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Comparative Study of Electroencephalogram Based on Virtual Reality Experience

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Abstract: In this study, we aim to compare and analyze the EEGs of the stable VR images and the dynamic VR images. We selected KBS VR content 'Summteo VR: relax place' for stable VR images and 'Roller Coaster VR' for dynamic VR images. 'Summteo VR: relax place' is a 360-droned stable image of a 5 min long shot of forest, river and sea. 'Roller coaster VR' is a 5 min playground driving Viking VR image that swings vertically and horizontally. We analyzed the EEG response of each examinee during each video viewing. In the experiment, we used muse for EEG, HMD leap for VR and Samsung VR smartphone. In the experiment, the examinee performed EEG measurement at each view of each image and extracted the data value from the application associated with muse of the EEG.

Key words: EEG, virtual reality, KBS VR, muse for EEG, Summteo VR, smartphone

INTRODUCTION

KBS aired live in September 2016 'Summteo VR' contents via. its terrestrial broadcasting network and mobile communication network at the same time. An increasing pursuit of expanding the VR content production market calls for studies on viewer responses. The images in virtual reality features wider viewing angles compared to flat and S3D images, resulting in a greater sense of immersiveness. In addition, the virtual reality experienced with the HMD implements 360° images through the head tracking technology which allows viewers to deeply immerse themselves in the image. In general, the VR produces 360° images and creates a greater sense of so-called presence than that of 2D images. This sense of presence becomes more firm and solid as images become sharper with the development of technology and the mutual interactive situation builds up as it is created in image with the VR attracting keen attention among viewers as a visual medium that successfully implements this sense of presence. Steuer attributes a sense of presence to two major factors of a feel of vitality and interactivity. "A feel of vitality" refers to the technical attribute that produces a more vivid environment as close as possible to the reality. That is the excellence of VR imaging technology is taken into account in expressing the unreal as if it were real. Second, the interactivity means that the environment expressed changes or modifies depending on the user's behaviors and reactions. The eye tracking of HMD today is sophisticated enough to support the VR interaction. The photographed environment follows the user selected line of sight and the current HMD satisfies the subjective perspective of users. Steuer (1992) in this case, the presence is amplified. The effect of presence is utilized to develop the medical rehabilitation content. Neurological diseases including brain injury and stroke involve degradation of various cognitive functions. Kim (2016) cognitive impairment is likely to be persistent and more importantly, causes social and occupational problems in general which calls for rehabilitation (Gronwall and Wrightson, 1981). The functional VR games are increasingly used as a rehabilitation program to promote the cognitive function. The functional games intended for medical purposes include exergaming, virtual game and the attention distraction game (Michael and Sande, 2016). The medical effects of these functional games come from the presence of VR. As a matter of fact, the rehabilitation effects for patients with damaged spinal and brain-nervous systems have been reported (Betker *et al*., 2007). On the other hand, the VR has shortcomings of causing dizziness due to various reasons. Currently, it is required to wear an HMD to be able to view VR images. Users who view VR content with an HMD on them experience discomfort, nausea, dizziness and further cyber sickness whose symptoms include severe headache or vomiting. By Kim (2016) cyber sickness is known to be caused by the visual information and the vestibular information and a conflict between them (Gyeong-Han and Hyeon-Taek, 2011). The vestibular

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system that helps maintain the brain balance makes a balance of our postures based on the visual information we obtain but the inconsistency between the visual information from the eyes and the position information felt the body causes sickness. The images seen after being filtered through the HMD are not the visual information while the viewer moves around which prevents the vestibular system from properly working to understand and interpret this information, causing sickness. The 'Best practices for VR/AR use and application's proposed by Korea Virtual Reality Industry Association recommends taking a number of measures to minimize sickness symptoms including latency optimization, frame rate optimization, virtual camera movement optimization, league organization, FOV (Field of View) adjustment, synchronization of sense mismatch, motion platform synchronization, User Interface (UI) placement, sound composition and stereoscopic 3D optimization. This guideline recommends that users take rest for at least 30 min to be able to make a comfortable use of VR (Anonymous, 2018). Viewing the VR content for an extended period of time may cause physical side effects such as dizziness, headache, nausea and eye sore as well as psychological side effects due to excessive immersion. Since, the interactivity and the presence of VR cause cyber sickness it is our primary goal to minimize its impact by presenting these guidelines which should not be taken lightly in producing the VR content in the future (Eun-Ju, 2016).

Description of research: This study has conducted a comparative analysis on the electroencephalography test that appears while viewing the static and dynamic VR images. This study aims to serve as a precedent study to be used to produce real-life VR images in the future that minimizes cyber sickness. KBS adopted 'Summteo VR' and 'Roller coaster VR' as a static and a dynamic VR images, respectively. 'Summteo VR' is a 5 min long calm and steady video shot of forest, river and sea captured by a 360° camera drone.

2D 'Summteo' was originally scheduled to be aired at 10:55 PM following the KBS 9 O'clock news during the weekdays (between Tuesday and Friday) and was intended to have viewers forget about hectic and complex everyday life for a while as a way of mental healing. 'Summteo VR' was produced as a 360° VR shot as a special feature to commemorate the broadcasting day. The program was aired on the my-K channel via. both the mobile VR broadcasting and the terrestrial broadcasting networks. This study has adopted the VR shot of 'Coastal road on the volcanic Island, Ulleungdo', the first of the eight episodes as an experimental shot. 'Ulleungdo Island, coastal road on the volcanic Island' is a VR long-taken shot of rocks and lava terrains in Ulleungdo, an iconic national geological park with the history of 2.5 million years.

'Roller Coaster VR' has selected one of the VR shots uploaded on YouTube. 'Roller Coaster VR' is a 5 min long shot of a viking ride in an amusement park that radically swings both vertically and horizontally.

These two shots have been tagged as a static and dynamic shots in a bid to simplify the evaluation of the experiment. The criteria to determine either a static or a dynamic shot is based on the method of production using the visual acceleration control. As discussed above, a discrepancy between the vestibular system and the visual images causes cyber sickness. Gam Gi-Taek has studied dizziness caused by visual acceleration and claimed that three dimensional images generate convergent eye movements and the acceleration of the visuals and failure to match between the two leads to cyber sickness. If three dimensional images are moving fast enough, the convergence of the two eyes is accelerated accordingly and failure to control leads to inconsistency of convergence which presumably causes cyber sickness among VR viewers (Gi-Taek *et al*., 2009). Meanwhile, Kim conducted tests on subjects based on the operating speed of slow-moving images and found that about 90% of the subjects experienced less cyber sickness (Young-Yun *et al*., 2002).

MATERIALS AND METHODS

The study asked subjects to watch the two video clips above for 5 min, during which their EEG responses were analyzed. The results obtained accordingly enabled to analyze the effects of the VR presence in more detail.

As shown in Fig. 1, the experiment of the study has adopted EEG measurement instrument Muse, HMD Leap

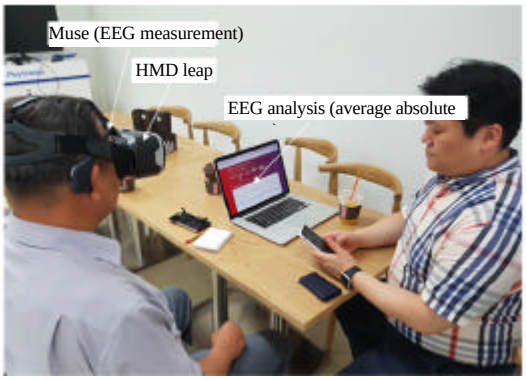

Fig. 1: A scene that compares and analyses the EEG when watching stable VR video and dynamic VR video

as a VR watching tool and Samsung VR smart phone as experiment tools. Muse is an instrument designed to measure electroencephalograms much like a heart rate monitor that detects heartbeats. The muse is equipped with seven sensors (two on the forehead, two behind the ears and three reference sensors) designed to sense minute signals to detect and measure brain activities (Fig. 1).

The experiment measured the electro encephalo grams while the subjects were watching each video clip once and had the application associated with the EEG measurement instrument muse extract the data.

A brain has billions of neurons in it each of which is connected with thousands of other neurons. Communications take place through small electric currents that travel around the enormous network of neurons and brain circuits and these synchronized electrical activities generate electroencephalograms.

When numerous neurons interact in this simultaneous manner, these activities are strong enough to be detected outside the brain. These brain activities are able to be amplified, analyzed and visualized by placing electrodes on the scalp which is called Electro Encephalography or EEG. The analysis was focused mainly on alpha waves, beta waves and gamma waves among various EEGs.

Alpha waves are a part of the EEG with the frequencies ranging between 8 and 13 Hz and are generated when we feel at ease physically and mentally. They are detected when we close our eyes and feel relaxed and comfortable. Beta waves, also known as stress waves have frequencies ranging between 13 and 32 Hz and are generated in bulk when we are tense and anxious. Gamma waves have frequencies ranging between 32 and 100 Hz and are generated from intense awareness and overriding thrill.

The EEG results used in this study use the absolute band power. The logarithm of the sum of the power spectral density of the EEG data is extracted for each of the alpha, beta and gamma wave channels. The use of logarithm results in a negative value if the absolute power is <1. It is expressed in logarithmic scale with the unit of Bels (B). The experiment shows the subjects each piece of content for 3 min, followed by analysis using 1 min except the stabilization time.

RESULTS AND DISCUSSION

The study results have shown that 'Summteo VR' content resulted in stable brain waves with no significant variation compared with 'Roller coaster VR'. Figure 2 a shows the average absolute band power of alpha waves over time. When it comes to the $_{\beta}$-wave indicating mental and physical stabilities, 'Summteo VR' shows a more stable graph than that of 'Roller coaster VR'.

However, in the first half and the second half session, 'Roller coaster VR' generated more alpha waves. In Fig. 2 b shows that 'Rollercoaster VR' generated more $_{\beta}$-waves indicating unstable conditions than 'Summteo VR' which indicates that 'Rollercoaster VR' is much higher than 'Summteo VR' in terms of the degree of intense awareness. Figure 2c depicts the graph of $_{\gamma}$-waves that are generated at the time of intense awareness and thrill where 'Roller coaster VR' generated more $_{\gamma}$-waves than 'Summteo VR'. In addition, 'Summteo VR' indicates an overall s table state with no significant changes in the amplitude of the graph (Fig. 2).

This study has adopted brain wave measurement as a method of analyzing virtual reality contents. The equipment used in the experiment is a portable device called 'Muse' which can also be called a meditation training instrument that tracks and visualizes 'peacefulness'. In general, 'Summteo VR' is presumed to

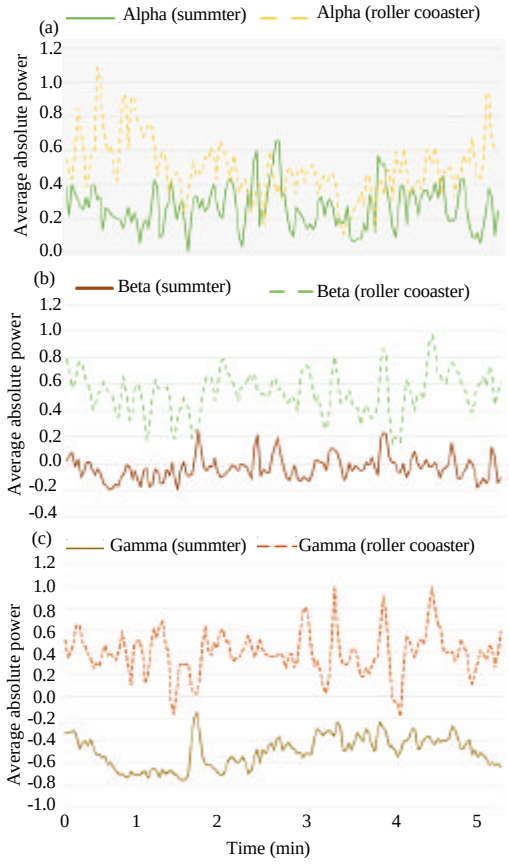

Fig. 2: Comparative EEG between KBS 'Summteo VR' and 'Roller Coaster VR'; a) Alpha waves; b) Beta waves and c) Gamma waves

generate more alpha waves but the experiment showed 'Roller coaster VR' actually generated more alpha waves which is considered to be an error caused by the insufficient number of subjects. It is noted that since, 'Summteo VR' shows an overall stable state without much fluctuations it shows stable and reliable results with little fluctuations between the viewing sessions. Beta waves, a sign of an unstable state were generated a lot in 'Roller coaster VR' due to the dynamic presence. It presumably causes increasing dizziness which in turn causes cyber sickness. Gamma waves that indicate a state of excessive thrill and arousal are considered to be generated a lot due to the dynamic presence 'Rollercoaster VR'.

'Summteo VR' creates a more stable graph than 'Rollercoaster VR' which is considered to be effective in virtual reality presence that requires healing or mental stability. The analysis of the alpha, beta and gamma waves enabled us to understand that 'Summteo VR' contributes to maintaining a stable emotional state. A radical dynamic video triggers dizziness, resulting in EEGs indicating unstable mentality. Further, studies will be needed to determine how this affects the pleasure of presence. In conclusion, a stable video clip of 'Summteo VR' is shown to create more stable mental state than 'Rollercoaster VR' in terms of presence and interactivity.

CONCLUSION

Virtual reality images are inevitably associated with cyber sickness as long as they rely on HMDs. However, the pleasure of presence is doubled due to improved VR images and highly functional HMDs. 'Summteo VR' intended for healing gives pleasure of presence thanks to stable images shot by drones equipped with cameras. We also enjoy riding a rollercoaster in the amusement park to feel the dynamic power of action. 'Rollercoaster VR' was produced to serve this purpose. However, 'Rollercoaster VR' causes cyber sickness due to the discrepancies in kinesthesia between the vestibular organ and VR images. The Electro Encephalo Graphy (EEG) for dynamic VR images generates unstable EEG responses to dynamic VR presence, causing cyber sickness.

SUGGESTIONS

The study findings suggest that the 360 R image EEG measurements will be able to provide the basic data in generating the image grammar in terms of two aspects of the most basic and fundamental human psychologies or peacefulness and anxiety.

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