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EEG for Assessing Game Experience via Character Identification

***Abstract*— The objective of this paper is to measure objective quantitative aspects of game user experience and examine whether the identification with the character influences game enjoyment. The motivation for this study arises from literature highlighting the connection between character identification and user enjoyment. To investigate this, digital twins of the respondents were generated. The methodology employed in this paper utilized an EEG device as an objective measurement tool, complemented by three subjective questionnaires. The findings revealed a strong correlation between character identification based on appearance, values, and personality, and some EMOTIVE Insight EEG metrics. This paper serves as a pilot study aimed at exploring further objective quantitative measures for game user experience.**

***Key words*—Game user experience, UX, EEG, Objective measuring equipment.**

I. Introduction

Despite their omnipresence, the advances of computer games has transcended conventional perceptions regarding the technological advancements in the field. Currently various games and game engines are offering their users the possibility of making a photorealistic character that can closely mirror any human likeness. In the review paper [1] the conclusion highlighted the potential connection between users identification with in-game characters and the level of overall game enjoyment.

There are two primary objectives of the paper. Firstly, it seeks to present a pilot study, its methodologies and results. Secondly, it aims to create a database of results obtained with both subjective and objective parameters of UX, intended to serve as a resource for forthcoming research endeavors.

Apart from introduction and conclusion, this paper consists of four other sections. In section two, a short theoretical background of the topic is presented. Section three delves into the method of the experiment, outlining all the steps taken in order to create the stimuli and set up the experiment site. Section four, highlights some of the most notable results that were based on the ANOVA analysis as well as some of the strong correlations that occurred. Finally, section five offers a discussion of presented results.

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II. Background

In relation to user experience (UX), there exist multiple approaches when it comes to testing it. One prevalent method of testing UX in websites and applications involves using Jacob Nielsen's Heuristics. The heuristic usability evaluation is wildly regarded for its precision, it tends to find more issues, and what is important it identifies more serious issues despite it being one of the more economically accessible methods [2].

Despite the great value that the heuristic evaluation, together with other methods of testing user experience, such as pluralistic usability walkthroughs, claims analysis, and cognitive walkthroughs [3] bring, it is crucial to emphasize the best application of these methods is in testing the UX of websites. Conversely, when it comes to the UX in computer games other methods were more commonly applied. Currently the user experience questionnaire (UEQ) stands as a prominent counterpart to heuristics in game UX assessment, due to its quick data collection and simplistic approach [4]. Furthermore, researchers have concluded that the UEQ can and should be translated and adjusted to cater the product's (game's) target demographic [5]. A supplementary approach highlighted in relevant literature is the use of standardized psychological tests, such as Self-Assessment Manikin (SAM) questionnaire that in its default state assesses emotional valence (positive-negative or pleasure-dissatisfaction), dominance (control-helplessness) and arousal (activation-deactivation). SAM found its application in game UX due to the three-dimensional emotion model as well as its widespread usage in psychological application [6].

Data gathered using subjective methods, while providing quantitative insights, does not offer a complete understanding of user experience. As a complementary strategy in evaluating user interface systems and the productivity of different computer games, researchers have utilized neurophysiological equipment [7]. Some of the more commonly used neurophysiological devices that possibly identify the measurable components of UX are electromyography (EMG), electrodermal activity (EDA) and galvanic skin response (GSR), electrocardiography (ECG), heart rate (HR), interbeat interval (IBI), electroencephalography (EEG) and functional near infrared spectroscopy (fNIRS) [7].

In this study, the device of interest is EEG, more specifically a consumer grade EEG device. Researchers from diverse disciplines compared different consumer grade EEG devices with medical grade ones. They concluded that, although consumer grade EEGs often exhibit a restricted evaluation range, limited data acquisition as well as a higher sensitivity to interference, especially in the devices that are using dry electrodes, the consumer grade EEGs are suitable for applications beyond medical practice [8]–[10].

III. Stimuli and Methods

In the experimental study, a series of assessments and measurements were conducted in order to investigate the participants' cognitive and emotional responses to audio-visual stimuli, presented in a form of a video clip. In order to collect the data that can be used in the future analysis the following steps were taken:

1. Creating stimuli that can be used for participants without gaming experience, which includes:
   - 1.1. Collecting appropriate sentences from video games.
   - 1.2. Adequate translation of sentences into the Serbian language, paying attention to the number of syllables in each sentence.
   - 1.3. Creating a survey to assess sentiment and excitability of collected sentences, including:
     - 1.3.1. Selecting a target group and conducting the survey.
     - 1.3.2. Analyzing survey results to verify the sentiment and excitability of sentences.
   - 1.4. Selecting sentences (based on the previous analysis) to be used in stimuli based on sentiment, excitability, and the number of syllables.
   - 1.5. Creating audio-visual stimuli, which involves:
     - 1.5.1. Selecting participants and a neutral actor for creating digital character mimics (rig).
     - 1.5.2. Learning and understanding the use of the MetaHuman framework.
     - 1.5.3. Using and understanding photogrammetry tools to obtain 3D scans of participants.
     - 1.5.4. Understanding concepts of, and using the free 3D model manipulation program, Blender.
     - 1.5.5. Familiarizing with basic concepts and using the LiveLink Face application for obtaining participant models and animations of the neutral actor used in the stimuli.
     - 1.5.6. Understanding concepts and using the Unreal Engine 5.2 program for creating MetaHuman characters, processing and adding mimics to characters, and rendering animations with sound (including the use of cameras and lighting in Unreal Engine 5.2).
     - 1.5.7. Understanding and using the MetaHuman Animator browser based application.
     - 1.5.8. Adjusting the audio-visual stimuli so that sentences appear in the optimal order.
     - 1.5.9. Adjusting the audio-visual stimuli so that sentences appear with an optimal spacing for EEG recording.
2. Using and creating the AD ACL (Activation-Deactivation Adjective Check List) test,
   - 2.1. Research for the translation of the test into the Serbian language.
3. Using and creating the SAM (Self-Assessment Manikin) test,
   - 3.1. Research for the translation of the test into the Serbian language.
4. Creating a questionnaire to measure the alignment of objective and subjective results.
5. Organizing and interpreting the results of the AD ACL (Activation-Deactivation Adjective Check List) test.
6. Organizing and interpreting the results of the SAM (Self-Assessment Manikin) test.
7. Organizing and interpreting the results of the questionnaire measuring the alignment of objective and subjective results.
8. Organizing and interpreting the results obtained through EEG monitoring.
9. Statistical analysis of the results of the AD ACL (Activation-Deactivation Adjective Check List) test, SAM (Self-Assessment Manikin) test, questionnaire measuring alignment of objective and subjective results, and results obtained through EEG monitoring,
   - 9.1. Mastery of basic statistical concepts and the use of statistical analysis tools, including the IBM SPSS program.
   - 9.2. Organizing results within the IBM SPSS program, and
   - 9.3. Analyzing results obtained using the IBM SPSS program.

A. Respondents

Five respondents participated in this research. The respondents are employed at the Faculty of Technical Sciences and belong to different age groups. In this research, all five subjects are female, so that only one actress whose facial expressions and voice are used to create the stimuli could be used. All respondents have none or limited experience playing video games and all respondents are native Serbian speakers. The respondents agreed to the declaration of anonymity and were familiar with the conditions of data collection, presentation and storage. All data is stored on the computer under a password and all tests are conducted under the code that was assigned to the subject. Therefore, at no time did the respondents give their first and last name, nor is it connected in any way with the collected data.

B. Experiment

As the first step, the participants took the AD ACL test (The Activation-Deactivation Adjective Check List), which served as an initial cognitive assessment. This assessment provided baseline data on participants' cognitive abilities and affective states before exposure to any experimental stimuli, ensuring that the participants were not influenced by greather external factors before the experiment. The AD ACL is a computerized assessment that measures a range of cognitive functions through a subjective rating of agreement with adjectives, including, but not limited to, activity, sleepiness, and vigor. In addition, it measures affective states, such as mood and arousal. For the purpose of this experiment, it was important to translate the test. The translation of the test was done according to the study [11]. Following the AD ACL test the participant were exposed to a series of video stimuli while their neural activity was recorded using the EMOTIV Insight EEG device. This phase enabled the monitoring of brain waves and emotional reactions of the participants while watching the video. The results used for this experiment were obtained using the companion program that comes with the EMOTIV Insight EEG device. The metrics of interest in this experiment are: attention, engagement, arousal, stress, relaxation, and interest.

The experimental setup was simple. Apart from the EEG device itself, two laptop computers were used. On one computer, the AD ACL test was performed together with accompanying tests, and apart from the tests, that computer was used in communication with the EEG device and had data on the subjects. The second computer was dedicated to displaying audio-visual stimuli. After the EEG-monitored video stimuli, the participants completed the Self-Assessment Manikin (SAM) questionnaire. For the purpose of this experiment, the subjective assessment of valence was tested, in order to check the emotional valence of the sentence, i.e. the subjectively percived sentiment for each subject individually and excitement as an additional control metric of both EEG recording and subjective evaluation of the values measured by the EEG device. At the same time as completing the SAM test, the participants filled out a supplemental questionnaire that was designed to be compatible with EEG recording metrics. This questionnaire contains questions that specifically relate to aspects of cognitive and emotional reactions that are monitored by EEG. Apart from the subjective assessment of attention, engagement, excitement, stress, relaxation and interest, three additional questions related to identification with the character on the screen were asked: the level of identification according to appearance, personality and values.

IV. Results

After completing the experimental research, a large amount of data was obtained. Together with the results of the examination of sentiment and the excitability of sentences, an extensive database was created that can be used in subsequent research. This section outlines the most notable results. Firstly, it is necessary to outline and describe the used variables.

- *Respondent*: Respondents are represented by values from 1 to 5 (for example respondent no1, respondent no2, etc.).
- *MetaHuman*: Value 1 represents a character that resembles the respondent, while value 2 represents a control character.
- *Pair*: Represents the ordinal number of a pair of sentences for each respondent. The sentences of a pair are of similar sentiment, excitability and number of syllables. The first sentence is spoken by a character who resembles the respondent, and the second by a control character who does not resemble the respondent.
- *EEG_engagement/arousal/stress/relaxation/interest*: Shows values obtained using the EMOTIV Insight device and accompanying software. Values are rational numbers in the interval 0 to 1.
- *SUB_engagement/excitement/stress/relaxation/interest*: Shows the values from the questionnaire for the measure of agreement of objective and subjective results. The values are natural numbers in the interval from 1 to 9.
- *SUB_similarity_Appearance/Personality/Values*: Shows the values from the questionnaire for the measure of conformity of objective and subjective results in the context of identification with the character. The values are natural numbers in the interval from 1 to 9.
- *SAM_sentiment/excitement*: Shows the values from the SAM test. The values are natural numbers in the interval from 1 to 9.
- *SentimentSentence*: A value of 1 represents a negative sentence, a value of 2 represents a neutral sentence and a value of 3 represents a positive sentence.

A. ANOVA analysis

Based on the results of the analysis of effects between subjects for the *EEG_arousal* variable, it was determined that there is a statistically significant effect of the *SentimentSentence* factor (F= 3.661, p = 0.030, $\eta_p^2 = 0.089$) on the *EEG_arousal* levels. Post hoc tests showed significant differences in mean values between the levels of *SentimentSentences* negative and neutral (Difference in Mean Value = 0.0388, p = 0.050). These results suggest that the *SentimentSentence* factor significantly affects *EEG_arousal*, especially in distinguishing between negative and neutral sentiment conditions.

Based on the results of the analysis of effects between subjects for the *SUB_interest* variable, it was observed that there is a statistically significant effect of the *SentimentSentence* factor (F= 4.327, p = 0.016, $\eta_p^2 = 0.095$) on the *SUB_interest* levels. After post hoc tests, it was found that there is a statistically significant difference in the mean values between the levels of positive and negative sentiment.

Based on the results of the analysis of effects between subjects for the *SUB_stress* variable, it was determined that the *SentimentSentence* factor has a statistically significant influence (F= 16.684, p < 0.001, $\eta_p^2 = 0.289$). This indicates that different levels of sentiment in sentences significantly affect *SUB_stress* scores. Post hoc tests showed significant differences in mean values of *SUB_stress* scores among different levels of *SentimentSentences*.

Based on the analysis of effects between subjects for the *SUB_relaxation* variable, it was determined that the *SentimentSentence* factor has a statistically significant influence (F= 4.084, p = 0.020, $\eta_p^2 = 0.091$). This indicates that different levels of sentiment in sentences significantly affect *SUB_relaxation* scores. Post hoc tests showed significant differences in mean *SUB_relaxation* scores between *SentimentSentence* levels.

Based on the analysis of effects between subjects for the variable *SUB_similarity_Appearance*, it was determined that the *SentimentSentence* factor has no statistically significant influence (F= 0.193, p = 0.825, $\eta_p^2 = 0.005$). This indicates that different levels of sentiment in the sentences did not significantly affect the results of *SUB_similarity_Appearance*. However, the main effects of the *MetaHuman* factor are statistically significant (F= 24.565, p < 0.001, $\eta_p^2 = 0.231$), indicating that the presence of a *MetaHuman* (MH that resembles the subject / control character) significantly affects *SUB_similarity_Appearance* scores.

Based on the analysis of effects between subjects for the variable *SUB_similarity_Personality*, it was determined that the *SentimentSentence* factor has a statistically significant influence (F= 21.336, p < 0.001, $\eta_p^2 = 0.342$). This indicates that different levels of sentiment in sentences significantly affect *SUB_similarity_Personality* scores. Post hoc tests revealed significant differences in mean *SUB_similarity_Personality* scores among different levels of *SentimentSentences*.

Based on the analysis of the effects from among subjects for the *SUB_similarity_Values* variable, it was determined that the *SentimentSentence* factor has a statistically significant influence ($F= 28.466$, $p < 0.001$, $\eta_p^2 = 0.410$). This indicates that different levels of sentiment in sentences significantly affect *SUB_similarity_Value* scores. Post hoc tests revealed significant differences in mean *SUB_similarity_Value* scores among different levels of *SentimentSentences*.

Based on the analysis of effects between subjects for the *SAM_sentiment* variable (SAM test results), it was determined that the *SentimentSentence* factor has a statistically significant influence ($F= 69.193$, $p < 0.001$, $\eta_p^2 = 0.628$). This indicates that different levels of sentiment in sentences significantly affect *SAM_sentiment* scores. Post hoc tests revealed significant differences in mean *SAM_sentiment* scores among different levels of *SentimentSentences*.

Based on the analysis of effects between subjects for the variable *SAM_arousal* (SAM test results), the *SentimentSentence* factor showed a statistically significant influence ($F= 3.360$, $p = 0.040$, $\eta_p^2 = 0.076$). This suggests that different levels of sentiment in sentences significantly affect *SAM_arousal* scores. Post hoc tests revealed a significant difference in means between the positive and neutral sentiment conditions.

B. Significant bivariate correlations

First correlation check was done in the context of subjective and objective results together with the MetaHuman variable.

- *EEG_attention* and *EEG_engagement* have a very strong positive correlation of 0.815**. This indicates a significant positive association between these two EEG variables.
- *EEG_attention* and *EEG_relaxation* have a very strong positive correlation of 0.795**. This indicates a significant positive association between these two EEG variables.
- *EEG_stress* and *EEG_relaxation* have a very strong positive correlation of 0.752**. This indicates a significant positive association between these two EEG variables.
- *SUB_similarity_Personality* and *SUB_similarity_Value* have a very strong positive correlation of 0.826**. This indicates that the respondents had a similar understanding of these two test questions.
- *SUB_similarity_Value* and *SAM_sentiment* also have a strong positive correlation of 0.760**.
- *SUB_similarity_Personality* and *SAM_sentiment* have a slightly lower value of 0.671**.
- *EEG_attention* and *SUB_attention* are also strongly positively correlated with a value of 0.857**. This suggests that subjective ratings of attention are closely related to EEG measures of attention.
- *SUB_arousal* and *SAM_arousal* are strongly positively correlated with a value of 0.692**.

The second correlation analysis introduced the sentiment of the sentence as a factor, resulting in several significant correlations, particularly evident in the subjectively reported outcomes, notably within the contexts of positive and neutral sentences. However, noteworthy correlations emerged specifically in the relationship between negative and neutral sentence sentiments (*SentimentSentence*) and their association with MetaHuman (*MetaHuman*).

- *SUB_similarity_Appearance* and *EEG_attention* have a very strong negative correlation of -0.973**, in the context of negative sentence valence and -0.977** in neutral sentence valence, both when delivered by a controlled MetaHuman.

V. Discussion

From the ANOVA analysis, it is observed that the sentiment of the sentence has a significant influence on the level of excitement obtained by EEG recording as well as on the subjective values of interest, stress, relaxation and the reported level of identification with the character in the context of personality and values. From this analysis, it can be seen that the sentence sentiment has an impact on the valence results of the sentence obtained from the SAM test, which indicates that the survey conducted for assessing the excitability and sentiment of the sentence gave correct and usable results. Sentence sentiment was also found to be significant in relation to SAM arousal scores. ANOVA analysis showed that the MH character has an impact on the subjective assessment of identification with the character in terms of its appearance, which may indicate that the respondents recognized themselves in the characters. In the bivariate analysis, correlations occurred between the variables in the domain of the results obtained by EEG measurement, the subjective evaluation of the respondents from the questionnaire for measuring the conformity of the objective measures and the results of the SAM test. The observed correlation between the results measured by the EEG device for attention and engagement may indicate that the more the stimulus captured the subjects' attention, the more their engagement with the stimulus increased. The situation is similar with attention and relaxation. The statistical processing of the results confirmed, as expected, the correlation of the subjectively reported rating of identification with the character in terms of personality and value with the valence value of the sentence from the SAM test. The correlation of the subjective feeling of arousal and the user's assessment of arousal from the SAM test indicates that the test subjects filled out the tests with dedication and consistency, that is, that they did not answer the questions randomly. What is interesting and certainly requires further investigation on a larger number of respondents is that there is a difference in the level and direction of the correlation observed between stress and relaxation based on the results obtained by EEG measurement on the one hand and subjectively reported values on the other. Furthermore, a strong positive correlation is observed between the level of attention obtained by EEG measurements and the level of attention obtained by the subjective assessment of the examinees. Although this correlation is not sufficient to confirm the validity of the use of this EEG device for the evaluation of user experience, it represents a motivation for further testing of EEG equipment for this purpose.

In the second correlation analysis that introduced the sentiment of the sentence as a factor to subjectively reported identification based on the apperence and EEG meassured attention had very strong negative correlations in the context of negative and neutral sentences. These findings suggest a consistent trend: as perceived similarity decreased, EEG measured attention levels notably decreased. This underscores an intensified relationship between diminishing similarity perception and declining attention levels, especially apparent in situations involving stronger negative and neutral sentence valences.

VI. Conclusion

Finding a link between the character identification and game enjoyment in the relevant literature prompted future research on the topic. In this paper, a methodology approach that encompasses both subjective and objective quantitative data is presented.

After conducting an experiment that followed the steps highlighted in the introduction of the paper, one can conclude that this type of experiment is feasible. After the ANOVA analysis, the results of the sentence sentiment survey are confirmed, which may indicate that this set of sentences can be used in further research, that is, that this methodology of sentence analysis and collection can be used to test UX for a specific video game. One of the conclusions is that by using a home computer one can get a sufficiently realistic representation of a person that can cause a certain level of identification with the character. Furthermore, from the ANOVA analysis, it can be concluded that in this type of experiment, sentiment can play a large role in the respondents' answers and reactions to the presented stimulus.

Bivariate analysis yielded the expected correlations in certain aspects, as was the case with identification with personality/character values and sentence sentiment. This analysis leads to the conclusion that the respondents devotedly answered the questions asked during the experiment. Consequently, it can be expected from the respondents who do not play video games to successfully participate in such tests. Bivariate analysis showed that there is a need to repeat this type of experiment in order to examine the correlation between stress and relaxation on a larger number of subjects. Besides, it leads to the conclusion that for some of the EEG values there is a correlation in the results measured by the EEG device and subjective assessments of respondents. This correlation is, as stated in the discussion, an additional motivation for further research of this type and further processing and interpretation of the extensive amount of results that this experiment has provided. Finally, the correlation analysis, which incorporated sentence sentiment as a factor in subjective identification based on appearance and EEG measurements, suggests a potential shift in attention away from characters that do not resemble the player, particularly evident in negative and neutral contexts.

This research, particularly through its pilot study, contributed to the linguistic localization of UX testing related to character identification in video games. Additionally, it involved constructing an extensive and invaluable database of results obtained with both subjective and objective parameters of UX, intended for future use and updates, while also encouraging the ongoing improvement of this experiment for evaluating user and player experiences in video games.

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APSTRAKT

Cilj ovog rada je da izmeri objektivne kvantitativne aspekte korisničkog iskustva u kompjuterskim igrama i ispita da li identifikacija sa likom utiče na uživanje u igri. Motivacija za ovu studiju proizilazi iz literature koja ističe vezu između identifikacije sa karakterom i zadovoljstva korisnika. Da bi se istražilo ovo, generisani su digitalni dvojnici ispitanika. Metodologija primenjena u ovom radu koristila je EEG uređaj kao alat za prikupljanje objektivnih kvantitativnih podataka, uz podršku tri subjektivna upitnika. Rezultati su pokazali jaku korelaciju između identifikacije sa karakterom na osnovu izgleda, vrednosti i ličnosti, i nekih EMOTIVE Insight EEG metrika. Ovaj rad služi kao pilot studija sa ciljem istraživanja daljih objektivnih kvantitativnih mera za korisničko iskustvo u igrama.

EEG za procenu korisničkog iskustva u kompjuterskim igrama putem identifikacije sa karakterom

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