Association for Information Systems
AIS Electronic Library (AISeL)

MWAIS 2018 Proceedings | Midwest (MWAIS)

5-2018

Neural Correlates of States of User Experience in Gaming using EEG and Predictive Analytics

Chandana Mallapragada
Missouri University of Science and Technology, cmdd8@mst.edu

Fiona Fui-Hoon Nah
Missouri University of Science and Technology, nahf@mst.edu

Keng Siau
Missouri University of Science and Technology, siauk@mst.edu

Langtao Chen
Missouri University of Science and Technology, chenla@mst.edu

Tejaswini Yelamanchili
Missouri University of Science and Technology, tyybf@mst.edu

Neural Correlates of States of User Experience in Gaming using EEG and Predictive Analytics

Chandana Mallapragada
Missouri University of Science and Technology
cmdd8@mst.edu

Fiona Fui-Hoon Nah
Missouri University of Science and Technology
nahf@mst.edu

Keng Siau
Missouri University of Science and Technology
siauk@mst.edu

Langtao Chen
Missouri University of Science and Technology
chenla@mst.edu

Tejaswini Yelamanchili
Missouri University of Science and Technology
tyybf@mst.edu

ABSTRACT

In this research, we will analyze EEG signals to obtain neural correlate classifications of user experience by applying predictive analytics. Boredom, flow, and anxiety are three states experienced by users interacting with a computer-based system. A within-subjects experiment was used to collect EEG data for these three states and a baseline. We will apply predictive analytics including linear regression, support vector machine, and neural networks to analyze and classify the EEG data for these three states of user experience.

Keywords

Neural correlates, electroencephalogram, predictive analytics, linear regression, support vector machine, neural networks.

INTRODUCTION

In human-computer interaction, user experience in gaming includes a variety of states such as flow, boredom, and anxiety. Flow, boredom, and anxiety are three main states of user experience identified by Csikszentmihalyi (1975, 1990, 1997) based on the balance of challenge and skill. When a user's skill is congruent with the difficulty level of the game, the player may experience an optimal state known as flow (Csikszentmihalyi, 1990; Nah et al, 2014). On the other hand, if the challenge posed by the game exceeds the user's skill, anxiety may arise, and if the challenge is low relative to the user's skill, the user gets bored (Chanel et al., 2008). This research examines the neural correlates of these three states of user experience using electroencephalogram (EEG). EEG refers to the electrical activity in the brain that arises from electrical impulses to facilitate communication between the brain cells (Muller et al., 2015).

The main objective of this research is to analyze the EEG data of three main states of user experience (i.e., flow, boredom, and anxiety) by applying predictive analytics techniques. Predictive analytics, a subset of data science, is a combination of statistical and empirical models to create and assess empirical predictions (Shmueli and Koppius, 2011). Predictive analytics help identify patterns based on past data in order to make predictions. Analytics can be used to improve accuracy of predictions without human involvement. Predictive analytics include statistical techniques, such as linear regression and logistic regression, as well as artificial intelligence and machine learning techniques, such as support vector machine (SVM), neural networks (NN), and cluster analysis. The goal of this research is to classify the neural mapping of the three user states of experience using predictive analytics techniques.

Given the importance of understanding user states of experience (i.e., flow, boredom, and anxiety) in the HCI context and the potential of using predictive analytics to determine these states using EEG data, our research question is as follows:

***Research Question*:** What are the neural correlates for three main states of user experience: flow, boredom, and anxiety?

BACKGROUND AND LITERATURE REVIEW

The main construct of interest in this research is flow. Flow is an optimal experience where an individual is totally absorbed into a task and does not think about his/her surroundings or time (Csikszentmihalyi, 1990). In Csikszentmihalyi's (1990) theory of flow, the flow state is conceptualized into nine components: (1) balance of challenge and skill; (2) merging of action and awareness; (3) clear goals; (4) immediate and unambiguous feedback; (5) concentration on the task at hand; (6) loss of self-consciousness; (7) sense of control over the task; (8) distorted sense of time; (9) autotelic experience.

Neural correlates of user states can be observed based on the density variations of the spectral bands, where each spectral band of EEG data represents a set of cognitive activity in the brain. EEG data can be classified into delta (1-4 Hz), theta (4-8 Hz), alpha (8-12 Hz), beta (12-30 Hz), and gamma (30-32 Hz) spectral bands. Theta band oscillations are related to memory processing and cognitive load; theta decreases with an increase in players' engagement (Sauseng and Klimesch, 2008). Alpha band oscillations are related to attentional processes while beta band oscillations are related to cognitive engagement (Lindsley and Wicke, 1974; Berka et al. 2007). EEG theta, alpha and beta are considered the most informative bands during gaming (Berta et al., 2013).

Predictive analytics can be used to analyze players' actions in response to challenges in the game (Suh and Alhaery, 2014). Recent studies have used predictive analytics to optimize players' gaming experience (Hair, 2007), where players are segregated based on their experience in gaming and their momentary scores. Analyzing variables such as scores and responses to situational changes in the computer-based gaming environment helps designers and developers understand both their target population and design dynamics to optimize gaming experience (Hair, 2007). Among the predictive analytics techniques, SVM is commonly used for classifying brain activity captured using Brain Computer Interface technologies such as EEG (Berta et al., 2013). Berta et al. (2013) recorded data consisting of different spectral patterns for boredom, flow, and frustration and fed them into the SVM model for training and testing (with an accuracy of 50.1%). A similar approach has been implemented by Chanel et al. (2008) in which Radial Basis Function SVM was used to classify user states of experience based on recorded physiological signals (accuracy is 53.33%). Linear regression provides the parameters for the relationship between independent and dependent variables that can be used to predict user experience (Tanaka et al., 1982). Although EEG data analysis has been carried out for decades, the application of advanced predictive analytics on EEG data is still limited. This research will apply predictive analytics to EEG data to predict three different user states of experience.

RESEARCH METHODOLOGY FOR DATA COLLECTION

A within-subjects laboratory experiment was designed to capture EEG recordings for boredom, flow, and anxiety using 64-channel EEG technology called Cognionics. We adapted this design from Berta et al. (2013) who used a plane battle game and 4-channel EEG technology. We used the video game, Tetris, to induce the flow, boredom, and anxiety states. The experiment consisted of five parts; each part is used to induce a different state of user experience, i.e., boredom, flow, anxiety, and two resting states.

We induced five states of user experience as follows. Resting state 1 was invoked by having the participant stare at a small cross on a blank screen of the same color as the background of the game used in the experiment. Resting state 2 was induced by making the subjects close their eyes and relax. For the state to induce boredom, the challenge of the game was maintained at the lowest level (i.e., level 1). In addition, the subject was provided with a mouse that has been click-disabled, such that the subject could not shorten the wait time for the block to fall but had to wait for each block to fall to the base. The flow state was induced by setting the game at level 5 and having the subject play until all the blocks piled up to the top. During the gameplay, the game level automatically increased as the subject cleared each level of difficulty. The anxiety state was induced by setting the challenge of the game at such a high level (i.e., level 15 and above) that it way surpassed the skill level of the subject.

At the end of each user state, the subject was asked to fill out a questionnaire that is used as a validation check for the manipulation. Also, a retrospective process tracing was carried out for each of the induced states, where each participant was asked to verbalize his/her experience while viewing a video recording of their gameplay. Based on the subject's verbalization of their states of user experience, we determined a 30-second interval that best represented each of the three induced user states.

RESEARCH METHODOLOGY FOR DATA ANALYSIS

EEG measurement provides a plethora of data that can be decomposed using different analytical procedures. Some open source software tools, such as EEGLab, BrainVision Analyzer, and R will be used to analyze the EEG data. The 30-second EEG segment for each state and each user will be further sub-divided into 3-second segments with an overlap of 1-second.

The segmented data is filtered to remove artifacts such as eye-movements, eye-blinks, internal and external noise, and muscle movements. The cleansed data is transformed from time series to frequency series by applying Fast Fourier Transformation extracted using Brain Vision Analyzer. The extracted data is fed as input to R-studio for performing predictive analytics. Linear regression helps to identify the dominant spectral band frequencies for the different states of user experience. SVM helps to classify the user states of experience based on the inputs provided.

CONCLUSION AND EXPECTED CONTRIBUTIONS

Our research adopts predictive analytics techniques to analyze EEG data. Unlike traditional data analysis, predictive analytics can identify patterns and potentially predict subsequent states of user experience based on the current states. More importantly, we are interested to identify the patterns of EEG neural mapping for flow, boredom, and anxiety states of experience, such that EEG can be used as another means of reliable measurement for them. In future research, we are also interested to develop predictive models for neural correlates of other states of user experience such as frustration, apathy, and enjoyment.

REFERENCES

1. Tanaka, H., Uejima, S. and Asai, K. (1982) Linear regression analysis with fuzzy model, *IEEE Transactions on Systems, Man and Cybernatics*, 12, 6, 903-07.
2. Berka, C., Levendowski, D.J., Lumicao, M.N., Yau, A., Davis, G., Zivkovic, V.T., Olmstead, R.E., Tremoulet, P.D. and 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, II, B231-B244.
3. Berta, R., Bellotti, F., De Gloria, A., Pranantha, D. and Schatten, C. (2013) Electroencephalogram and physiological signal analysis for assessing flow in games, *IEEE Transactions on Computational Intelligence and Artificial Intelligence in Games*, 5, 2, 164-175.
4. Chanel, G., Rebetez, C., Bétrancourt, M. and Pun, T. (2008) Boredom, engagement and anxiety as indicators for adaptation to difficulty in games, *Proceedings of the 12th International Conference on Entertainment and Media in the Ubiquitous Era*, New York, NY, USA, ACM, 13-17.
5. Csikszentmihalyi, M. (1975) Beyond boredom and anxiety, Jossey-Bass, San Francisco, CA.
6. Csíkszentmihályi, M. (1990) Flow: The psychology of optimal experience, Harper & Row, New York, NY.
7. Csikszentmihalyi, M. (1997) Finding flow: The psychology of engagement with everyday life, Basic Books, New York, NY.
8. Hair Jr, J. F. (2007) Knowledge creation in marketing: the role of predictive analytics, *European Business Review*, 19, 4, 303-315.
9. Lindsley, D. B. and Wicke, J. D. (1974) The electroencephalogram: Autonomous electrical activity in man and animals, *Bioelectric Recording Techniques*, New York, NY, USA, Academic Press, 3-83.
10. Müller-Putz, G. R., Riedl, R. and Wriessnegger, S. C. (2015) Electroencephalography (EEG) as a research tool in the information systems discipline: Foundations, measurement, and applications, *Communications of the Association for Information Systems*, 37, 46, 911-948.
11. Nah, F. F. H., Eschenbrenner, B., Zeng, Q., Telaprolu, V. R. and Sepehr, S. (2014) Flow in gaming: Literature synthesis and framework development, *International Journal of Information Systems and Management*, 1, 1-2, 83-124.
12. Sauseng, P. and Klimesch, W. (2008) What does phase information of oscillatory brain activity tell us about cognitive processes? *Neuroscience & Biobehavioral Reviews*, 32, 5, 1001-1013.
13. Shmueli, G. and Koppius, O. R. (2011) Predictive analytics in information systems research, *MIS Quarterly*, 35, 3, 553-572.
14. Suh, E. and Alhaery, M. (2014) Maximizing player value through the application of cross-gaming predictive models, *International Journal of Contemporary Hospitality Management*, 26, 8, 1243-1269.