addition, it was examined whether there is a dependence of the commitment on concentration (

Tab. **A1**), using the CHI-Squared independence test. The analysis showed six engagement indices that there is no relationship between engagement and concentration (Tab. 6). The statistical value for each index is greater than the value of the Chi-Squared distribution for 4 degrees of freedom, which is $\chi_4^2 = 9{,}48773$.

Tab. 6. Results of the CHI-Squared statistical test.

Index	Statistical value CHI Square	Number of degrees of freedom
Index1	150,0472	4
Index2	142,0259	4
Index3	130,8962	4
Index4	126,3576	4
Index5	121,7529	4
Index6	152,8122	4

The results obtained from the analysis made it possible to create a formula (1), which is based on the engagement index

$$Assessment\ of\ the\ element = \frac{Engagement\ to\ the\ element}{Number\ of\ events} * \frac{1}{Engagement\ at\ a\ given\ level} \quad (1)$$

First, the player's level of engagement with the item in the game is determined. The result is then divided by the amount of engagement that accompanies the test person at a given level of the game in order to determine what was the average engagement at that particular moment. And finally, it was divided by the number of occurrences of a given element. This resulted in an average engagement for a particular element in the game. Taking into account whether the engagement level is low/medium/high (as will be determined later in the article), we can determine whether a given element in a 2D platform game should be corrected or removed.

Then, appropriate thresholds for low, medium and high levels of engagement (the breakdown that was used in Tables 7 to 14) were determined for each of the engagement indices. The intervals were calculated as follows:

1. The 10th and 90th percentile have been calculated for the engagement observed for each player at Zone1, Zone3, Zone4 and Zone5 levels.
2. The arithmetic mean was determined for all players from the results obtained in step 1.
3. For each level (Zone1, Zone3, Zone4 and Zone5) the difference between the 90th percentile and the 10th percentile has been calculated.
4. The obtained range was divided into 3 in order to obtain three ranges – for low, medium and high engagement

Zone2 level was not included in the calculation because there were no obstacles or enemies – it was the so-called interim.

Formula created and calculated thresholds (**Błąd! Nie można odnaleźć źródła odwołania.**) of the engagement at a given level allowed for the evaluation of the following elements in the game:

- Moving Platform moving up and down, sideways, with spikes (Tab. C1). In most cases, the indices indicate average engagement. Index4 is the most distinct.
- Spikes - a static object, the hero loses his life if he enters it (
- Tab. **C2**). All the indices are consistent and indicate the average engagement when spike-bypassing players.
- Destruction of the column - a static column which, after being destroyed, leads to the next stage in the game (Tab. **C3**). Only Index2 indicates low exposures during the destruction of the column, the others indicate medium.
- Moving a box - moving an item triggers an action in the game, e. g. closure of the water gap (Tab. C4). Index4 indicates low engagement when moving the box, others indicate medium.
- Standing in a designated place causing the platform to move (
-). As with moving a box, only Index4 indicates low engagement when standing on a platform that is moving.
- Attack from "gun" – Key Down O (Tab. **C6**). Nearly all the indices indicate average engagement on shooting. The exception is the Zone4 and Index4 level, where it indicates high engagement.
- Attack by monsters – Boss (
- Tab. **C7**), Chomper, Spritter (
- Tab. **C8**). The indices for the attack by regular Chomper show mainly high level of engagement, while for Spritter mainly medium level. Referring to the last opponent, the so called "Boss" – you can see that attacking by Ball is at a medium level, Light at a high level, while Throwgranade is hard to say.

The final stage was to examine the visibility and memory of the social campaign's emblems placed in the game. For this purpose, the number of times an average person looked at a banner was calculated (Tab. 7). For the analysis of this objective, the eye-tracker and Matlab software were used, with the following scheme:

1. The eyesight of the test person was traced using EyeTracker.
2. File in txt format was generated, containing the viewing coordinates x, y and time unit
3. The Matlab program analyzed where:
   a. first of all, the emblem was found in every screenshot,
   b. secondly, within the designated area, it was calculated how many times the person looked and how much time person spent looking at the sign.

This made it possible to determine which location for the emblem in the game is the best and how much time it takes to remember the social campaign (Tab. 7), as well as whether we pay more attention to banner ads in case of greater engagement. This shows that most people noticed the emblem representing a pregnant woman – 25 people and the average time of looking at the advertisement was 2 seconds.

Tab. 7. Average time of looking at the sign.

Name of the advertisement	Average number of glances at the emblem	Average time of glances at the emblem	How many people have seen the sign on the basis of the survey	Level	How many people have reached the level
Pregnant woman	72	2,311378	25	Zone1	28
Key	27	0,879667	14	Zone2	28
Alcohol	13,73077	0,44902	10	Zone2	28
Stop	17,23077	0,565488	12	Zone3	28
Bottle	16,80769	0,527995	17	Zone3	28
Syringe	2,538462	0,081886	10	Zone4	22
Tap	47,26923	1,539069	20	Zone4	22
Drag	9,692308	0,323447	11	Zone4	22
Selfie	2,576923	0,08306	5	Zone5	9
Key2	5,153846	0,173572	13	Zone5	9

In addition, the memorization rate (Tab. 8) was calculated by dividing the number of people who saw the mark by the total number of participants in the study (see: formula (2)).

$$Memorable = \frac{Number\ of\ people\ seen\ the\ sign\ on\ the\ bassi\ of\ the\ survey}{28} \quad (2)$$

Tab. 8. Emblem memorization rate expressed as a percentage

Name of the advertisement	Memorization rate
Pregnant woman	89%
Key	50%
Alcohol	36%
Stop	43%
Bottle	61%
Syringe	36%
Tap	71%
Drag	39%
Selfie	18%
Key2	46%

4. DISCUSSION

The main aim of the study was to develop a method to determine the degree of player engagement in the individual elements of the game. In addition, additional objectives have been achieved, among which we can mention:

- to investigate which obstacles to social advertising have been more memorable,
- indication which elements in the game should be corrected.

It was helpful to create a formula (1) to evaluate the elements in the game and to determine which index should be used on the basis of comparing the results obtained with the opinion of the respondents. The constructed formula is based only on the engagement itself, because examining the engagement ratio for a given element to the engagement that is at a given level allows to determine whether a given element contributes significantly to the player's engagement. As a result, we have the answer as to whether we should correct or remove an item in the game. The ratio itself, by mathematical definition, is the quotient of one value to another, which is intended to indicate the identity or relative size difference of the two quantities. Therefore, the formula created seems to be quite good enough in mathematical as well as functional terms, as will be discussed later in this chapter.

Matlab software and survey data were used for analysis. As a result, the engagement in elements such as up-and-down, sideways, spiked moving platforms, for which Index4 should be used (Tab. C1,

Tab. **C2**), was assessed, as it is the only one reflecting the correct opinions according to the respondents. Interestingly, the only biggest difficulty in the game for people participating in the survey was jumping from platform to platform. The low engagement turned out to be the case with PushableBox, PreasurePad and Column Destruction. And these elements should certainly be improved, or their placement limited because there were too many of them - PushableBox and PreasurePad. For these two elements Index4 (Tab. C4,

), should be used for the assessment and for Column Destruction Index2 (

Tab. **C3**). In the game, it was the only item that had to be destroyed and it did not cause any difficulties, as evidenced by the commitment obtained. It seems that this element should be removed and not corrected, because some of the people surveyed about 40% were wrong in this case or wasted time because they did not know if they could destroy it. For the remaining elements, it was not clearly indicated which Index should be used, and this is the case for an object with a medium level of engagement (

Tab. **C2**) – all Indexes indicated this way. A similar situation is for the attacking monsters - Chomper, Spritter (

Tab. **C8**) and the final opponent, the so-called final boss (Tab. **C7**), who attacks with different powers. And the same is true to indicate which method of fighting is the best - even or with firearms. According to the respondents, the melee fight was better than shooting, but the engagement in both cases was the same, i. e. average, as shown by the formulated formula. From the results, it is not possible to determine which index should be used for this purpose, because in case of melee combat all indexes fit, and for shooting all but 4.

Referring to the results of social advertising, it was found that most people, because almost 90% of the respondents remembered the sign on which the pregnant woman was placed. The reason for this is to place the sign when jumping from platform to platform when, as confirmed by the survey, the player's engagement was high. In addition, from the platform where the sign was located, the next level was moved to the next level, which could also affect the memory. Moreover, the average time of looking at the sign was 2 seconds, which could also be relevant. In addition, the majority of respondents, i.e. 70% remembered the sign showing the ban on using drinking tap water, which was in the place where you jumped on the platform to avoid spikes. It can be assumed that the combination of medium engagement in the case of a spike element in the game and high for a moving platform helps to remember social advertising. On the other hand, the characters located on the horizontal Zone2, which was a transition level, were remembered by 43% of people on average. It would seem that there will be many more because each time the key is lifted, there is a close-up on the door and the graphic emblems next to it. This fact may also be influenced by the short time of looking at the advertisements, but also by the lack of action at this level. Least people, because only 5 remembered the sign representing the ban on taking pictures. He was at the door on the last level. This is because only 9 people have reached this level. On the other hand, 13 people indicated an advertisement with a ban on driving under the influence of alcohol on Zone5, which is apparently not true, but this may be due to the fact that a fairly similar sign was placed at the door, but on Zone2 level. Low memorization efficiency is also for a sign representing drugs at Zone4 level. Probably because the monsters absorbed more attention than the sign in the background that didn't stand out.

5. CONCLUSIONS

The results of research aimed at evaluating the elements in the game are presented, and at which we obtain greater memory of graphic emblems. In this achievement, it was decided to create an appropriate pattern based on the player's commitment. Then, on the basis of the opinions, the optimal Index4 for moving and static objects and Index2 for destruction were selected, as they best represent the opinion of the respondents.

It should be taken into account that these findings are based on one type of game and that further research will be needed to extend the results of the methodological approach to assessing which elements in the game need to be improved and at which ads need to be placed, not only by analysing the player's engagement but also by adding further indicators from other categories, such as emotions. However, these results support the view that Index 2 and 4 can be judged to be the best index to illustrate these elements in the game and for a high level of commitment, ads should be placed on the item to be remembered. Additionally, graphic emblems depicting social campaigns should be placed in a place where other activities such as fighting will not distract attention, everyone will be able to reach the level where the last placed advertisement is and the graphics of each advertisement should stand out from the others. As a result, we will get a better result for remembering among the respondents.

Conclusions on graphic emblems should be understood in the context of certain constraints. This is due to the fact that not all respondents have reached the final level and therefore the analysis is in some cases based on low sample size. At this point, a formula

was created for evaluating in-game elements based on the player's engagement and it was checked which index should be used for moving elements, static objects, and when destroying objects. The next step will be to prepare a revised game to establish the reliability of the selected Index in order to ensure that current performance is not an anomaly due to the current number of people who have reached a given level.

Author Contributions

K.B.: Conceptualization, software, validation, formal analysis, writing–original draft preparation, writing–review and editing; M.B, A.B.: Conceptualization, methodology, writing–review and editing, supervision; J.D.: software, validation, visualization. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

REFERENCES

2D Platformer—Asset Store. (b.d.). *Unity Asset Store*. Retrieved September 2, 2019 from https://assetstore.unity.com/packages/essentials/tutorial-projects/2d-platformer-11228

Berka, C., Levendowski, D. J., Lumicao, M. N., Yau, A., Davis, G., Zivkovic, V. T., Olmstead, R. E., Tremoulet, P. D., & Craven, P. L. (2007). EEG correlates of task engagement and mental workload in vigilance, learning, and memory tasks. *Aviation, Space, and Environmental Medicine*, *78*(5 Suppl), B231–244.

Brown, E., & Cairns, P. (2004). A Grounded Investigation of Game Immersion. *CHI '04 Extended Abstracts on Human Factors in Computing Systems* (pp. 1297–1300). The ACM Digital Library. https://doi.org/10.1145/985921.986048

Chang, Y., Yan, J., Zhang, J., & Luo, J. (2010). Online In-Game Advertising Effect: Examining the Influence of a Match Between Games and Advertising. *Journal of Interactive Advertising*, *11*, 63–73. https://doi.org/10.1080/15252019.2010.10722178

Chaouachi, M., & Frasson, C. (2012). Mental Workload, Engagement and Emotions: An Exploratory Study for Intelligent Tutoring Systems. *Intelligent Tutoring Systems. ITS 2012. Lecture Notes in Computer Science* (vol 7315). Springer Heidelberg. https://doi.org/10.1007/978-3-642-30950-2_9

Chen, J. (2007). Flow in Games (and Everything else). *Commun. ACM*, *50*(4), 31–34. https://doi.org/10.1145/1232743.1232769

Costello, B., & Edmonds, E. (2009). A Tool for Characterizing the Experience of Play. *Proceedings of the Sixth Australasian Conference on Interactive Entertainment*, *2*, 1–10. https://doi.org/10.1145/1746050.1746052

Csikszentmihalyi, M. (1990). *Flow: The Psychology of Optimal Experience*. Harper Perennial Modern Classics.

Ewing, K. C., Fairclough, S. H., & Gilleade, K. (2016). Evaluation of an Adaptive Game that Uses EEG Measures Validated during the Design Process as Inputs to a Biocybernetic Loop. *Frontiers in Human Neuroscience*, *10*, 223–223. https://doi.org/10.3389/fnhum.2016.00223

Filsecker, M., & Kerres, M. (2014). Engagement as a Volitional Construct: A Framework for Evidence-Based Research on Educational Games. *Simulation & Gaming*, *45*(4–5), 450–470. https://doi.org/10.1177/1046878114553569

Freeman, F. G., Mikulka, P. J., Prinzel, L. J., & Scerbo, M. W. (1999). Evaluation of an adaptive automation system using three EEG indices with a visual tracking task. *Biological Psychology*, *50*(1), 61–76.

Gałuszka, D. (2016). Nowy wymiar reklamy-in-game advertising oraz advergaming. *Kultura i Historia*, *29*, 33–49.

GameAnalytics. (n.d.). *GameAnalytics*. Retrieved April 5, 2020 from https://gameanalytics.com/

Hofman-Kohlmeyer, M. (2017). Komunikacja marketingowa w grach komputerowych—Współczesne kierunki badań. *Studia Ekonomiczne*, *328*, 70–82.

Hondrou, C., & Caridakis, G. (2012). Affective, Natural Interaction Using EEG: Sensors, Application and Future Directions. W I. Maglogiannis, V. Plagianakos, & I. Vlahavas (Eds.), *Artificial Intelligence: Theories and Applications* (s. 331–338). Springer Berlin Heidelberg.

Hyman, P. (2007). *Burger King has it their way with advergame sales*. Hollywood Report.

Iacovides, I., Aczel, J., Scanlon, E., Taylor, J., & Woods, W. (2011). Motivation, Engagement and Learning through Digital Games. *IJVPLE*, *2*, 1–16. https://doi.org/10.4018/jvple.2011040101

Ijsselsteijn, W., van den Hoogen, W., Klimmt, C., De Kort, Y., Lindley, C., Mathiak, K., Poels, K., Ravaja, N., Turpeinen, M., & Vorderer, P. (2008). Measuring the experience of digital game enjoyment. *Proceedings of Measuring Behavior* (pp. 88–89). Noldus.

Jennett, C., Cox, A. L., Cairns, P., Dhoparee, S., Epps, A., Tijs, T., & Walton, A. (2008). Measuring and defining the experience of immersion in games. *International Journal of Human-Computer Studies*, *66*(9), 641–661. https://doi.org/10.1016/j.ijhcs.2008.04.004

Jurcak, V., Tsuzuki, D., & Dan, I. (2007). 10/20, 10/10, and 10/5 systems revisited: Their validity as relative head-surface-based positioning systems. *NeuroImage*, *34*(4), 1600–1611. https://doi.org/10.1016/j.neuroimage.2006.09.024

Kamzanova, A. T., Matthews, G., Kustubayeva, A. M., & Jakupov, S. M. (2011). EEG indices to time-on-task effects and to a workload manipulation (Cueing). *World Academy of Science, Engineering and Technology*, *80*, 19–22.

Kiedy reklama flirtuje z gamingiem... (2015, March 20). *Marketer+ przewodnik po marketingu*. https://marketerplus.pl/teksty/artykuly/reklama-flirtuje-gamingiem/

Koster, R., & Wright, W. (2004). *A Theory of Fun for Game Design*. Paraglyph Press.

Lee, C., Kwon, J., Hong, J., & Lee, D. (2010). *A Study on EEG based Concentration Power Index Transmission and Brain Computer Interface Application* (s. 537–539). Springer. https://doi.org/10.1007/978-3-642-03882-2_142

Lilly, J. M., & Olhede, S. C. (2010). On the Analytic Wavelet Transform. *IEEE Transactions on Information Theory*, *56*(8), 4135–4156. https://doi.org/10.1109/TIT.2010.2050935

Lilly, J. M., & Olhede, S. C. (2012). Generalized Morse Wavelets as a Superfamily of Analytic Wavelets. *IEEE Transactions on Signal Processing*, *60*(11), 6036-6041. https://doi.org/10.1109/TSP.2012.2210890

Lokowanie produktów w grach komputerowych—Prawo własności intelektualnej. (b.d.). Retrieved April 3, 2020 from https://www.pwi.us.edu.pl/kategorie/prawo-reklamy/253-lokowanie-produktow-w-grach-komputerowych?jjj=1586621566826&jjj=1586626966769

Lombard, M., & Ditton, T. (1997). At the heart of it all: The concept of presence. *Journal of Computer-Mediated Communication*, *3*(2).

Mcmahan, A. (2003). Immersion, engagement, and presence: A method for analyzing 3-D video games. *The Video Game Theory Reader* (pp. 67–86). Routledge, Taylor & Francis Group.

McMahan, T., Parberry, I., & Parsons, T. D. (2015). Evaluating Player Task Engagement and Arousal Using Electroencephalography. *Procedia Manufacturing*, *3*, 2303–2310. https://doi.org/10.1016/j.promfg.2015.07.376

Pope, A. T., Bogart, E. H., & Bartolome, D. S. (1995). Biocybernetic system evaluates indices of operator engagement in automated task. *Biological Psychology*, *40*(1–2), 187–195. https://doi.org/10.1016/0301-0511(95)05116-3

Przybylski, A. K., Scott Rigby, C., & Ryan, R. (2010). A Motivational Model of Video Game Engagement. *Review of General Psychology*, *14*, 154–166. https://doi.org/10.1037/a0019440

Ravaja, N., Saari, T., Salminen, M., Laarni, J., & Kallinen, K. (2006). Phasic Emotional Reactions to Video Game Events: A Psychophysiological Investigation. *Media Psychology*, *8*(4), 343–367. https://doi.org/10.1207/s1532785xmep0804_2

Rubin, B. (b.d.). *Policies & Programs to Reduce Distracted Driving*. Retrieved September 9, 2020 from https://www.government-fleet.com/156182/policies-programs-to-reduce-distracted-driving

Schoenau-Fog, H. (2011). The player engagement process—An exploration of continuation desire in digital games. *Proceedings of DiGRA 2011 Conference: Think Design Play*.

Smith, M., & Gevins, A. (2005). Neurophysiologic monitoring of mental workload and fatigue during operation of a flight simulator. *Proceedings of SPIE - The International Society for Optical Engineering* (5797). Society of Photo-Optical Instrumentation Engineers. https://doi.org/10.1117/12.602181

Statista. (2017). *Video games advertising spending worldwide from 2010 to 2020 (in billion U.S. dollars)*. https://www.statista.com/statistics/238140/global-video-games-advertising-revenue/

Sweetser, P., & Wyeth, P. (2005). GameFlow: A Model for Evaluating Player Enjoyment in Games. *Computers in Entertainment*, *3*(3), 3–3. https://doi.org/10.1145/1077246.1077253

Tamborini, R., & Skalski, P. (2006). The role of presence in the experience of electronic games. *Playing video games: Motives, responses, and consequences* (pp. 225–240). Lawrence Erlbaum Associates Publishers.

The motion monkey. (2017). *UK Advergame Design & Development*. https://www.themotionmonkey.co.uk/advergames/

Tsipouras, M. G. (2019). Spectral information of EEG signals with respect to epilepsy classification. *EURASIP Journal on Advances in Signal Processing*, *2019*(1), 10. https://doi.org/10.1186/s13634-019-0606-8

United Nations World Food Programme. (2017). *Food Force*. https://web.archive.org/web/20050605073447/http://www.food-force.com/

Unity—Analytics. (b.d.). *Unity*. Retrieved April 5, 2020 from https://unity3d.com/unity/features/analytics

Vourvopoulos, A., Bermudez, I., Badia, S., & Liarokapis, F. (2017). EEG Correlates of Video Game Experience and User Profile in Motor-imagery-based Brain—Computer Interaction. *The Visual Computer*, *33*(4), 533–546. https://doi.org/10.1007/s00371-016-1304-2

Wachowiak, M., Smolikova-Wachowiak, R., Johnson, M., Hay, D., Power, K., & Williams-Bell, F. (2018). Quantitative feature analysis of continuous analytic wavelet transforms of electrocardiography and electromyography. *Philosophical Transactions of The Royal Society A Mathematical Physical and Engineering Sciences*, *376*, 20170250. https://doi.org/10.1098/rsta.2017.0250

Yamada, F. (1998). Frontal midline theta rhythm and eyeblinking activity during a VDT task and a video game: Useful tools for psychophysiology in ergonomics. *Ergonomics*, *41*(5), 678–688. https://doi.org/10.1080/001401398186847

Yang, M., Ewoldsen, D., Dinu, L., & Arpan, L. (2006). The Effectiveness of „in-Game" Advertising: Comparing College Students' Explicit and Implicit Memory for Brand Names. *Journal of Advertising*, *35*, 143–152. https://doi.org/10.2753/JOA0091-3367350410

Yee, N. (2006). Motivations for play in online games. *Cyberpsychology & Behavior : The Impact of the Internet, Multimedia and Virtual Reality on Behavior and Society*, *9*(6), 772–775. https://doi.org/10.1089/cpb.2006.9.772

Yenigun, S. (2012). *Presidential Campaigns Rock The Gamer Vote: NPR*. https://www.npr.org/2012/10/01/162103528/presidential-campaigns-rock-the-gamer-vote?t=1582567815999

Appendix A

Tab. A1 Distribution of engagement by the group

Index1

		Low	Medium	High
		<= -0,64	(-0,64; -0,02]	> -0,02
High	> 0,69	0	1	7
Medium	(-0,17; 0,69]	4	33	5
Low	<= -0,17	5	25	3

Index2

		Low	Medium	High
		<= -0,64	(-0,64; -0,02]	> -0,02
High	> 0,34	0	6	12
Medium	(-0,33; 0,34]	4	48	3
Low	<= -0,33	5	5	0

Index3

		Low	Medium	High
		<= -0,64	(-0,64; -0,02]	> -0,02
High	> 0,34	0	4	9
Medium	(-0,34; 34]	3	46	6
Low	<= 0,34	6	9	0

Index4

		Low	Medium	High
		<= -0,64	(-0,64; -0,02]	> -0,02
High	> 0,23	0	11	6
Medium	(-0,27; 0,23]	5	41	9
Low	<= -0,27	4	7	0

Index5

		Low	Medium	High
		<= -0,64	(-0,64; -0,02]	> -0,02
High	> 0,53	7	4	1
Medium	(0,06; 0,53]	2	40	4
Low	<= 0,06	0	15	10

Index6

		Low	Medium	High
		<= -0,64	(-0,64; -0,02]	> -0,02
High	> 0,65	8	0	1
Medium	(0,08; 0,65]	1	49	2
Low	<= 0,08	0	10	12

Appendix B

Tab. B1 Distrubution of engagement by level in game

Zone1

	Index1	Index2	Index3	Index4	Index5	Index6
High	> 0,35	> 0,39	> 0,35	> 0,38	> 0,69	> 0,70
Medium	(-0,45; 0,35]	(-0,42; 0,39]	(-0,47; 0,35]	(-0,41; 0,38]	(-0,16; 0,69]	(-0,14; 0,70]
Low	<= -0,45	<= -0,42	<= -0,47	<= -0,41	<= -0,16	<= -0,14

Zone3

	Index1	Index2	Index3	Index4	Index5	Index6
High	> 0,38	> 0,46	> 0,35	> 0,39	> 0,70	> 0,68
Medium	(-0,40; 0,38]	(-0,36; 0,46]	(-0,44; 0,35]	(-0,38; 0,39]	(-0,13; 0,7]	(-0,10; 0,68]
Low	<= -0,40	<= -0,36	<= -0,44	<= -0,38	<= -0,13	<= -0,10

Zone4

	Index1	Index2	Index3	Index4	Index5	Index6
High	> 0,43	> 0,46	> 0,36	> 0,45	> 0,76	> 0,71
Medium	(-0,32; 0,43]	(-0,33; 0,46]	(-0,45; 0,36]	(-0,35; 0,45]	(-0,10; 0,76]	(-0,11; 0,71]
Low	<= -0,32	<= -0,33	<= -0,45	<= -0,35	<= -0,10	<= -0,11

Zone5

	Index1	Index2	Index3	Index4	Index5	Index6
High	> 0,64	> 0,62	> 0,56	> 0,51	> 0,90	> 0,75
Medium	(-0,08; 0,64]	(-0,14; 0,62]	(-0,27; 0,56]	(-0,20; 0,51]	(0,0012; 0,90]	(-0,08; 0,75]
Low	<= -0,08	<= -0,14	<= -0,27	<= -0,20	<= 0,0012	<= -0,08

Appendix C

Tab. C1 Assessment of engagement for the Moving Platform

	MovingPlatform			
	Zone1	**Zone3**	**Zone 4**	**Zone5**
Index1	high	medium	medium	medium
Index2	high	medium	medium	medium
Index3	średnie	medium	medium	medium
Index4	high	high	low	medium
Index5	medium	medium	medium	medium
Index6	medium	medium	medium	medium

Zone4		
	MovinPlatform – sideways	**MovingPlatform with spikes**
Index1	medium	medium
Index2	medium	high
Index3	medium	medium
Index4	medium	high
Index5	medium	medium
Index6	medium	medium

Tab. C2 Assessment of engagement for the Spikes

Zone4	
	Spikes
Index1	medium
Index2	medium
Index3	medium
Index4	medium
Index5	medium
Index6	medium

Tab. C3 Assessment of engagement for the destruction of the column

Zone1	
	CollisionEnter – DestructibleColumn_Whole
Index1	medium
Index2	low
Index3	medium
Index4	medium
Index5	medium
Index6	medium

Tab. C4 Assessment of engagement for PushableBox

Zone4	
	PushableBox
Index1	medium
Index2	medium
Index3	medium
Index4	low
Index5	medium
Index6	medium

Tab. C5 Assessment of engagement for PreasurePad

Zone4	
	PreasurePad
Index1	medium
Index2	medium
Index3	medium
Index4	low
Index5	medium
Index6	medium

Tab. C6 Assessment of engagement for attack from the gun

	KeyDown – O		
	Zone3	**Zone4**	**Zone5**
Index1	medium	medium	medium
Index2	medium	medium	medium
Index3	medium	medium	medium
Index4	medium	high	medium
Index5	medium	medium	medium
Index6	medium	medium	medium

Tab. C7 Assessment of engagement when the monsters Boss attacked

	Zone5 – Boss		
	Ball	**Ligh**	**Throwgrandae**
Index1	medium	high	high
Index2	medium	high	high
Index3	medium	high	medium
Index4	medium	high	high
Index5	medium	high	medium
Index6	medium	high	high

Tab. C8 Assessment of engagement when the monsters Chomper, Spritter attacked

	Attack Chomper		Attack Spritter
	Zone3	**Zone4**	**Zone4**
Index1	high	high	medium
Index2	high	high	medium
Index3	low	low	medium
Index4	high	low	low
Index5	high	high	medium
Index6	high	high	medium