2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering
Education for 130 Years
ASEE
Paper ID #37129

Work in Progress: Physiological Assessment of Learning in a Virtual Reality Clinical Immersion Environment

Prof. Christine E. King, University of California, Irvine

Dr. Christine King is an Assistant Teaching Professor of Biomedical Engineering at UC Irvine. She received her BS and MS from Manhattan College in Mechanical Engineering and her PhD in Biomedical Engineering from UC Irvine, where she developed brain-computer interface systems for neurorehabilitation. She was a post-doctorate in the Wireless Health Institute at the University of California, Los Angeles, and a research manager in the Center for SMART Health, where she focused on wireless health monitoring for stroke and pediatric asthma. Her current research is on engineering education and women's health, specializing in pedagogy strategies to promote learning and innovation in design-build-test courses, including senior design, computer programming, and computer-aided-design courses, as well as pre-partum and partum medical devices.

Kit Roy Feeney
Quangminh Tang
Milan Das
Dalton Salvo

Introduction:

The National Academy of Engineering has identified personalized learning as one of the 14 Grand Challenges for engineering in the 21st century [1]. Education is now shifting to a personalized process in which student learning is tailored to the individual needs and abilities. In addition, the Creating Helpful Incentives to Produce Semiconductors (CHIPS) and Science Act have listed experiential training as a strategic objective [2] for US educational institutions. In biomedical engineering (BME) programs, this includes the need for clinical immersion experiences, or learning from synergistic transactions between people and the environment [3] within a healthcare setting.

Clinical immersion programs have been widely used in BME and bioengineering curricula [4], as it allows students to observe the clinical environment, better understand the practical application of medical devices, and identify unmet clinical needs in healthcare. However, due to the lack of access to nearby medical centers, hospital access for non-essential personnel, and increasing class sizes, availability of such programs are limited. As a result, these programs have typically been offered only to a select number of students (e.g. 15-20 students) [5-7]. To resolve this lack of access and move beyond prior research that utilized traditional video recordings [9-10], the Dept. of BME at the University of California Irvine (UCI) developed a virtual reality (VR) clinical immersion platform for student learning of clinical procedures and identification of unmet clinical needs [8]. The UCI VR platform enables a more comprehensive presentation of the full spectrum of staff and equipment involved in a clinical procedure [11-12]. The platform was piloted in Spring of 2022 as part of a junior-level unmet needs finding course for undergraduate BME students [8]. Initial assessment of this program revealed that the VR clinical immersion experiences greatly amplified the students' phenomenological sensations of immersion and presence [8]. In this work, we further examine the phenomenological framework of educational VR platforms [13-15] by focusing on the felt sensations of boredom and psychological engagement while virtually immersed in clinical procedures.

Methods:

We adopted the boredom definition of Fahlman et al. as “the aversive experience of having an unfulfilled desire to be engaged in satisfying activity” due to their comprehensive list of how boredom manifests itself in terms of the subjects’ arousal and cognitive apprehension [18]. Focusing on state boredom as the felt response to a discrete and concrete external experience, we attempted to track the state the student is in when they say “this lesson is boring” or “this video is boring.” Conversely, we also attempted to track the state of psychological engagement or attention to allow us to better analyze the effectiveness of our VR clinical immersion environments. Therefore, we implemented psychological and physiological methods for data collection. For our psychological methods, we had participants self-report their state of boredom and engagement using questionnaires intended to determine such through their felt responses and perception of time. Our physiological methods included collecting participants' electroencephalogram (EEG) data, heart rate, heart rate variability (HRV), and eye tracking.

Study Protocol:

Prior studies that quantify boredom from EEG [17] suggest that the default mode network (DMN) area of the brain is consistently activated during boredom, which includes the medial prefrontal cortex, posterior cingulate cortex, and inferior parietal lobe. Additionally, these studies indicate that EEG recorded over these regions of the brain exhibit increases in power in the alpha (8-12 Hz) and theta (4-8 Hz) frequency bands when compared to non-boredom physiological states. Therefore, our study examined the alpha and theta bands of EEG over the frontal and parietal lobes of the brain while participants were immersed in boring and exciting environments; we compared this data to EEG collected during the VR clinical immersion environments to determine whether the VR videos elicited neurophysiological behaviors more closely associated with boredom or engagement. Our study was approved as an IRB exempt protocol by the University of UCI Institutional Review Board (UCI IRB exempt No. 2678).

To perform the above comparison, three individuals, two of whom had no prior experience watching medical procedures or performing clinical immersion within a hospital setting (see Table 1 for demographic data), participated in the study. For each experiment, participants watched videos wearing an HP-Reverb G2 Omnicept VR headset over their EEG cap. We had the participants watch three videos: a boring video, an interesting video, and a clip from our VR clinical immersion videos while their data was recorded. Each video was 17 minutes long and participants were given roughly a 5-minute break in between each video to allow them to restabilize.

State boredom often derives from information or environmental stimuli that is monotonous, redundant, and/or meaningless [18]. Thus, for our boring control sample, we selected a 1989 Microsoft Word tutorial [19]. Due to the general familiarity our demographic has with Microsoft Word along with the age and obsolescence of the interface, we believe this video meets the criteria necessary to induce state boredom. For our interesting control sample, we selected a video covering alien reproduction vehicles and the mysterious deaths of scientists exploring alternative means of energy generation [20]. While this video could be categorized as a “conspiracy theory,” the accuracy of the information delivered is not as crucial to the experiment as much as presenting information that is highly interesting to the participants. Given the recent rise in public interest of aliens and importance of energy generation, we surmised that the topic generates higher levels of psychological engagement. Lastly, our VR clinical immersion video consisted of a clip from a spinal deformation operation recorded by the UCI medical student team [21].

Data Acquisition:

Each subject was seated and an EEG cap (Compumedics USA, Charlotte, NC) with 19 sintered Ag-AgCl electrodes, arranged according to the 10-20 International Standard, was used for EEG recording and worn under the VR headset. Conductive gel was applied to a subset of four electrodes at the following locations: F3, F4, P3, P4. These channels were selected because they corresponded to the frontal (F) and parietal (P) lobes, areas of the cerebral cortex generally active during boredom [16]. The frontal and parietal lobes are part of the DMN, a network of interacting regions that produce strong and slow frequencies during the resting state [17]. The ground channel, located near FPz, was used as a common average reference electrode. The signals were amplified (gain: 5000) and band-pass filtered (1-35 Hz) using four single-channel EEG bioamplifiers (Biopac Systems, Goleta CA), and were digitized (sampling rate: 200 Hz, resolution: 16 bits) by the MP160 data acquisition system (Biopac Systems). Data acquisition was performed using Acqknowledge Software (Biopac Systems). Resulting EEG data was imported into MATLAB (Mathworks, Natick, MA) for signal processing and analysis. We used the sensors built into the VR headset to collect heart rate, HRV, and eye tracking data (for information on the specific sensors: https://developers.hp.com/omnicept/docs/fundamentals).

Data Analysis:

To preprocess the EEG data, the first and last 120-seconds of data was removed from analysis to remove potential behavioral transition states. The raw EEG voltages were then plotted over time visually inspect the data for noise or recording errors. The Fourier transform was then applied to calculate the power spectral density (PSD) estimate using Welch’s method for spectral density estimation [22]. Welch’s PSD estimate was computed in two point overlapping windows and the periodogram was calculated using the discrete Fourier transform (DFT). To compare the PSD levels in the delta (1-3 Hz), theta (4-8 Hz), alpha (8-12 Hz), and beta (13-30 Hz) frequency bands for each video and participant, the power-frequency plots were limited from 1-30 Hz. To affirm normal data distribution for parametric statistical analysis, the team conducted a Kolmogorov-Smirnov goodness-of-fit hypothesis test. If no normal distribution was found, the Kruskal-Wallis one-way ANOVA with a 1% significance level was performed to compare PSD among EEG channels between each video type, a non-parametric method to assess if more than two independent samples have the same median. To analyze the other physiological data, we used MATLAB to plot the heart rate, HRV, and XY gaze coordinates and then overlayed the gaze plot onto the subject's video recording in Adobe Premiere Pro (Adobe, San Jose, CA).

Results:

The power spectrum analyses of the EEG revealed that the PSD in the alpha band (8-12 Hz) changed over EEG channels P3 and P4, the parietal lobe, for all videos for subject 1(see appendix Fig. 1). However, the PSD over this band changed over the frontal lobe, channels F3 and F4, for the boring and clinical immersion videos, but did not change significantly for the exciting video (see appendix Fig. 2-4). This is consistent with prior EEG studies [17] and showed that the clinical video power spectrum more closely resembled the boring video than the exciting video for Subject 1. No change in PSD was observed over all EEG channels in the theta (4-8 Hz) frequency bands across the videos. Lastly, the eye tracking data (example shown here: https://youtu.be/m4T8kIQqQqo) showed that participants were engaged throughout the clinical immersion videos, and gazed mainly at the first person view at the medical devices, and utilized the 360 view to see technicians and supporting physicians. Analysis of heart rate and HRV were too similar in range across all videos, and HRV had too low of a sampling rate to discern any correlations within or across the videos (example Fig. 7-8)

For the boredom control video psychological questionnaire (See appendix Table 3), all participants noted high levels of boredom with an average of 9 out of 9 and started to feel bored in less than ⅓ of the total video length. One participant fell asleep, and the others noted high levels of drowsiness after watching the video. Additionally, all participants felt that the video was longer than in actuality by a reasonable margin. For the interesting control video (see appendix Table 4), participants noted higher levels of engagement with an average of 6, and all participants noted beginning to feel bored at around the 10-minute mark. No participants fell asleep, but all did note a slight increase in drowsiness. One participant felt the video was longer than in actuality, while the other two felt it was shorter than in actuality. The clinical immersion video (see appendix Table 5) elicited an average level of engagement at 6.33, with two of the participants beginning to feel bored at around 10 minutes. No participant fell asleep, one felt a drowsiness level of 7 out of 9 while the other two did not experience any drowsiness from watching the video. Interestingly, all participants felt that the video was longer than in actuality.

Discussion:

Due to issues during data acquisition, the EEG statistical analysis was inconclusive despite observing statistical difference in subjects 2 and 3 (see appendix Table 1). Namely, Subject 2's boredom and clinical trials had noisy EEG data due to excessive artifacts (see appendix Fig. 5 and Fig. 6). Subject 3 had too high impedances to detect EEG over channel F3 and F4, so although significant p-values were found for these subjects, they are likely due to errors (see appendix Table 2). Despite the errors in our data, preliminary results suggest that we can accurately track state boredom physiologically, as seen by the changes in alpha band PSD. To resolve these issues, future work will include conducting preliminary tests to guarantee data accuracy, checks during experimentation to assess for EEG artifacts such as motion and line noise, and removing EEG channels due to excessive noise or high impedance. Additionally, it proved to be extremely challenging synchronizing the EEG, eye tracking, and video recordings as they operate independently from one another. Moving forward we will be redesigning our data collection platform so that they are more accurately synchronized for higher quality data in our continuing experimentation.

References:

[1] National Academy of Engineering. Grand Challenges for Engineering. http://www.engineeringchallenges.org/challenges/learning.aspx. Accessed: 2020-10-22.

[2] White House Office of Science and Technology Policy. Draft national strategy on microelectronics research. https://www.whitehouse.gov/wp-content/uploads/2022/09/SML-DRAFT-Microlectronics-Strategy-For-Public-Comment.pdf. Accessed: 2022-10-22.

[3] A. Y. Kolb and D. A. Kolb. Experiential learning theory: A dynamic, holistic approach to management learning, education and development. *The SAGE handbook of management learning, education and development*, 42:68, 2009.

[4] Kotche, Miiri, Anthony E. Felder, Kimberlee Wilkens, and Susan Stirling. "Perspectives on bioengineering clinical immersion: history, innovation, and impact." *Annals of biomedical engineering* 48 (2020): 2301-2309.

[5] J. Stephens, S. Rooney, E. Arch, and J. Higginson, “Bridging Courses: Unmet Clinical Needs to Capstone Design (Work in Progress),” in *2016 ASEE Annual Conference & Exposition Proceedings, June 26, 2016, New Orleans, Louisiana.* [Online]. Available: ASEE PEER, Doi: 10.18260/p.26393.

[6] J. Kadlowec, T. Merrill, S. Sood, J. Greene Ryan, A. Attaluri, and R. Hirsh, “Clinical Immersion and Team-based Design: Into a Third Year,” in *2017 ASEE Annual Conference & Exposition Proceedings, June 24-28, 2017, Columbus, Ohio.* [Online]. Available: ASEE PEER, Doi: 10.18260/1-2—28040.

[7] W. H. Guilford, M. Keeley, B. P. Helmke, and T. E. Allen. "Work in Progress: A Clinical Immersion Program for Broad Curricular Impact," in *2019 ASEE Annual Conference & Exposition, June 15, 2019, Tampa, Florida*. [Online]. Available: ASEE PEER, Doi: 10.18260/1-2—33581.

[8] C. King, D. Salvo, J. Wang, S. Rao, R. Sreedasyam, A. Kulkarni, S. Braich, and I. Sharma. Work in progress: Development of virtual reality platform for unmet clinical needs finding in undergraduate biomedical engineering design programs. *In Proc. of the 2022 ASEE Annual Conference & Exposition*, 2022.

[9] V. Mittal, M. Thompson, S. M. Altman, P. Taylor, A. Summers, K. Goodwin, and A. Y. Louie, “Clinical Needs Finding: Developing the Virtual Experience—A Case Study,” *Annals of Biomedical Engineering*, vol. 41, pp. 1899–1912, March 2013.

[10] E. P. Brennan-Pierce, S. G. Stanton, and J. A. Dunn, “Clinical Immersion for Biomedical Engineers: Pivoting to a Virtual Format,” *Biomedical Engineering Education*, vol. 1, no. 1, pp. 175–179, Jan. 2021.

[11] R. M. Tamim, R. M. Bernard, E. Borokhovski, P. C. Abrami, and R. F. Schmid, “What Forty Years of Research Says About the Impact of Technology on Learning,” *Review of Educational Research*, vol. 81, no. 1, pp. 4–28, March 2011.

[12] O. A. Meyer, M. K. Omdahl, and G. Makransky, “Investigating the Effect of Pre-training When Learning Through Immersive Virtual Reality and Video: A Media and Methods Experiment,” *Computers & Education*, vol. 140, no. 103603, Oct. 2019.

[13] J. F. Morie, “Ontological Implications of Being in Immersive Virtual Environments,” in *SPIE Proceedings 6804, The Engineering Reality of Virtual Reality*, Jan. 27-31, 2008, San Jose, California, no.

680408, I. E. McDowall, M. Dolinsky, Eds. pp. 1–12, Feb. 8, 2008. [Online]. Available: https://doi.org/10.1117/12.778617.

[14] A. Heinzel and T. Heinzel, “The Phenomenology of Virtual Reality and Phantom Sensations,” *Studia Philosophia*, 55:3, pp. 81–96, 2010.

[15] J. Tham, A. H. Duin, L. Gee, N. Ernst, B. Abdelqader, and M. McGrath, “Understanding Virtual Reality: Presence, Embodiment, and Professional Practice,” *IEEE Transactions on Professional Communication*, 61:2, pp. 178–195, June 2018.

[16] Yelamanchili, Tejaswini. n.d. “Neural Correlates of Flow, Boredom, and Anxiety in Gaming: An Electroencephalogram Study,” 123.

[17] Raffaelli, Quentin, Caitlin Mills, and Kalina Christoff. 2018. “The Knowns and Unknowns of Boredom: A Review of the Literature.” *Experimental Brain Research* 236 (9): pp. 2451–62. https://doi.org/10.1007/s00221-017-4922-7.

[18] Fahlman, Shelley A., Kimberley B. Mercer-Lynn, David B. Flora, and John D. Eastwood. “Development and Validation of the Multidimensional State Boredom Scale.” *Assessment*, 20:1, pp. 68-85, Feb., 2013.

[19] Whamtan. “THE MOST BORING VIDEO EVER MADE (Microsoft Word tutorial, 1989),” *YouTube,* Apr. 20, 2014.

[20] The Why Files. “How to Build a Working UFO | Alien Reproduction Vehicles (ARVs),” *YouTube*, Dec. 8, 2022.

[21] UCI Virtual Reality. “Spinal Deformation,” *YouTube,* Apr. 11, 2022.

[22] Parhi, Keshab K., and Manohar Ayinala 2013. "Low-complexity Welch power spectral density computation." *IEEE Transactions on Circuits and Systems I: Regular Papers* 61:1, pp. 172-182.

Appendix:

Figure 1: Power spectrum for EEG Channel P3 for subject 1 for all videos.

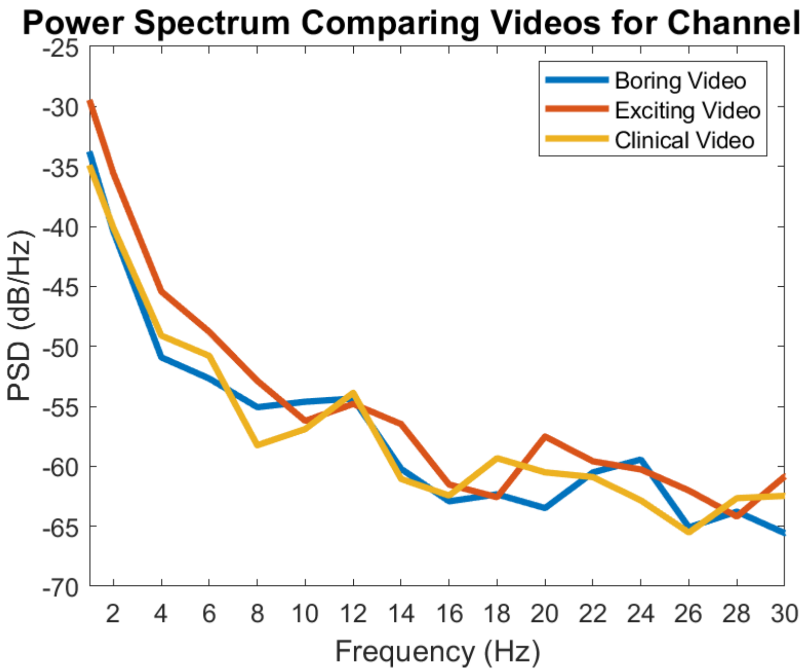

Figure 2: Power spectrum of boring control video across all EEG channels for subject 1.

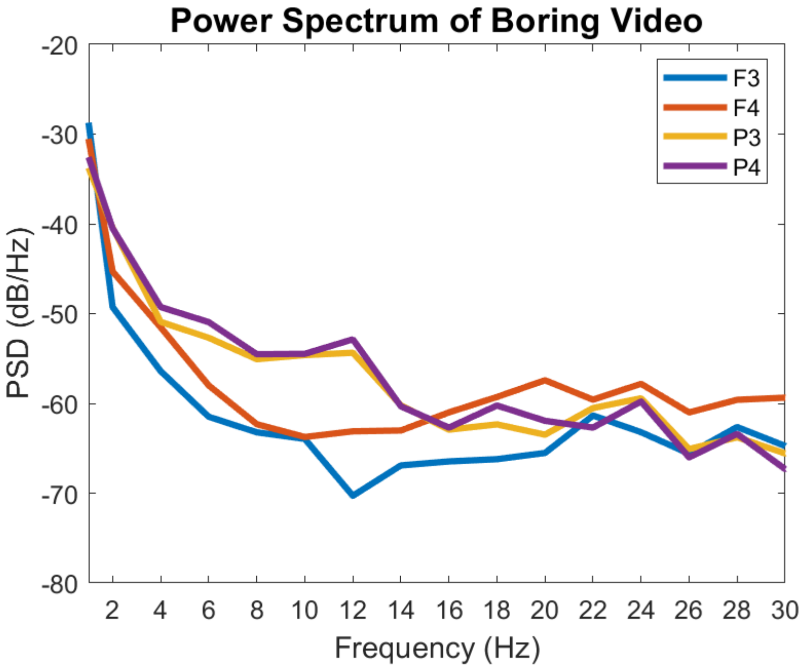

Figure 3: Power spectrum of the exciting control video across all EEG channels for subject 1.

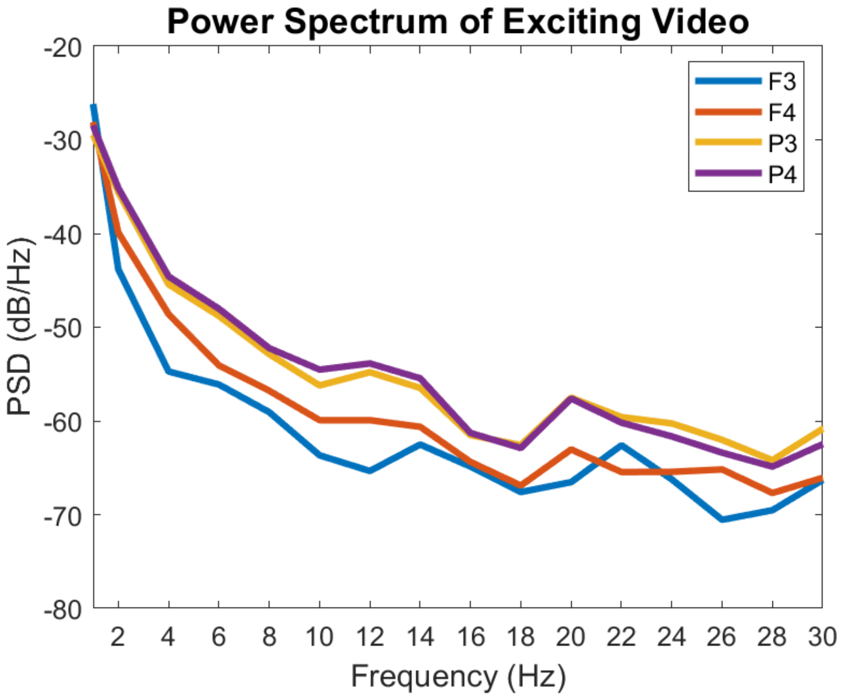

Figure 4: Power spectrum of the clinical control video across all EEG channels for subject 1.

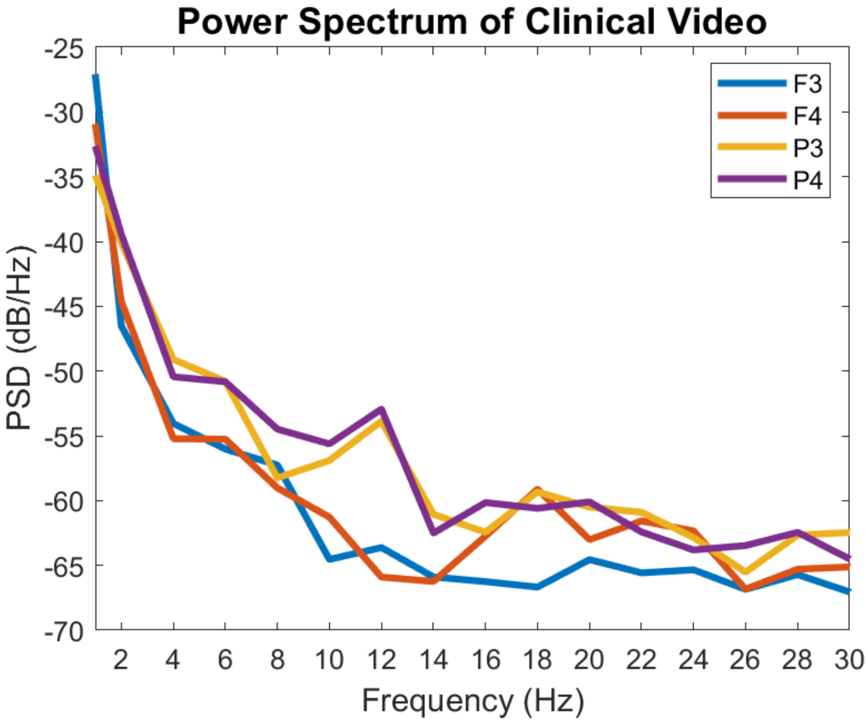

Figure 5: EEG time plot for subject 2's boring video for all EEG channels.

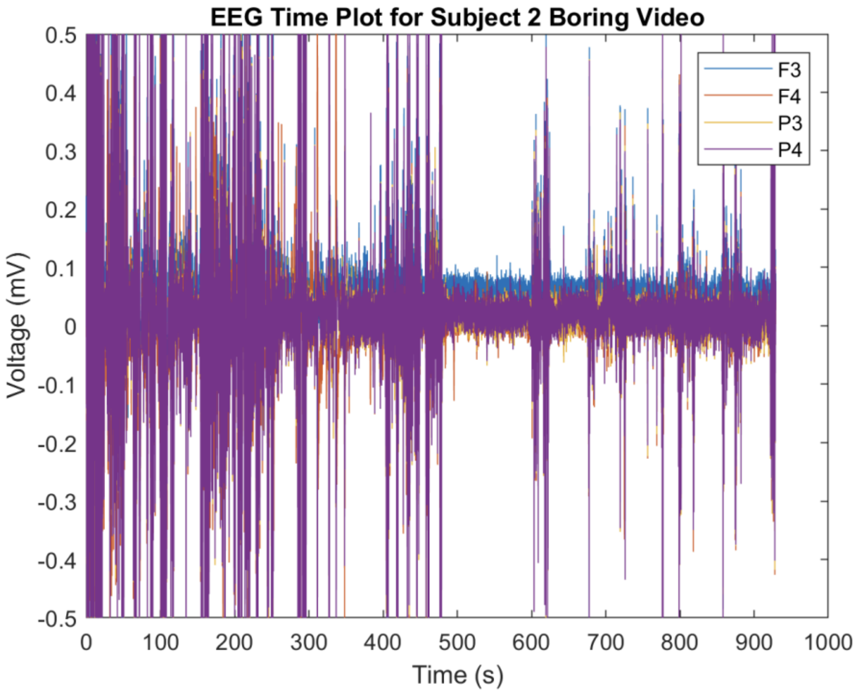

Figure 6: EEG time plot for subject 2's clinical immersion video for all EEG channels.

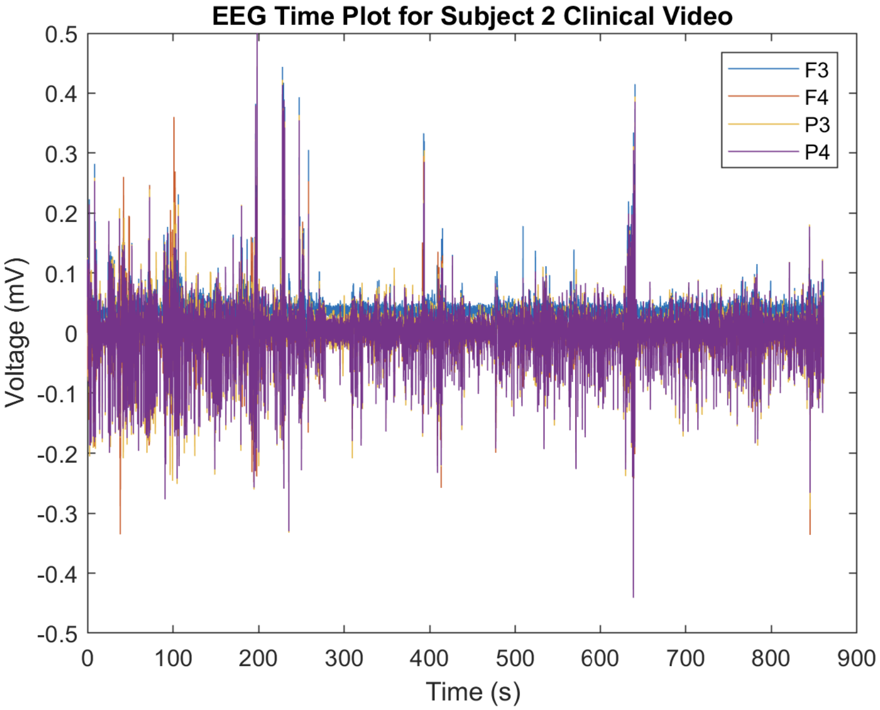

Figure 7. Heart rate time plot for subject 2’s clinical immersion video.

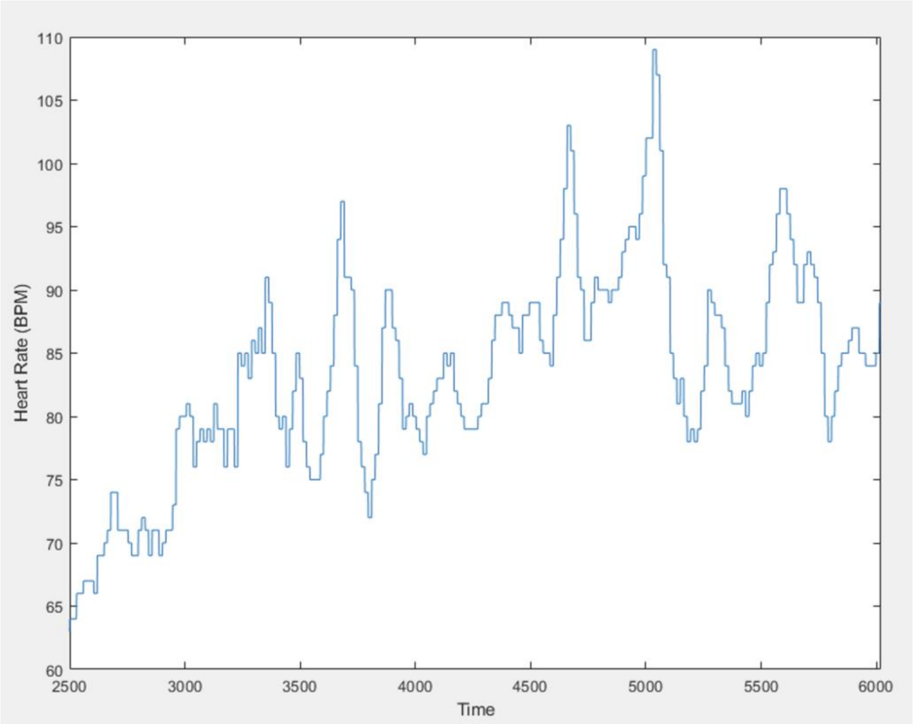

Figure 8. Heart rate variability (HRV) time plot for subject 2’s clinical immersion video.

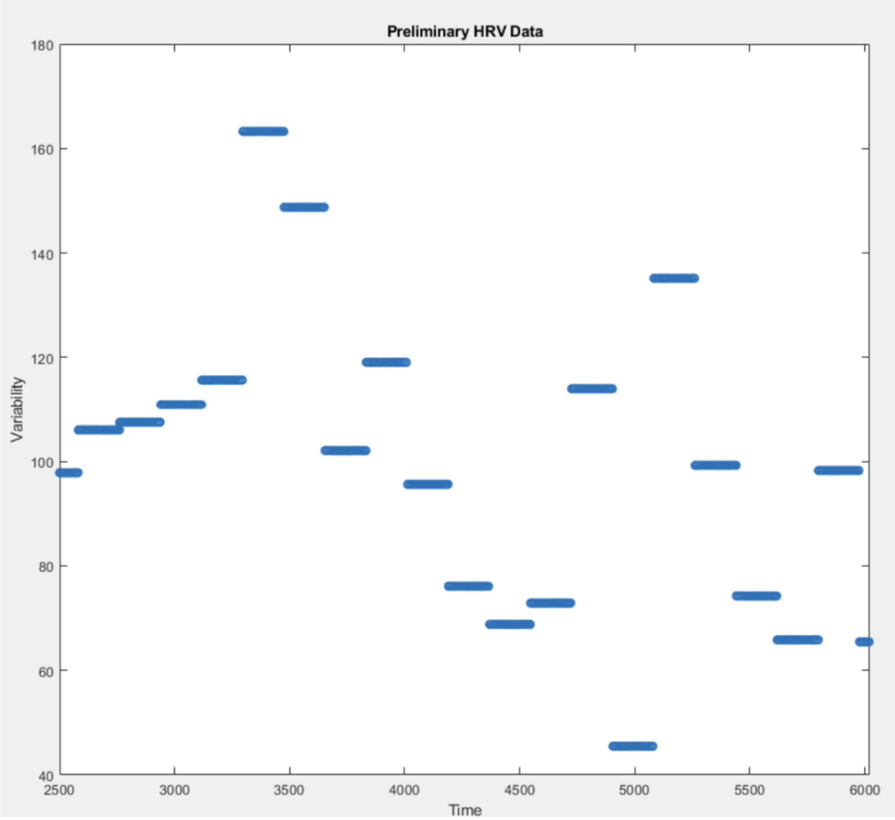

Table 1: Demographics of the study participants.

Subject	**Age**	**Ethnicity**	**Gender**	**Past Experience Watching Medical Procedures?**
1	20	Asian American	Male	No
2	21	Caucasian/Asian American	Male	No
3	33	Caucasian	Male	Yes

Table 2: Kruskal-Wallis one-way ANOVA p-values for each EEG channel across all subjects to assess the statistical difference between the clinical immersion video to the boring and exciting videos. A * denotes that the null hypothesis is rejected at a 1% significance level.

Subject	**Channel F3**	**Channel F4**	**Channel P3**	**Channel P4**
Subject 1	0.4691	0.3364	0.1987	0.7039
Subject 2	$1.7408\text{x}10^{-8}$ *	$3.4188\text{x}10^{-7}$ *	$3.5425\text{x}10^{-7}$ *	$4.8518\text{x}10^{-7}$ *
Subject 3	$1.36642\text{x}10^{-5}$ *	$1.1184\text{x}10^{-5}$ *	0.3103	0.5905

Table 3: Boredom Control Video Questionnaire

Questions	**Subject 1**	**Subject 2**	**Subject 3**
On a scale from 1-9 how bored were you while watching this video? (1=Not bored at all, 9= Extreme boredom)	9	9	9
On a scale from 1-9 how interested were you while watching this video? (1=Not engaged at all, 9=Intense engagement)	2	1	2
Roughly how many minutes into the video until you started to get bored?	3 minutes	30 seconds	4 minutes
Did you fall asleep/fight to stay awake? (1=Completely awake, 9=Fell asleep)	8	9 (Fell asleep about halfway through the video)	7
Relatively speaking, how long did the video feel to you?	30 minutes	10 minutes (excluding sleep)	25 minutes
On a scale from 1-9 how tired were you before conducting the experiment (1=completely awake, 9=completely exhausted)	3	3	7

Table 4: Interesting Control Video Questionnaire

Questions	**Subject 1**	**Subject 2**	**Subject 3**
On a scale from 1-9 how bored were you while watching this video? (9 high) If so, when	5	4	3
On a scale from 1-9 how interested and engaged in the video were you? (1=Not engaged at all, 9=Intense engagement)	6	5	7
Roughly how minutes into the video until you started to get bored?	10 minutes	10 minutes	10 minutes
Did you fall asleep/fight to stay awake? (1=Completely awake, 9=Fell asleep).	6	3	3
Relatively speaking, roughly how long did the video feel to you?	20 minutes	10 minutes	15 minutes
On a scale from 1-9 how tired were you before conducting the experiment (1=completely awake, 9=completely exhausted)	5	4	6

Table 5: VR Clinical Immersion Video Questionnaire

Questions	**Subject 1**	**Subject 2**	**Subject 3**
On a scale from 1-9 how bored were you while watching this video? (9 high) If so, when	3	2	6
On a scale from 1-9 how interested and engaged in the video were you? (1=Not engaged at all, 9=Intense engagement)	8	8	3
Roughly how minutes into the video until you started to get bored?	10 minutes	Did not get bored	10 minutes
Did you fall asleep/fight to stay awake? (1=Completely awake, 9=Fell asleep).	1	1	7
Relatively speaking, roughly how long did the video feel to you?	25 minutes	20 minutes	23 minutes
On a scale from 1-9 how tired were you before conducting the experiment (1=completely awake, 9=completely exhausted)	7	5	6