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Enhancing the Virtual Reality experience using Brain-Computer Interfaces

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Genesis project

GENESIS (Leveraging neuroMarkers for Next-generation Immersive Systems) is a European research project focused on improving virtual reality experiences using brain-computer interface methods, particularly EEG. The project is led by the Centre de Recherche en Informatique, Signal et Automatique de Lille in France, and includes three other partners:

- Centre de Recherche Inria Rennes - Bretagne Atlantique (France)
- ETH Zurich (Switzerland)
- KOÇ UNIVERSITY's Intelligent User Interfaces Laboratory (Turkey)
- University of Essex

The project aims to develop passive BCI systems that can detect users' mental states in real-time and adapt the virtual content to improve immersion and reduce cybersickness. By leveraging neurophysiological markers, the GENESIS project aims to pave the way for the next generation of virtual reality systems.

The GENESIS project is part of the **CHIST-ERA** consortium, which is a collaborative initiative between research funding organizations in Europe and beyond. CHIST-ERA aims to support novel and multidisciplinary research projects that have the potential to lead to significant breakthroughs in information and communication technologies. Funded by Horizon Europe within the European Innovation Council's Pathfinder programme, CHIST-ERA supports high-risk and high-impact research projects, including GENESIS, to strengthen European capabilities in promising new or emerging ICT research topics.

Virtual Reality



Virtual Reality or VR is a "Computer-generated simulation of a three-dimensional environment the user is able to view and manipulate or interact with" [4].

Virtual reality is transitioning from a phase of initial hype to a period of increased adoption and practical applications. One area where VR is predicted to see significant growth is in simulation, with a survey conducted by the National League for Nursing and publisher Wolters Kluwer suggesting that **adoption of VR for simulation could increase from 10% to 45% within the next five years.** [4].

The ever-increasing use of Virtual Reality (VR) has brought forth the need to address the challenges that impede its adoption and undermine its potential to enhance the user experience. The necessity to resolve such issues stems the prospect of its continued growth, which calls for comprehensive measures to be taken to ensure its effective utilization. Failure to address the challenges of VR can impede its development, rendering it less effective and potentially hindering its ability to fully realize its potential as a technology.

The problem of Cybersickness

Cybersickness (CS) is a term used to refer to symptoms, such as nausea, headache, and dizziness that users experience during or after virtual reality immersion [1]. Studies have indicated that this phenomenon affects a majority of virtual reality users, ranging between 60% and 95% of users [1] [5], **with up to 13% prematurely terminating their exposure due to the severity of the symptoms** [1]. Despite being extensively researched, the underlying causes of cybersickness remain uncertain and several theories are actively being investigated[3].

The most widely accepted theory is the sensory conflict theory. It states that the discrepancy between the visual, vestibular and proprioceptive senses cause CS, as well as expectation and experiences [8].

Currently, cybersickness is mostly measured using questionnaires presented after VR exposure. However, they have been criticized due to their subjective and delayed nature:

"Questions remain with regard to what questionnaires of presence and CS are truly measuring [...] according to a meta-analysis, almost 50% of questionnaire studies documented effects of social desirability on their results" [6]

Measuring CS using EEGs

Utilizing Passive Brain-Computer Interfaces (BCIs), specifically Electroencephalograms (EEGs), offers a promising approach to address Cybersickness and enhance the user experience in virtual reality. BCIs provide objective measurements of neural activity to overcome the limitations of subjective assessments, allowing for real-time feedback and mitigation. Moreover, BCIs hold potential to reduce interindividual variance and enable individualized and adaptive solutions.

As such, research in this field has been growing rapidly, as shown in Figure 1.

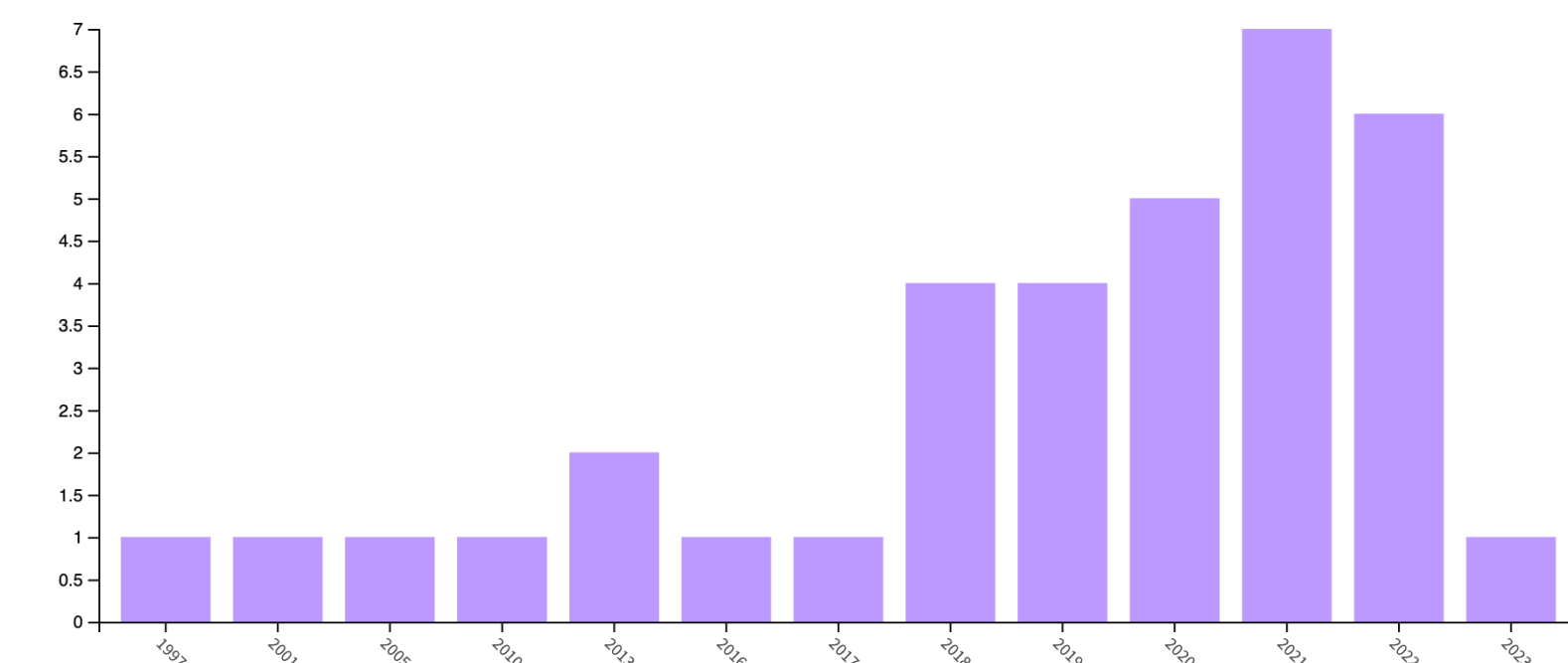


Figure 1. Number of papers studying BCIs and Cybersickness each year

Numerous strategies have been reported in the literature and have exhibited promising outcomes. Considerable investigation has been carried out to identify electroencephalogram (EEG) neuromarkers of cybersickness [2]. Notably, deep learning methods have been effectively employed by several research teams for cybersickness detection, with a mean precision of **93%** [7]. Furthermore, some researchers are extending beyond the scope of detection and exploring multi-subject classification or replicating state-of-the-art performance while introducing constraints.

Future works

The expanding field of research concerning VR and BCIs has generated a multitude of intriguing questions and challenges yet to be addressed. The following list outlines some of the avenues that warrant further investigation in this field, which will be explored in the course of this thesis:

1. Delving into the neuromarkers that correlate with cybersickness,
2. Unraveling the underlying neural patterns that give rise to cybersickness.
3. Establishing a standardized research methodology and vocabulary that spans both VR and BCI domains.
4. Devising novel methods to probe the subjective experience and cognitive state of VR users.
5. Identifying the links between different assessment techniques, such as subjective ratings, BCI measures, and physiological symptoms, to facilitate the detection and monitoring of specific mental states.
6. Utilizing the brain activity data in real-time to dynamically modify the VR experience.

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