Investigation on Player and Virtual Environment Interaction

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Abstract. The paper introduces an investigation on player and virtual environment interaction. A computer game (spaceship navigation through randomly flying asteroids) with different levels of difficulty was created in order to elicit and test human emotions when playing. Emotional responses (excitement, frustration, and engagement/boredom) to the computer game were recorded using Emotiv Epoc device. Spaceship manoeuvring speed and acceleration were included in the investigation as well. Significant relationships between some of the personality traits, emotional reactions and manoeuvring characteristics were found. Emotional responses were significantly increasing when the density of asteroids was increasing. Excitement and frustration signals showed correlations when gaming. Significant increase in manoeuvring speed and acceleration were observed after spaceship and asteroid collision. Positive correlations were found between extraversion and excitement during experiment. The gaming experience and manoeuvring acceleration was strongly negatively related when the difficulty of the game was lower and strongly positively related when it was higher.

Keywords: Virtual environment · Computer game · Emotions · Personality · Player's affective state

1 Introduction

Computer games became a common form of entertainment, so they are expected to generate emotional involvement, excitement and motor or cognitive challenges. Game developers spend a great deal of effort trying to create technology that would be able to create this rich experience. However this task is harder than it sounds, because a player is not just a blank table that mechanically responds to provided stimulations. Decision to play or not to play, preference for certain game genre, response to game appearance, visual and auditory stimulations, persistence of play, reactions to challenges and fails depend on many individual factors like previous game and life experience or personality traits. Research findings support an idea that we play the way we are. For example, study of Wohn and Wash [1] show that observer could identify personality traits of the player by simply looking at a screenshot of created virtual

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environment. In another study, persistence during game play predicted person's persistence in other life tasks, such as learning [2].

On the other hand computer games are also not passive. They create new reality and offer opportunities for players to meet their needs [3]. The more game corresponds with the needs of the player, the more motivated he or she is to play. Findings of Tone et al. [4] show that certain characteristics of games may even cause player to become addicted.

Thus, as Khong and Thwaits [5] state, video games constitute a genre of software that involves interface and user experiences, it makes sense that it should be studied from the perspective of Human-Computer Interaction (HCI). Looking from the perspective of game developers, knowledge about HCI might help to develop responsive technologies that will be able to adapt to player needs. From the psychological perspective a comprehensive knowledge about interaction between player characteristics and game features is needed for a better understanding of the process of game play and its impacts on users [6].

There are quite a lot of different studies done in the field of computer games and affective states of a player using various means to evaluate them. Shaker et al. [7] investigate self-reflected player experiences (engagement, challenge and frustration) and player movements when playing Super Mario Bros computer game, but the affective states of the players are not measured from bio-signals in real time. Holmgard et al. [8] describe a study where a computer game is dedicated to help people with post traumatic stress disorder. A player is given different stressful situations (usually caused by previous experiences in a war) and his skin conductance is measured to objectively evaluate his stress level during a game in real time. Gutica and Conati [9] present a research where students were playing educational mathematical game and their emotions were observed and evaluated by judges. The improved mathematical skills correlated to the observed emotional states as engaged concentration. Chanel et al. [10] describe a Tetris game study when player's affective state is evaluated according to physiological signals as electro-dermal activity, blood volume pulse, skin temperature, and chest cavity expansion. The purpose is to keep a player engaged and regulate the level of game complexity according to the changes of the player's affective state – to decrease difficulty if a player becomes anxious and to increase it if a player is bored. Some studies propose affective models or game engines [12,13] for collaborative virtual environment games. Pröll [13] examines Emotiv Epoc device for various gaming purposes.

This research is dedicated to investigate the relationship between player personality traits, emotional (EEG-based) response to a computer game when playing, and user manoeuvring characteristics (speed and acceleration) during a game. A computer game was created for this purpose and Emotiv Epoc device was used to measure emotional reactions (excitement, frustration and engagement/boredom).

2 Virtual Environment – "Spaceship" Computer Game

A virtual environment (computer game) with different levels of intensity was created to investigate its influence on player's emotions and behaviour, and game play experience relations with personality traits.

A player controls a spaceship using keyboard buttons (left, right, up, and down) and tries not to collide with asteroids that are flying to the spaceship. The principle of a game is shown in Fig. 1.

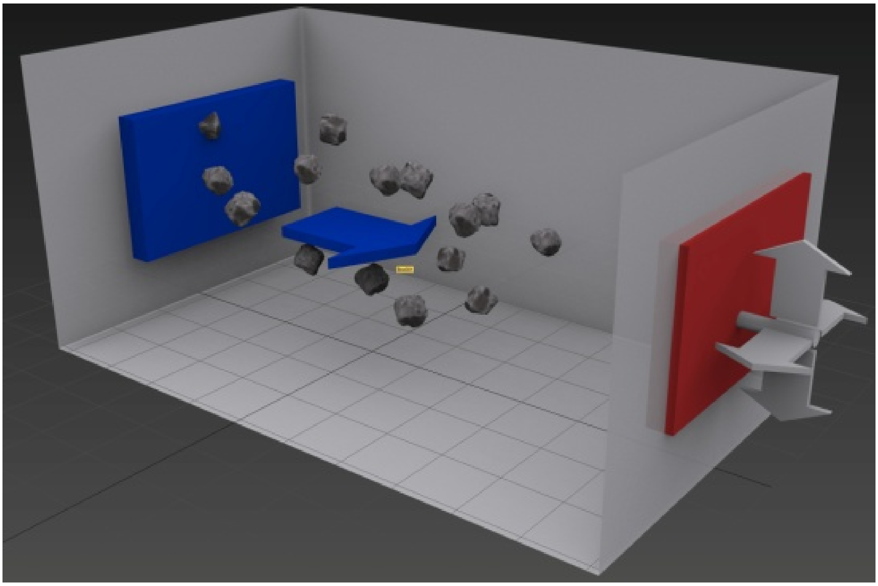

Fig. 1. Randomly generated asteroids flying to the spaceship

The generator of the asteroids is programmed so that the asteroids are randomly generated in a limited rectangle area (Fig. 1, back rectangle) and can appear in any point of the rectangle with the same probability. In this way a dispersion of the asteroids on the screen is created and they are spread in the whole space area. The generated asteroids are of different sizes within the predefined size limits. The asteroids fly in the same velocity but their number differs in different phases of a game. When the asteroids reach the front (monitor) plane, they are invisibly destroyed to avoid "wondering" asteroids and accidental collisions. If an asteroid is not destroyed, it can begin flying back after reaching the front plane.

The distance between the plane where asteroids are generated and the front plane, where they are invisibly destroyed is more than ten seconds long if evaluating it by the speed of an asteroid. The generated asteroid becomes visible to a player 4-5 s later after the generation. After it becomes visible it reaches the possible collision (with a spaceship) plane in 6-7 s and a few more seconds are needed to reach the front plane where they are invisibly destroyed. The spaceship is not situated on the front plane; it is placed on a potential collision plane and is all visible to the player. It is important to note that if an approaching asteroid is in the centre and the spaceship is in the centre at that moment, it is not possible to avoid a collision two seconds before the potential collision. In order to elicit stronger emotional reaction to a collision of a spaceship and an asteroid visual (fire) and audible (strong crash sound) effects are produced.

Fig. 2 and Fig. 3 demonstrate two scenes and situations of a game.

Fig. 2. Asteroids flying to the spaceship without a collision

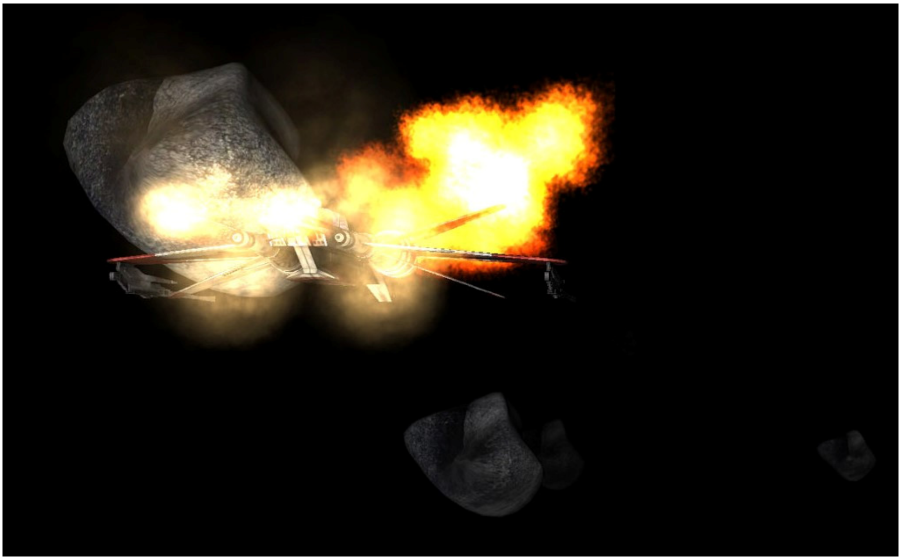

Fig. 3. A collision of a spaceship and an asteroid (with visual fire effect)

Fig. 2 illustrates asteroids flying to the spaceship without a collision (the spaceship leaves a smoke band behind it) and Fig. 3 shows a collision of a spaceship and an asteroid when a fire visual effect is present together with a collision sound. However the spaceship is not visually affected after a collision and the game is continued.

Game simulator was created using Unity 3D engine and C# programming language. A PC with i7 processor 8 GB RAM and Nvidia GeForce 8600 GT video card was used. The computer game was played using full HD 65” diameter monitor (screen resolution 1920x1080), and surround 5.1 sound system.

3 Experiment and Data

3.1 Sample

15 university students (nine (60.0%) males, six (40.0%) females, age M=22.9 (1.3), range 21-26) participated in the study. Ten (66.7%) participants reported that they play computer games regularly, every day. Other participants reported playing computer games from several times a week to several times a year. There were no participants who had no gaming experience. Average hours per week spent gaming was 12.5 (11.8) and ranged from 0 to 35. All the participants preferred using their personal computer for gaming (19 (100%)), one (6.7%) participant also used mobile phone as gaming platform in his daily life. Participants mention playing almost all game genres: strategy – 9 (60.0%), RPG – 8 (53.3%), MMO – 7 (46.7%), simulations – 3 (20.0%), action – 2 (13.3%), other – 3 (20.0%).

3.2 Psychological Tests and Data Collection

Several aspects of personality, sensation seeking and Big Five personality traits, were measured in this study.

Sensation seeking was evaluated using Sensation Seeking Scale – form V (SSS-V, [14], Lithuanian translation by Pranckevičienė, Ružas, 2012). Reliability of the SSS-V was acceptable for the data analysis (Cronbach α = .77). The SSS-V score addresses extent to which participants are drawn towards feelings and experiences that are novel, varied, thrilling, possibly risky and intense. Trait of sensation seeking is related to low tolerance of routine and boredom. Previous research shows that sensation seeking might be related to players emotional response and playing behaviour. In Fang and Zhao [6] study sensation seeking had significant positive effect on enjoyment of computer game play. Sensation seeking is found to be a good predictor of high or even pathological involvement in online games [15].

Big Five personality traits were evaluated using The Big Five Inventory (BFI; [16,17,18], Lithuanian translation by Vytautas Magnus university, Psychology Department, 2009). Reliability of all BFI scales was acceptable for the data analysis (Cronbach α ranged from .65 to .88). BFI measures five core personality dimensions: extraversion vs. introversion, agreeableness vs. antagonism, conscientiousness vs. lack of direction, neuroticism vs. emotional stability, openness vs. closeness to experience. Big Five personality traits are often analyzed in relationship with gaming behaviour [19,20].

Participants were also asked about frequency of computer game play, hours per week spent playing, types of the games played and game platforms used.

After the experiment participants were asked to subjectively evaluate their general emotional state, satisfaction with their performance during the game play and to express their opinion about game characteristics.

3.3 Stages of the Experiment

At first the whole procedure of the experiment was explained in details to the volunteer and if he or she did not want to participate in the experiment, it was possible not to take part in it. Before the beginning of the experiment, a volunteer signed an agreement to participate in the experiment and to let using his or her data in the study.

The experiment started with psychological tests that were described in 3.2. A volunteer was given as much time as he or she needed to fill the tests. He or she was also asked to choose a nickname and to use it in the tests instead of his or her real name to assure confidentiality of the data. The same nicknames were used later during a game play to strengthen the impression of a usual computer game.

After the tests were completed the Emotiv Epoc device that records EEG inputs from 14 channels (according to international 10-20 locations: AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, AF4) [21] was put on the head of the volunteer, making sure that all the contacts are in the right places and properly attached to the skin. The computer game was started when the bio-signals were steady.

The environment of the experiment aimed to create a cosy home type atmosphere. A volunteer was sitting on a sofa-bed and the play was performed on a large screen monitor in the special laboratory for virtual reality experiments. The game was controlled by a wireless keyboard. At the same time only a volunteer and a person responsible for the experiment was in the room. The lights were off to minimise any possible visual distraction.

The computer game had several intensity stages. At first one minute was given for getting used to the game environment. Only one asteroid in ten seconds was generated. The second phase was more intense and one asteroid in two seconds was generated in the next four minutes. The third stage was the most intense and aimed to cause stressful situations for the volunteer. Two asteroids in one second were generated for five minutes. The last phase that lasted one and a half minute was aimed for relaxing and again only one asteroid in ten seconds was generated.

After the computer game, the volunteers were asked to reflect their emotional state after the game play and to report their impressions of various game characteristics as quality, ease of game control, as well as frustration level induced by background, sound, speed, density of asteroids, smoke, explosions, and video discrepancies.

3.4 Emotional and Game-play Data Processing

During the experiment three pre-processed emotional signals – excitement, frustration and engagement/boredom – were recorded using Emotiv Epoc device. Values of the three signals varied from zero to one. If excitement, frustration and engagement were low, the value was close to zero and if they were high, the values of parameters were close to one. The signals were recorded with the sampling period of T_0=0.5 s.

The coordinates of a spaceship two times per second and the exact time of the collision were recorded as well. Two derivative parameters were calculated and added after the experiment. Using the coordinates of the spaceship, manoeuvring speed and acceleration of a spaceship were calculated and later used in the statistical analysis.

SPSS 13.0 software was used for statistical analysis. Nonparametric correlations and criteria for two related samples comparison were used because of the small sample size. Matlab software was used for processing the required data for later statistical analysis.

Relations between personality traits, gaming experience, emotional signals and spaceship manoeuvring speed as well as acceleration were calculated using the data from the second (two asteroids per second were generated) and the third (ten asteroids per second were generated) stage of the game.

There was more specific analysis performed, using excitement, frustration, and spaceship manoeuvring speed and acceleration signal intervals of 14.5 s around the collision action (seven seconds before the collision and seven seconds after the collision). Interval of seven seconds before the collision was chosen as an asteroid becomes visible on the monitor screen six-seven seconds before the possible collision. The same length interval was taken after the collision as the reaction time to visual and audible stimuli for every person is different.

These intervals were selected from each volunteer data, but the statistical analysis was performed for the whole group at once. Only single collisions in the selected intervals were analysed. There were lots of cases where several collisions were present in the 14.5 s length interval, but they were not taken into the analysis as there is a need of larger amounts of data for more complex analysis.

Fig. 4 shows all the single intervals of frustration signal around the collision for one of the volunteers in the experiment Stage II. Vertical dotted lines denote the collision moment and the time is set to zero at this point. Fig. 5 shows all the single intervals of frustration signal around the collision for the same volunteer in the experiment Stage III. It can be seen from the figures that the signals behave differently. To analyse the data in detail the intervals of 14.5 s around the collision were divided into three smaller intervals. The first sub-interval included signal values from -7 s to -2.5 s before the collision; the second sub-interval included the values from -2 s to 1.5 s – the close collision environment and the third included values from 2 s to 7 s after a collision. Such sub-intervals were selected based on the fact that the collision starts to become unavoidable 2 s before a collision and taking into account that it takes some time for the sound and visual collision effects to disappear. Maximal values from each sub-interval were calculated for excitement, frustration, manoeuvring speed, and acceleration signals to analyse the changes in the sub-intervals that is to investigate if there are significant changes in the signals before the collision, during it and after it. Engagement/boredom signals were not analysed this way as they did not vary in the vicinity of the collisions.

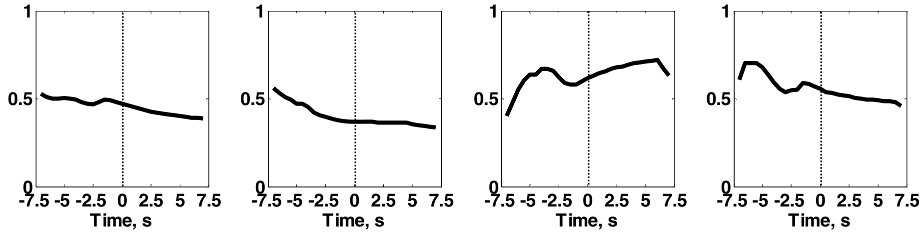

Fig. 4. Samples of frustration signal around the collision in the experiment stage 2. Vertical dotted lines denote the collision moment.

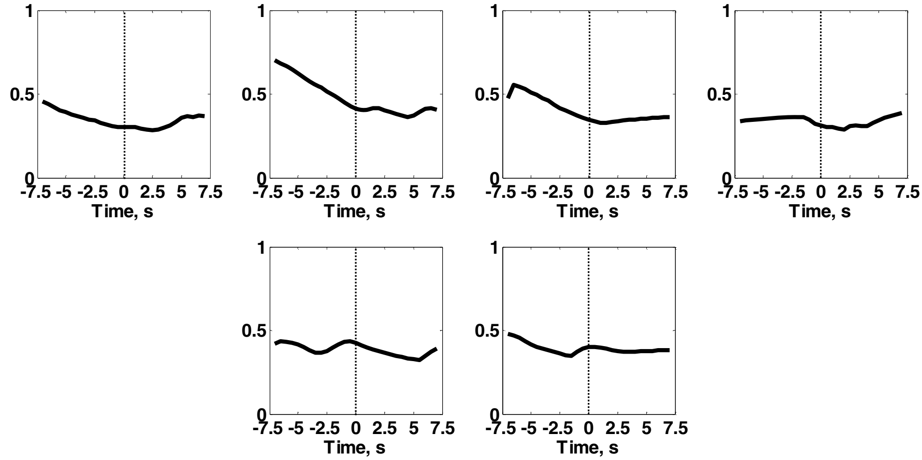

Fig. 5. Samples of frustration signal around the collision in the experiment stage 3. Vertical dotted lines denote the collision moment.

4 Results

4.1 Impact of Computer Game on Player

Emotional signals of the players during different computer game stages (with different asteroid generation frequency) were compared. Sub-intervals of spaceship-asteroid collisions environment were investigated when emotional signals as well as spaceship manoeuvring speed and acceleration were taken into account.

Significant changes in frustration and engagement were registered between Stage II and Stage III of the computer game (Table 1). At Stage II frustration increased while boredom decreased. A statistical tendency observed that excitement also increased ant Stage III. At Stage III manoeuvring speed was faster, but no significant changes in manoeuvring acceleration were observed.

Table 1. Changes in excitement, frustration, engagement, manoeuvring speed and acceleration during the experiment. Wilcoxon Signed Ranks Test.

Stage of the experiment (III-II)		N	Mean rank	Z	p
excitement III - excitement II	Negative Ranks	4	7.50	-1.70	0.09
	Positive Ranks	11	8.18		
frustration III - frustrationII	Negative Ranks	3	7.00	-2.22	0.03
	Positive Ranks	12	8.25		
engagement III - engagement II	Negative Ranks	13	8.38	-2.78	0.01
	Positive Ranks	2	5.50		
speed III – speed II	Negative Ranks	5	6.20	-1.65	0.10
	Positive Ranks	10	8.90		
acceleration III - acceleration II	Negative Ranks	7	7.86	-0.28	0.78
	Positive Ranks	8	8.13		

The test for the sub-intervals of collision interval in excitement signal showed that there are significant change between sub-interval 1 and sub-interval 3 (Table 2). Excitement signal is increasing more often than decreasing after spaceship collision with an asteroid (comparing pre-collision and post-collision sub-intervals).

Table 2. Changes in excitement in collision interval when evaluating their sub-intervals. Wilcoxon Signed Ranks Test.

Excitement		N	Mean rank	Z	p
sub-interval 3 – sub-interval 1	Negative Ranks	39	49.77	-3.551	<0.000
	Positive Ranks	73	60.10		
	Ties	3	-		
sub-interval 2 – sub-interval 1	Negative Ranks	65	56.30	-1.258	0.209
	Positive Ranks	48	57.95		
	Ties	2	-		

The test for the sub-intervals of collision interval in frustration signal showed that there are significant change between sub-interval 1 and sub-interval 2 (Table 3). Frustration signal is decreasing more often than increasing if comparing the pre-collision and collision sub-intervals.

Table 3. Changes in frustration in collision interval when evaluating their subintervals. Wilcoxon Signed Ranks Test.

Frustration		N	Mean rank	Z	p
sub-interval 3 – sub-interval 1	Negative Ranks	60	54.43	-0.03	0.97
	Positive Ranks	54	60.92		
	Ties	1	-		
sub-interval 2 – sub-interval 1	Negative Ranks	77	60.48	-4.33	<0.00
	Positive Ranks	35	47.74		
	Ties	3	-		

Table 4. Changes in manoeuvring speed in collision intervals when evaluating their sub-intervals. Wilcoxon Signed Ranks Test.

Speed		N	Mean rank	Z	p
	Negative Ranks	48	61.99		
sub-interval 2 – sub-interval 1	Positive Ranks	65	53.32	-0.702	0.483
	Ties	2	-		
	Negative Ranks	39	59.74		
sub-interval 3 – sub-interval 1	Positive Ranks	71	53.17	-2.155	0.031
	Ties	5			

Analysis of speed and acceleration changes in subintervals before and after collision revealed, that significant increase in speed is observed after collision (sub-interval 3) comparing with speed before collision (sub-interval 1) (Table 4)

Changes in acceleration in three collision sub-intervals more frequently resembled U-shape form: acceleration decreased in sub-interval 2 comparing with sub-interval 1, and increased again in sub-interval 3 comparing with sub-interval 1 (Table 5).

Table 5. Changes in acceleration in collision intervals when evaluating their subintervals. Wilcoxon Signed Ranks Test.

Acceleration		N	Mean rank	Z	p
sub-interval 3 – sub-interval 1	Negative Ranks	68	62.76	-2.604	0.009
	Positive Ranks	47	51.11		
sub-interval 2 – sub-interval 1	Negative Ranks	43	61.53	-1.923	0.055
	Positive Ranks	72	55.89		

The comparison of excitement, speed and acceleration sub-intervals showed negative correlations between some sub-intervals of the signals (Table 6). Post-collision sub-intervals of excitement signal correlate with all three speed sub-intervals.

Table 6. Relationship between excitement and speed and acceleration. Spearman rho.

	Speed			Acceleration		
Excitement	Sub-interval 1	Sub-interval 2	Sub-interval 3	Sub-interval 1	Sub-interval 2	Sub-interval 3
Sub-interval 1	-0,010	-0,091	-0,123	-0,105	0,111	0,075
Sub-interval 2	-0,045	-0,123	-0,121	-0,143	0,138	0,096
Sub-interval 3	-0,217**	-0,246***	-0,205**	-0,066	0,158	0,053

**Correlation is significant at p<0.05, (2-tailed)

***Correlation is significant at p<0.01, (2-tailed)

The comparison of frustration, manoeuvring speed and acceleration sub-intervals showed positive correlations between pre-collision and collision sub-intervals of frustration and collision sub-interval of speed as well as pre-collision sub-intervals of acceleration signals (Table 7).

Table 7. Relationship between frustration and manoeuvring speed and acceleration. Spearman rho.

	Speed			Acceleration		
Frustration	Sub-interval 1	Sub-interval 2	Sub-interval 3	Sub-interval 1	Sub-interval 2	Sub-interval 3
Sub-interval 1	0,127	0,194**	0,151	0,243***	0,169	0,025
Sub-interval 2	0,118	0,196**	0,167	0,213**	0,166	0,094
Sub-interval 3	0,009	0,111	0,034	0,141	0,162	0,023

**Correlation is significant at p<0.05, (2-tailed)

***Correlation is significant at p<0.01, (2-tailed)

4.2 Player's Contribution to Gaming Experience

Relationships between personality traits and gaming experience as well as emotional signals and game properties (manoeuvring speed and acceleration) in different stages of the game were investigated.

Statistical analysis revealed that personality traits were not significantly related to frequency of computer game play, but correlated with hours per week spent gaming (Table 8). More expressed trait of neuroticism correlated with more gaming hours per week, while negative relationship was observed between more expressed sensation seeking, extraversions, agreeableness and conscientiousness.

Table 8. Relationship between personality traits and involvement in computer gaming. Spearman rho.

	Involvement in computer games	
Personality traits	Frequency	Hours per week
Sensation seeking	-0.08	-0.52**
Extraversion	-0.21	-0.47*
Agreeableness	-0.12	-0.54**
Conscientiousness	-0.22	-0.51**
Neuroticism	-0.04	0.55**
Openness	-0.37	-0.24

*Correlation is significant at p<0.1, (2-tailed)

** Correlation is significant at p<0.05, (2-tailed)

As can be seen in Table 9 extraversion positively correlated with excitement during all stages of experiment. Observed correlations were relatively strong taking into account small sample size.

Data analysis revealed unexpected results. Openness to new experiences was related to higher levels of frustration during experiment. Contrary to expectations, negative correlation was found between frustration and trait of neuroticism.

No statistically significant relationships were observed between personality traits and Emotic Epoc measures of engagement (Table 10), although some tendencies that are in line with previous research were found: sensation seeking and openness to new experiences correlated positively with higher engagement, while neuroticism showed tendency to be negatively related to engagement.

Table 9. Relationships between personality traits and excitement and frustration. Spearman rho.

	Excitement			Frustration		
Personality traits	Stage I	Stage II	Average	Stage I	Stage II	Average
Sensation seeking	0.07	0.28	0.23	0.35	0.31	0.34
Extraversion	0.68***	0.43	0.50*	0.09	-0.09	-0.06
Agreeableness	-0.03	-0.15	-0.11	0.27	0.35	0.37
Conscientiousness	0.36	0.30	0.33	0.03	0.08	0.06
Neuroticism	0.13	0.11	0.10	-0.37	-0.41	-0.43
Openness	-0.13	-0.19	-0.23	0.49*	0.56**	0.53**

*Correlation is significant at p<0.1, (2-tailed)
**Correlation is significant at p<0.05, (2-tailed)
***Correlation is significant at p<0.01, (2-tailed)

Table 10. Relationship between personality traits and engagement. Spearman rho.

	Engagement		
Personality traits	Stage I	Stage II	Average
Sensation seeking	0.26	0.01	0.35
Extraversion	0.30	-0.22	-0.03
Agreeableness	-0.16	0.08	0.02
Conscientiousness	0.00	0.02	0.10
Neuroticism	0.08	-0.11	-0.25
Openness	0.26	0.08	0.28

Table 11. Relationship between personality and speed during experiment. Spearman rho.

	Speed			Acceleration		
Personality traits	Stage I	Stage II	Average	Stage I	Stage II	Average
Sensation seeking	-0.15	-0.19	-0.12	-0.22	-0.15	-0.22
Extraversion	0.23	0.22	0.17	0.24	0.19	0.59**
Agreeableness	0.00	0.25	0.13	0.01	-0.06	0.08
Conscientiousness	-0.05	0.18	0.03	0.29	0.04	0.51**
Neuroticism	0.23	0.17	0.17	0.31	-0.16	0.08
Openness	0.20	0.03	0.12	0.29	0.46*	-0.04

*Correlation is significant at p<0.1, (2-tailed)
**Correlation is significant at p<0.05, (2-tailed)

No statistically significant correlations were observed between spaceship manoeuvring speed and personality traits (Table 11). However positive correlations between extraversion, conscientiousness and acceleration were found.

Hours per week spent gaming were negatively correlated with excitement during the experiment (Table 12), indicating that more experienced players are less likely to feel satisfaction during computer game, especially when the game is not very challenging. Frequency of computer gaming and hours spent gaming correlated negatively with frustration. These results might indicate that more experienced players feel more comfortable and relaxed even facing new game and user interface and might be used to such forms of stimulation. No relationship was found between computer game experience and engagement during the experiment.

Table 12. Relationship between gaming frequency and excitement. Spearman rho.

Involvement in computer games	Excitement			Frustration		
	Stage I	Stage II	Average	Stage I	Stage II	Average
Frequency	-0.22	0.15	0.00	-0.62**	-0.49*	-0.52**
Hours per week	-0.37	-0.18	-0.28	-0.47*	-0.33	-0.37

*Correlation is significant at p<0.1, (2-tailed)

**Correlation is significant at p<0.05, (2-tailed)

Frequency of computer gaming did not correlate with manoeuvring speed during experiment (Table 13). The more experienced a player was, the less he or she accelerated during non intensive phase of experiment, and were more prone to acceleration during more challenging phase of the game.

Table 13. Relationship between gaming frequency and manoeuvring speed and acceleration. Spearman rho.

Involvement in computer games	Speed			Acceleration		
	Stage I	Stage II	Average	Stage I	Stage II	Average
Frequency	-0.12	0.07	0.01	0.52**	0.63***	0.07
Hours per week	0.18	0.15	0.19	-0.32	0.15	-0.31

**Correlation is significant at p<0.05, (2-tailed)

***Correlation is significant at p<0.01, (2-tailed)

5 Conclusions and Discussion

Emotional responses are changing between the stages of the game when the density of asteroids is increasing. More challenging tasks evoke higher levels of frustration but at the same time generate higher engagement and excitement. Frustration and engagement/boredom signals are changing in larger extent than excitement and spaceship manoeuvring speed signals.

Analysis of changes in emotional responses in sub-intervals before, around, and after collisions with the asteroid supported the idea that collision experience has significant impact of player’s emotional response. Although collision might be considered as negative and unpleasant event, data of this study show increase of excitement after collision. The highest level of frustration was before a collision and it shows tendency to decrease just after a collision. This data supports the idea that excitement and frustration during the game play are correlated phenomena and some level of frustration is needed for game to evoke excitement. Trajectories of changes in frustration an excitement let us speculate, that high frustration before collision is replaced by decrease of the tension just after collision, when player understands that he or she could not change this situation and followed by increased excitement and motivation to play.

Changes in spaceship manoeuvring speed and acceleration in sub-intervals before, around and after collision with the asteroid reflect expected players behaviour – significant increase in speed and acceleration were observed after the collision because they where decreased by the collision incident. However speed and acceleration of the spaceship were related to player's emotional responds as well. Analyzing the pre-collision, collision and post-collision sub-intervals, weak inverse correlations were found between all three subintervals of speed and post-collision subinterval of excitement. Weak direct correlations were found between pre-collision and collision sub-intervals of frustration and collision sub-interval of speed as well as pre-collision subintervals of acceleration. These results indicate that players who experience higher levels of frustration might be linked to higher manoeuvring speed and acceleration during computer game; however this does not directly convert to higher level of excitement. Although small sample size and very simple statistical procedures do not let us draw very strong concussions, these results are in line with Yerkes–Dodson law of optimal emotional arousal [22] indicating that optimal balance between challenge of the task and level of frustration must be found for player to feel excited. This is the place where HCI might make impact. Personality traits were not strongly related with emotional responses to a computer game. The strongest relationship was found between extraversion and excitement. Extraversion was positively related to excitement during experiment. These results are in line with psychological theories because it is known that extraverts are in general more prone to experience positive emotions. Extraversion is found to be related to more frequent technology use [20]. However not all studies find relationship between extraversion and gaming behaviour [23].The study showed that higher neuroticism is related to a lower frustration what contradicts with usual psychological rules, but this result could be explained by a sample of the experiment as the most experienced players had the highest neuroticism scores while the gaming experience had inverse correlation to frustration signals. Positive correlation between neuroticism and hours spent gaming are in line with studies that report positive relationship between expressed neuroticism and game addiction [24]. There were no correlations found between personal characteristics and manoeuvring speed, manoeuvring acceleration was related to consciousness as well as to extraversion.

Although sensation seeking is found to be related to gaming behaviour in other studies [6], [15], this study failed to replicate these results. Contrary to expectations, sensation seeking was negatively related to hours spent gaming and did not correlate with excitement during experiment.

The gaming experience was not statistically significantly related to excitement signal, but there is a tendency that more experienced players experience less excitement and less frustration especially in the second stage of the game (2 asteroids/s are generated). There was no correlation between gaming experience and engagement found. These results support our speculations about importance of frustration-excitement relationship for enjoyment of a computer game. Although more experienced players showed less frustration during the game, their excitement was lower.

The gaming experience and acceleration was strongly negatively related in the second stage of a game and strongly positively related in the third stage of a game. That means that more experienced players accelerated less where the density of asteroids was smaller (two asteroids per second were generated) and accelerated more where the density of the asteroids was larger (ten asteroids per second were generated). These results indicate that more experienced game players get used to certain levels of stimulation and it becomes harder to achieve higher levels of excitement. Small sample size does not let us to perform more precise analysis where various personality traits and level of game experience were controlled. However our data supports the idea that the player contributes to the game experience and personal factors may impact excitement and frustration levels during the game.

Game properties' relations with user's personality traits and physiological signals lead to the development of emotion-oriented adaptive computer games. Objective information about the preferences and reactions of the payers would allow constructing game scenarios of continuous engagement without using excessive elements.

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