Literature review of the use of EEG to measure cognitive load (or working memory) in the context of VR or 2D vs 3D environments

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Literature review

During the last decade, emerging technologies for Virtual Reality (VR) and its realistic delivery of the sense of presence (Zou, Liu, Guo, & Wang, 2015) raised the interest in the potential use of VR applications in various fields including entertainment, medical industries, and education ((Zou et al., 2015); (Hamrol, Górski, Grajewski, & Zawadzki, 2013)). However, the research analyzing cognitive load and effects on our information processing mechanism in the 3D environment is yet very limited (Slobounov, Ray, Johnson, Slobounov, & Newell, 2015). In this chapter, we will review the recent literature on the use of Electroencephalography (EEG) to measure the cognitive load in 3D environments in comparison to 2D.

In their seminal paper, researchers ()Slobounov2015 introduce two studies evaluating brain function and human behavior in 3D versus 2D VR scenarios. The focus of one of the experiments was the postural stability and cognitive load. The within-group test was conducted where each participant was exposed to two conditions of a moving room on the force platform: first 2D VR and second fully immersive 3D VR (Slobounov et al., 2015). EEG scans from the study indicated the increase of theta signals in the frontal and central topographical points of interest for the fully immersive 3D environment in the comparison to a 2D environment. This implies a significantly higher load of stimuli processed by the brain. In addition to EEG data, the sense of presence was observed using the measure of destabilization. The data shows that users experience a stronger sense of presence while observing the room motion in fully immersed 3D VR (Slobounov et al., 2015).

Another article from the *International Journal of Psychophysiology* by ()Dan2017 analyzes the cognitive load of the processing events that occur while performing a folding task with guided instructions. A within-group experiment was conducted on 17 participants performing folding tasks of a box and a crane with a 3D and 2D guide. "The digital avatar of the instructor in real size was projected so that it seemed to be demonstrating the folding steps in front of the participant" (Dan & Reiner, 2017) for the 3D condition and a 2D display with the same instructions was displayed for the second condition (for further details refer to (Dan & Reiner, 2017)). The EEG measures of alpha and theta power were used to observe the test participants performance as well as to calculate the cognitive load index (CLI). The experiment results showed that even though, the three-dimensional displayed provided a larger amount of visual cues needed to be processed, the observation of a 2D folding instruction triggered higher theta power . In the 2D condition, users had to accommodate for the lack of spatial cues of a two-dimensional display in order to fully comprehend the multidimensional task that had to be observed and later performed (Dan & Reiner, 2017).

From the results of both of the papers, we could evaluate that immense amount of data provided by 3D environments has higher cognitive load while presenting a stronger sense of presence and contributing towards better performance of special tasks. However, both of the aforementioned studies have their limitations and require further exploration to achieve more consistent results. In addition to that only tasks on a multidimensional level were performed which leaves the question open when it comes to cognitive load observations on the low dimensional tasks in 3D VR compared to 2D VR. Such knowledge is necessary while designing and developing efficient and user friend application that could enhance the learning effects and user performance.

References

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