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Comparative Study of Emotion Elicitation Between 4K UHD Screen and Virtual Reality Using EEG

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Abstract. Emotion elicitation is part of the emotion recognition approach. The devices used to assist participants in triggering emotions towards stimuli are essential. The selection of the proper emotion elicitation device can influence people's emotions so that it helps in detecting sharper emotions. Virtual reality or VR is widely used because it bridges the lab-controlled and the real world. However, usage of virtual reality becomes a limitation for users, such as motion sickness, age segmentation and, non-ergonomic design when used overlapping the head with EEG. This research compared emotion elicitation between 4K Ultra High Definition (UHD) screens with much higher clarity and resolution than the virtual reality, namely Oculus Quest 2. This research uses power spectral density as feature extraction. This study shows that the power spectral density feature in theta, alpha, and beta band power, the overall mean in all brain regions or only in the frontal lobe, excels in virtual reality devices. In a calm environment, an increase of theta band power shows higher relaxation. The dynamic environment is evidenced by an increase in alpha and beta band power, which shows an increase in arousal. However, the superiority of the 4K UHD resolution is not a better guarantee in emotion elicitation.

INTRODUCTION

Human emotion includes in the affective computing field in the topic of human behavior[1]. This research deals with behavior, decision-making, and mental health[2][3]. Emotions recognition can conduct in various ways, such as through voice, facial expressions, body gestures [4], and physiological measurements[5]. Emotion recognition through facial expressions has a large amount of research. However, this technique is unreliable because it can be engineered and is less natural [6]. On the other hand, the emotion recognition technique through physiological measurements is a trending and reliable technique [7].

Emotion recognition is divided into three approaches; emotion modeling, classification, and elicitation [1]. Emotion elicitation relates to stimuli that can affect affective states [1]. Stimuli are grouped into two groups, namely active emotion elicitation and passive emotion elicitation [1]. Passive emotion can be in the form of pictures, music, or videos. The video combined with audio-visual is one of the stimuli that most influence human response [8].

The device used in displaying stimuli divides into three devices; non-immersive, semi-immersive, and immersive devices. Non-immersive devices usually use a screen, while immersive devices use virtual reality. Comparative research between the screen and virtual reality has been done in [9][10][11][12]. These studies resulted in the advantages of using virtual reality as an immersive device. However, other studies prove that there is not too much of a significant difference between 2D and 3D. It depends on the content of the stimuli themselves[13].

This research will examine the comparison of emotional patterns between non-immersive devices and immersive devices. Stimuli are videos with a calm and dynamic environment. The difference with previous studies is the resolution to be compared. Devices used are a 43” 4K UHD screen and Oculus Quest 2. The resolution comparison is 3840 x 2160 pixels on the 4K UHD Screen and 1832 x 1920 pixels on the Oculus Quest 2. The resolution affects eye comfort and visual fatigue [14]. In addition, the resolution and size of the screen affect a more positive mood and high

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attendance [15][16]. Processing results of EEG recording to determine pattern differences on the 4K UHD screen and virtual reality that uses frequency domain analysis with the power spectral density (PSD) feature. The method used is Fourier Fast Transform (FFT). The feature extraction used is the mean FFT of five power bands, namely alpha, beta, gamma, delta, and theta results on 14 channels on Emotive Epoc X.

This research aims to compare the use of device in emotion elicitation between 2D and 3D. Choosing the right emotion elicitation device can help detect sharper emotions. The device that is considered the best at this time is virtual reality as an immersive device[9][10][12][11]. However, virtual reality has several disadvantages, such as motion sickness [9][17] and overlapping use when combined with EEG [18][19], so it requires a new device that is simpler. In addition, this testing utilized the increased resolution available on the 4K UHD screen. Other studies have not carried out comparative testing on the UHD screen.

RESEARCH METHODOLOGY

Participants

This research tested was conducted at universities consisting of 35 participants; 12 women and 23 men with an average of 24 years old. Approximately 90% of participants had never used virtual reality. In addition, five participants were excluded from the sample due to dizziness when using VR, did not complete all trial stimuli, and poor signal quality when recording EEG Quality Signal Emotive Epoc X. The amount of data analyzed was 30 people, with eight women and twelve men.

Experiment Protocol

This research used a 4K 43” Smart Samsung screen and HMD Oculus Rift Quest 2. The EEG signal was taken using Emotiv Epoc X with 14 channels and a 128Hz sampling rate. Motion Sickness is one of the obstacles in using virtual reality so that the experiment used a comfortable seat. The stimuli used consisted of two classifications, namely calm environment, and dynamic environment. The video consists of two environments that will test on a different device. Each participant will see four videos with a duration of two minutes each. An overview of the Stimuli used is shown in Table 1.

TABLE 1. Stimuli Used

Video	4K Screen	Virtual Reality	Source
Calm Environment	Virtual Nature 360-5.7K	Virtual Nature 360-5.7K	Youtube ECOVR
Dynamic Environment	Extreme 360 Roller Coaster VR-4K	Extreme 360 Roller Coaster VR-4K	Youtube 3D VR-360Videos

The procedure carried out was that participants fill out a self-description questionnaire before testing. The questionnaire consists of data on (i) age, (ii) gender, (iii) use of glasses, (iv) use of contact lenses, (v) hours of sleep in the last 24 hours, (vi) use of virtual reality, and (vii) valence level of participants before recording the EEG data. Further, participants were given an explanation about the experiment to be carried out, the SAM questionnaire, and the procedure for using VR Oculus Quest 2. Participants sit in comfortable chairs with a room temperature of 24 degrees. The right and left of the screen were covered when conducting experiments on a 4K UHD screen device; thus, participants could focus more on the stimuli. In virtual reality device, Oculus Quest 2 is placed on a tripod to not interfere with the participants’ focus. However, Oculus did not put on the head because it will interfere with the Emotiv Epoc X usage in retrieving EEG signals.

Participants got the freedom to stop the experiment if they felt dizzy or uncomfortable using virtual reality or 4K UHD screen device. Then, participants had to relax for 43 seconds by relaxing their eyes closed, relaxing by opening their eyes while listening to relaxing music. After experimenting, participants filled out the SAM questionnaire to determine the conditions of valence and arousal[20]. The EEG recording results were cut for 41 seconds in the initial due to the relaxation period, which carries out based on the instructions of the Emotivpro 2.7.0.34 software. Then, it was carried out a band-pass between 0 to 60 Hz.

Processing and Feature Extraction

EEG recordings of 30 participants were analyzed in the frequency domain using FFT. The output of FFT is power bands. Power bands are divided into five frequencies, namely delta (0.5 – 4 Hz), (ii) theta (4 – 8 Hz), (iii) alpha (8 – 13 Hz), (iv) beta (13 – 40 Hz), (v) gamma (30 – 50 Hz)[21]. Here, FFT is carried out on each channel of the four trials on thirty subjects. FFT in (1), where X is EEG data, N is the length of EEG data, k is an index iteration from 1 to N, and i is the imaginary unit. The feature extraction stage in the frequency domain used the mean of five power bands. Mean is the average of the data. It is useful to maintain the accuracy of the output data from some noise data[22].

$$X_k = \frac{1}{N/2}\sum_{k=1}^{N/2} X_{2n} e^{(2\pi i)2nk/(\frac{N}{2})} + \frac{1}{\frac{N}{2}}\sum_{k=1}^{\frac{N}{2}} X_{2n+1} e^{\frac{(2\pi i)2nk}{\frac{N}{2}}} \quad (1)$$

Then, The frequency domain will be analyzed using Power Spectral Density (PSD) from each power band. It intends to investigate the dominance of the power band in experiments conducted through 4K UHD and Virtual Reality devices. We will examine the increase of PSD in the theta power band to check the relaxed state of the calm environment. In addition, we will test the increase in alpha and beta power bands on the dynamic power band to investigate the rise in arousal. Figure 1 shows several kinds of feature extraction options in the frequency domain[23].

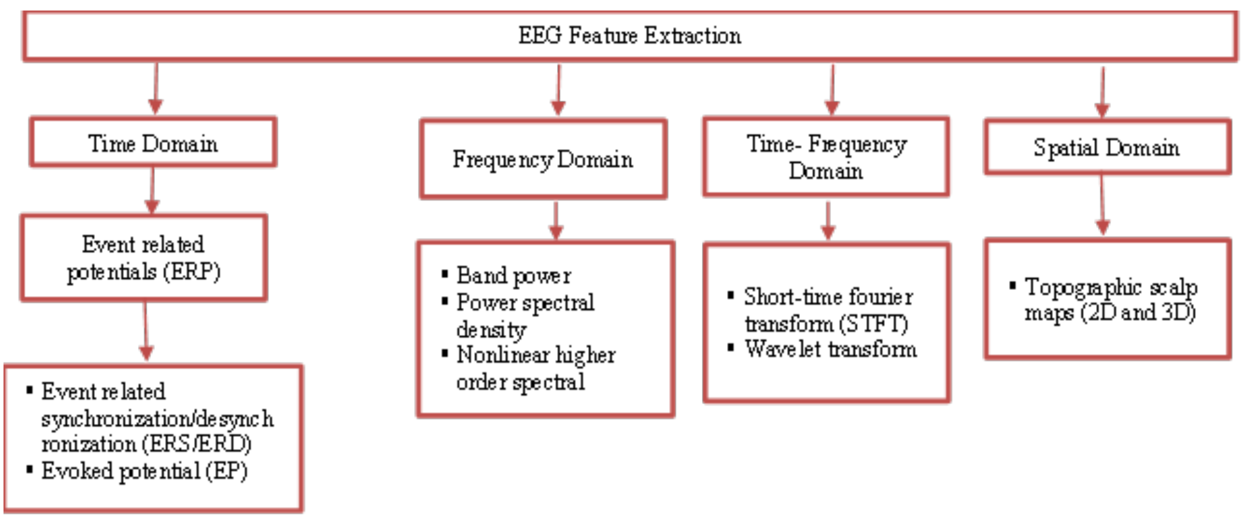


FIGURE 1. EEG Feature Extraction

RESULT AND DISCUSSION

This research compares 2D and 3D devices in emotion elicitation. The compared device is a 4K UHD screen with a higher resolution than virtual reality. The EEG used to measure brain signal activity has 14 channels, namely AF3, AF4, F3, F4, FC5, FC6, F7, F8, T7, T8, P7, P8, O1, and O2. The F code in front of the channel describes the channel in the frontal part. Code T shows the temporal domain, Code P for parietal, and Code O for Occipital. An overview of channel placement is shown in Fig. 2 [24].

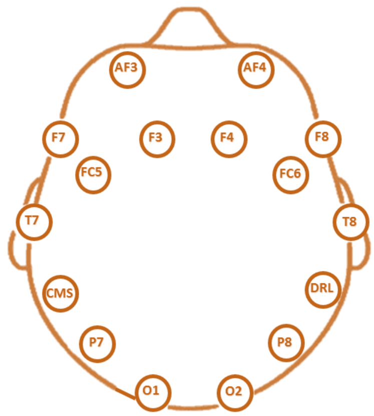
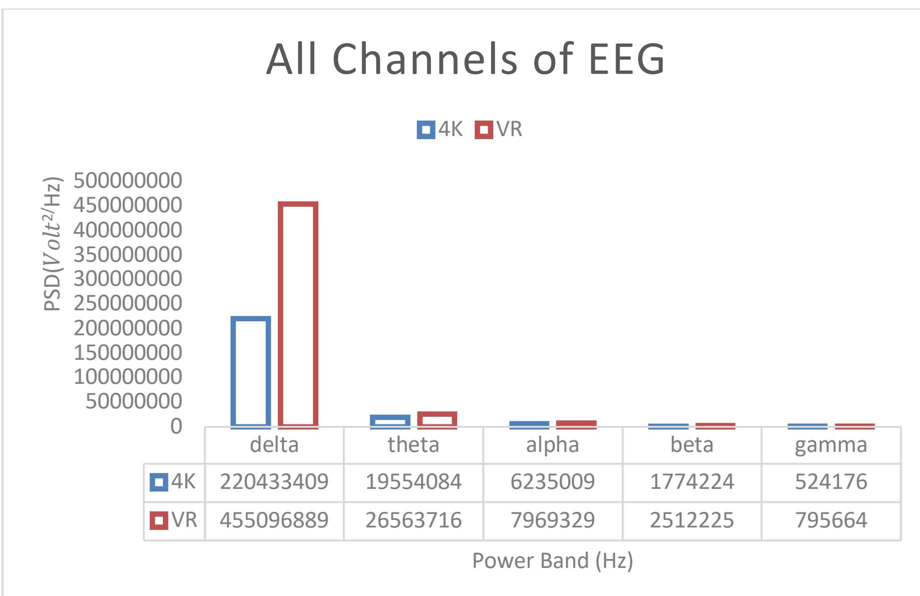


FIGURE 2. Channels on Emotiv Epoc X

The analysis carries out by looking at the average power spectral density condition in each power band. It intends to find a signal strength comparison in two different devices with the same stimuli in Table 1. The PSD difference generally results in a calm and dynamic environment shown in Fig. 3 and Fig. 4.



	delta	theta	alpha	beta	gamma
4K	220433409	19554084	6235009	1774224	524176
VR	455096889	26563716	7969329	2512225	795664

FIGURE 3. The Mean of PSD Pattern at All-Region in Calm Environment

In Fig. 3, a video calm environment experiment uses a natural environment for relaxation purposes. PSD results show that virtual reality device has superior strength in all signals than 4K UHD screen device. In Fig. 4, a video dynamic environment experiment using a roller coaster to cause stress. Again, PSD results show that virtual reality device has absolute advantages in overall band power. Furthermore, it shows that virtual reality as an immersive device for two different environments is still the best device for emotion elicitation.

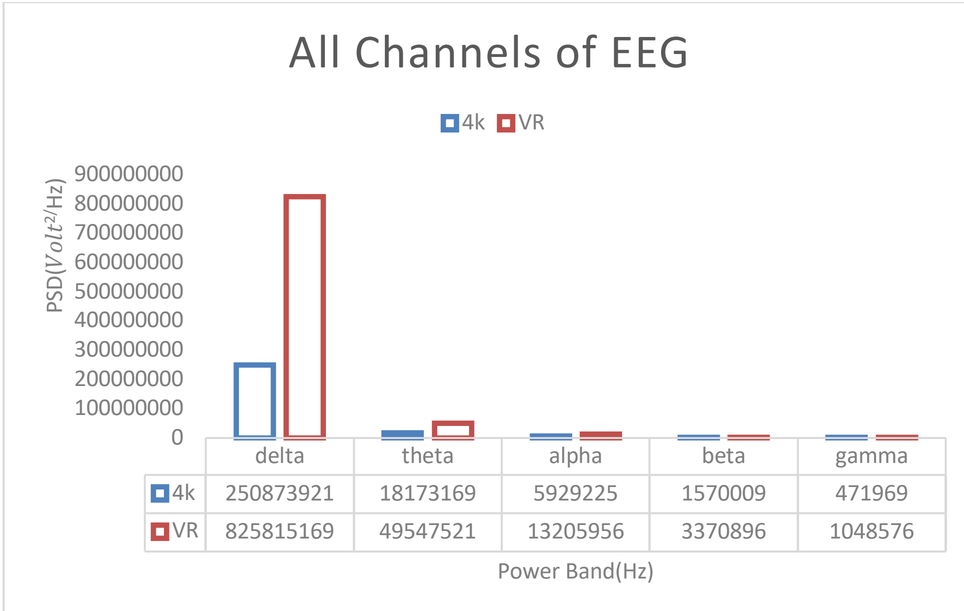


FIGURE 4. The Mean of PSD Pattern at All-Region in Dynamic Environment

Each power band is averaged as a whole on 14 channels in the previous analysis. The following analysis is analyzed based on the part of the brain. The brain parts were classified based on four interests adapted to the Emotiv Emotiv Epoc X channel; Frontal, Temporal, Parietal, and Occipital. The frontal lobe was analyzed because this area was detected as the center of all information in exploring emotions[25][26]. In addition, the Frontal Lobe has the highest electrode feature rating Frontal Lobe[27]. An overview of the comparison results shows in Fig. 5 and Fig. 6.

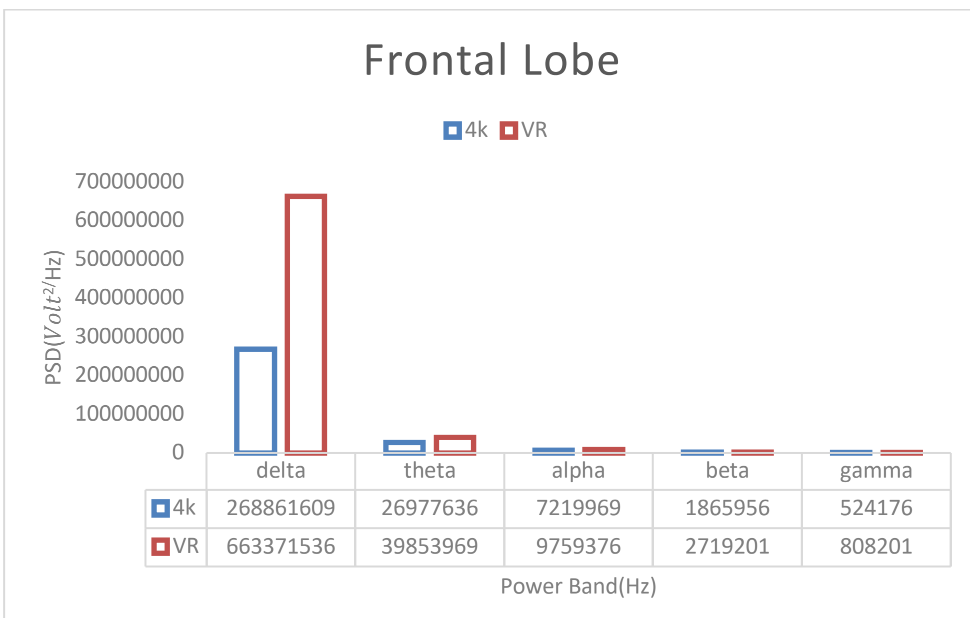


FIGURE 5. The Mean of PSD at Frontal Lobe in Calm environment

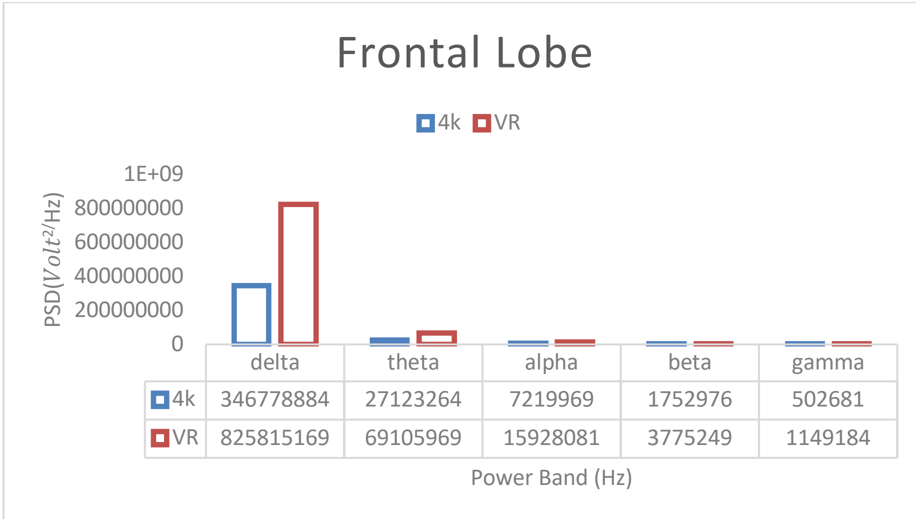


FIGURE 6. The Mean of PSD at Frontal Lobe in Dynamic environment

Figures 5 and 6 show the same superiority of all power bands in frontal lobe analysis, namely on virtual reality devices. Thus, at this stage, the summary of the comparative study as a whole is shown in Table 2. Table 2 illustrates the same pattern: all experiments on virtual reality devices are higher than 4K UHD Screens.

TABLE 2. Summary of Comparative Study

PSD of Power Band	All-Region of Brain				Frontal Lobe			
	Calm Environment		Dynamic Environment		Calm Environment		Dynamic Environment	
	4K UHD Screens	Virtual Reality	4K UHD Screens	Virtual Reality	4K UHD Screens	Virtual Reality	4K UHD Screens	Virtual Reality
Delta	lower	higher	lower	higher	lower	higher	lower	higher
Theta	lower	higher	lower	higher	lower	higher	lower	higher
Alpha	lower	higher	lower	higher	lower	higher	lower	higher
Beta	lower	higher	lower	higher	lower	higher	lower	higher
Gamma	lower	higher	lower	higher	lower	higher	lower	higher

For more specific results, we will focus on theta band power in a calm environment experiment. In the theta band power, there is an increase when tested on virtual reality. In addition, there was an increase in alpha and beta band power for dynamic environment experiments when tested in virtual reality. This is in line with the previous research that alpha and beta bands are correlated with arousal states[28][29][30][9], while the theta band is associated with relaxation/meditation states[29][9].

CONCLUSION

This paper discusses the comparison of the device for emotion elicitation. The stimuli used is video. Two videos are compared and have different characteristics, namely calm environment and dynamic environment. The video specifications used in the trial are videos with a minimum quality of 4K and 360 facilities for virtual reality. This research is a fair comparison. In previous studies, comparisons of device elicitation using screens with resolutions below 4K UHD resulted in superior virtual reality as an immersive device**.** However, this experiment wanted to prove the influence of high resolution and clarity innovation on the 4K UHD screen. Analysis in the frequency domain using FFT by analyzing the power spectral density (PSD) feature shows the dominance superiority in all band power, namely: delta, theta, alpha, beta, and gamma on virtual reality devices. These results have the same pattern either in all brain regions or only in the frontal lobe. Three bands power indicate the strength of the device in virtual reality. In the calm environment experiment, an increase in theta indicates a relaxed state. While in the dynamic environment experiment, the increase in alpha and beta power bands showed a rise in arousal. The experimental results show that the 4K UHD screen device is inferior to virtual reality as an immersive device. Higher resolution in the 4K UHD screen does not affect emotion elicitation performance.

The existing challenge is the lack of videos with both specifications, namely 4K resolution and 360 videos. In the pre-trial process, a survey was conducted on 15 participants to select interest videos. Many videos with 4K specifications have excellent graphics but cannot test because they do not have 360 facilities to try virtual reality. Tropical Beach 4K Ultra HD Nature Video - Beautiful Maldives places on earth with Relaxation Music in Deep music channels on Youtube is one of the most exciting videos in the pre-experiment from the questionnaire results of 15 participants because of the color composition and the way of capturing pictures. Future research can compare the 4K UHD screens with virtual reality on more varied emotions with more exciting video content such as Maldives videos. It is to ensure and prove previous research that focused on stimuli content than the device.

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