The Correlation Analysis Between Cybersickness and Postural Behavior in Immersive VR Experience

Ying Zhong[1], Ke-Ao Zhao[1], Leping Zhang[1], Fangming Zhao[1], Wentao Wei[2] and Feilin Han[1]

[1]Department of Film and Television Technology, Beijing Film Academy, and [2]School of Design Arts and Media, Nanjing University of Science and Technology, China

北京电影学院 BEIJING FILM ACADEMY
Department of Film & Television Technology 影视技术系

scan to contact me

Background

Though these immersive and interactive artworks push the boundaries of storytelling and visual demonstration, VR content is still facing user experience issues. Cybersickness is one of the critical problems that keeps users away from VR content. To guarantee comfort, VR content creators need approaches to analyze user experience to avoid triggering cybersickness.

Content creator's need:
- easy-to-use
- impact free
- intuitive
- timly feedback

Inspiration:
- postural instability hypothesis
- observation of hand postural behaviours in practices

We would like to analyze the forearm muscular variation and hand movements to predict when and where participants have cybersickness in an HMD-wearing immersive environment. The possibility of sEMG as a cybersickness measurement was evaluated, and user studies were designed to investigate the correlations between cybersickness and postural behaviours.

Methods

Study design

Experiments were designed as a **within and between-subject study**, using the cybersickness intensity, forearm muscular variation, and hand movement as dependent variables. The experiments had four sessions (one instruction session and three experience sessions) to collect physiological data and self-reported cybersickness intensity from participants. The overall data collecting and analysis process is shown as Figure 1 illustrated.

Data collecting:
- Groundtruth: measured by Simulator Sickness Questionnaire (SSQ) and Fast Motion Sickness Scale (FMS).
- sEMG: measured by Myo Armband and collected during stimulation and before the experiment.
- Video: used to record participants' right forearm and hand movements while viewing VR story.

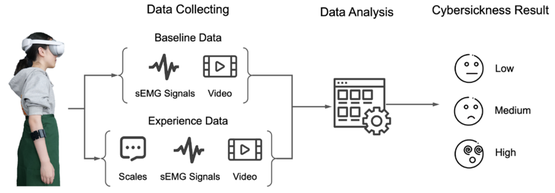

Figure 1. sEMG armband and RGB camera were used to collect data and build the sEMG-CBD (sEMG- video Cybersickness Benchmark Dataset)

Data Analysis

- FMS scores were used to label sEMG and video data as three levels (L as Low, M as Medium and H asHigh).
- sEMG signals were:
  (1) filtered with a highpass filter (cut-off frequency of 45 Hz),
  (2) calculated the average power-spectrum density of each class,
  (3) extracted four features (MAV, RMS, MDF and MNF).
- Videos were used to calculated specific joints' trajectories.

Experimental Results

Simulation content and correspondent sEMG signals and hand joints trajectories

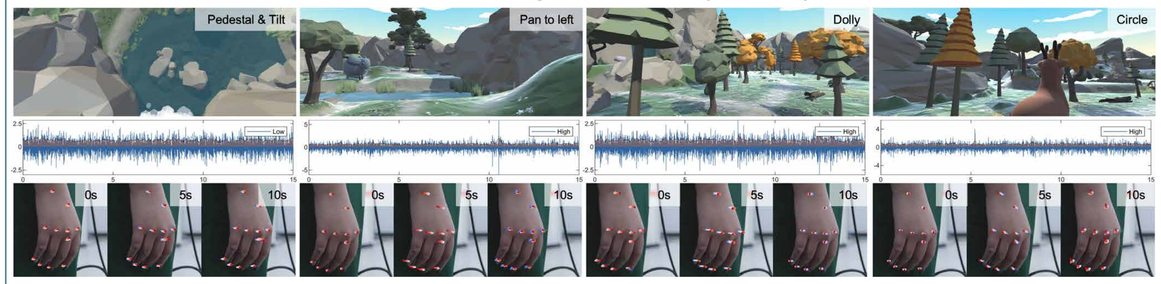

Figure 3. First-row images are the simulation contents of 2nd, 10th, 13th, 14th 15-second. Second-row images show correspondent sEMG signals of channel 7 (muscles flex fingers) from Participant 26, whose cybersickness intensity was L, H, H, and H respectively. Third-row images show the trajectories of hand joint in y and z axis from Participant 26.

Illustration of forearm muscle and hand joints

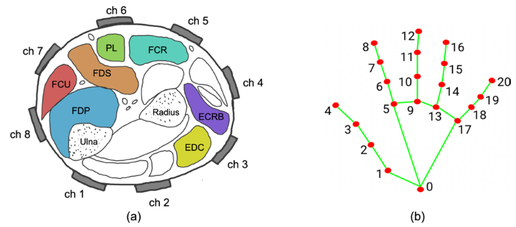

Figure 2. (a) shows the electrode placement of the Myo armband and the forearm cross-section. (b) shows the hand joints provided by Mediapipe and used in our correlation analysis.

Correlation analysis of ratings and sEMG features

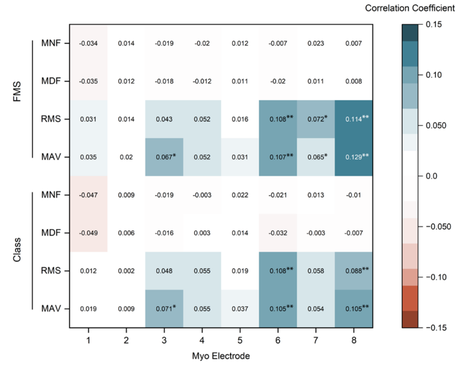

Figure 4. Correlation matrix of FMS ratings and classes and featurecl of 8 channels, which blue represents positive correlation coefficients and red represents negative coefficients. Note: * indicates p-value < 0.05 and ** indicates p-value < 0.01.

sEMG power spectral density comparison

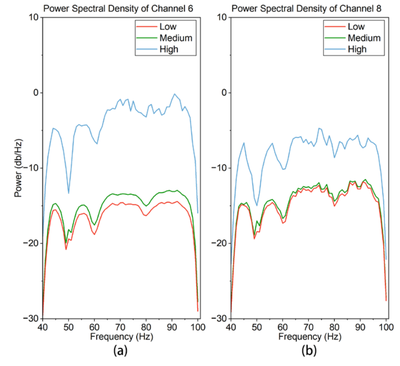

Figure 5. Comparing the sEMG signals and power spectrum density of Low (red), Medium (green), High (blue). (a) and (b) shows the average power spectrum density of channel 6 and 8 respectively.

Difference of SSQ scores

	N	O	D	TS
SSQ0 & SSQ1	<0.001	<0.001	<0.001	<0.001
SSQ1 & SSQ2	<0.001	<0.001	<0.001	<0.001
SSQ2 & SSQ3	0.334	0.172	0.707	0.668

Table 1. Table shows the two-tailed p-values of the Mann-Whitney U test conducted to the four groups of SSQ score. SSQ_0 represent the baseline scores, and the other groups represent the scores after each experience. TS as total score, N as nausea, O as oculomotor, and D as disorientation.

Difference and correlation of joint's movement

	0Y	0Z	1Y	4Y	4Z	5Y	12Z	16Z	20Z
L&H	0.015	0.036	0.017	0.028	0.027	0.029	0.023	0.485	0.014
M&H	0.009	0.106	0.013	0.008	0.125	0.012	0.171	0.267	0.229

(a)

	0X	1X	5X	9X	12X	13X	16X	17X
L&H	0.007	0.016	0.021	0.006	0.031	0.015	0.064	0.008

(b)

	0Y	0Z	1Y	4Y	4Z	5Y	12Z	16Z	20Z
FMS	0.042	0.064*	0.044	0.044	-0.066*	0.040	-0.076**	-0.082**	-0.079**
Classes	0.063*	0.055*	0.063*	0.057*	-0.058*	-0.057*	-0.062*	-0.069*	-0.067*

(c)

	0X	1X	5X	9X	12X	13X	16X	17X
FMS	0.081**	0.064*	0.079**	0.091**	0.073**	0.079**	0.054*	0.080**
Classes	0.071**	0.064*	0.063*	0.075**	0.059*	0.068*	0.052	0.073**

(d)

Table 2. (a) and (b) shows the significant p-value of Mann-Whitney U test conducted to the averages and the total length, respectively. (c) and (d) shows the significant correlation coefficients of correlation analysis conducted to the averages and the total length, respectively. * indicates p-value < 0.05 and ** indicates p-value < 0.01.

Conclusion

Hand joint's movement:
- participants tend to bend fingers or move wrists as the sickness increases.

sEMG signals:
- have features positively correlated with the severity of cybersickness,
- have higher power spectral density when experiencing severer sickness,
- are consistent with hand movements when participants have dizzy feeling.

Participants:
- were unaware of hand postural changes.

Postural instability hypothesis:
- the magnitude of instability related to the intensity of sickness is in accordance with the sEMG signals and hand movement variation.

We conducted a user study to build the sEMG-CBD and employed statistical analysis to summarize the regular pattern of participants' dizziness status under VR experiences. According to the findings of the study, forearm sEMG signals and hand movements significantly correlate with FMS ratings. Participants' forearm and hand movements intuitively reflect their cybersickness intensity. The study results demonstrate that sEMG signals could be employed as a cybersickness measurement in VR viewing experience analysis.

The study presents the possibility of continuously measuring cybersickness during user experience. In future work, we will conduct experiments incorporating sEMG armband and other physiological sensors to investigate the effect of multimodal methods in cybersickness detection. The methods that have more natural experience will also be investigated for the better application in real-life human-computer interaction and VR content production.

Acknowledgement

This work was supported by The National Social Science Fund of China (No. 20BC040) and the National Natural Science Foundation of China (No. 62002171). Thanks to the participants for contributing to user experience research work.