Towards Predictive Models for Cybersickness in Virtual Environment: Current State and Future Directions

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Introduction

Background

- Virtual reality (VR) is receiving enough attention to be regarded as a revival era and technologies related to the implementation of VR systems continue to evolve.
- VR systems are applied not only in entertainment but also in various fields such as medicine, rehabilitation, education, engineering, and military. However, negative symptoms and safety aspects of the VR experience (e.g., cyber sickness, fatigue, and mental workload) have been raised.
- Especially, cybersickness, also known as virtual reality sickness, VR sickness, simulator sickness, VIMS, VRISE, or other terms, is a type of motion sickness that occurs when a person's sensory perceptions are mismatched within a virtual environment, leading to discomfort, nausea, dizziness, and other symptoms.
- Thus, effective prediction, assessment, and mitigation of cybersickness are essential for ensuring a seamless user experience and enabling the development of more immersive VR environments.

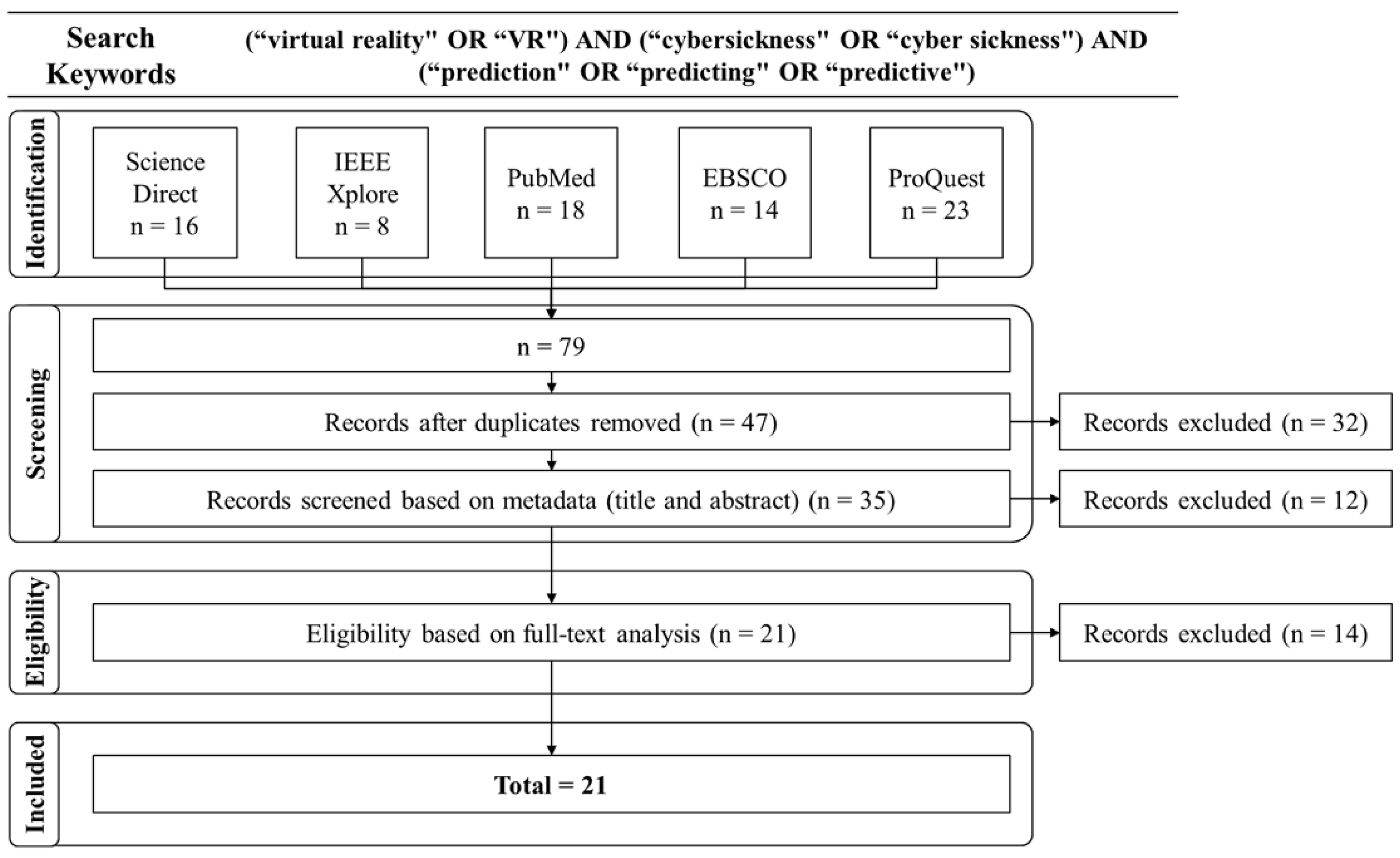
Research Objective

- This study aims to review predicting methods of cyber sickness in VR environments systematically to identify research trends and to clarify future research directions.

Method

The Protocol of PRISMA

- A systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyzes (PRISMA)



Information Source

- To cover a broad spectrum of perspectives of engineering and medical fields, five web databases were selected: Science direct, IEEE Xplore, PubMed, EBSCO, and ProQuest.

Inclusion and prescreening criteria

- The main search keywords were virtual reality, cybersickness, and prediction.
- These words can be used in acronyms or other words.
- In addition, the journal articles in English were searched only.

Eligibility criteria

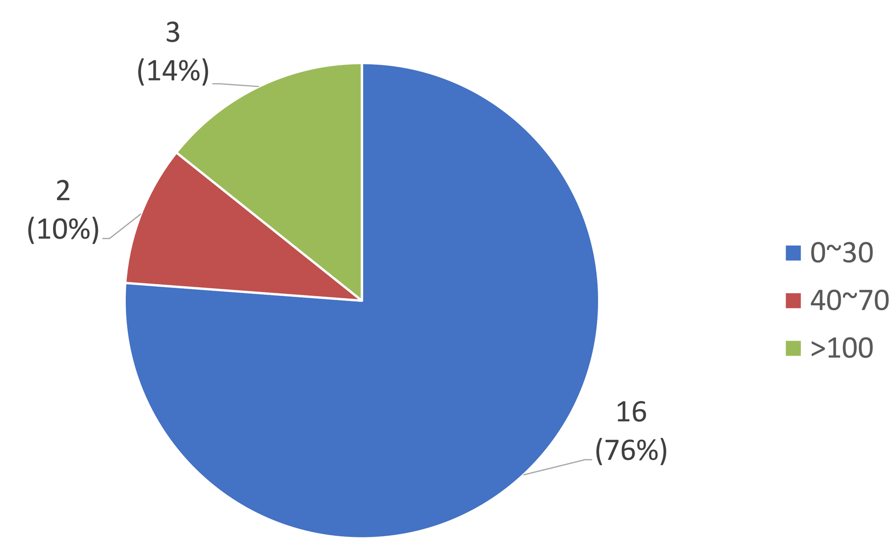
- After the screening process was completed, final articles were selected based on the full-text. In this process, there were two essential selection conditions.
- The selected articles should use VR system and propose the ML/DL based model of predicting cybersickness. No restrictions other than these conditions were made.

Study selection

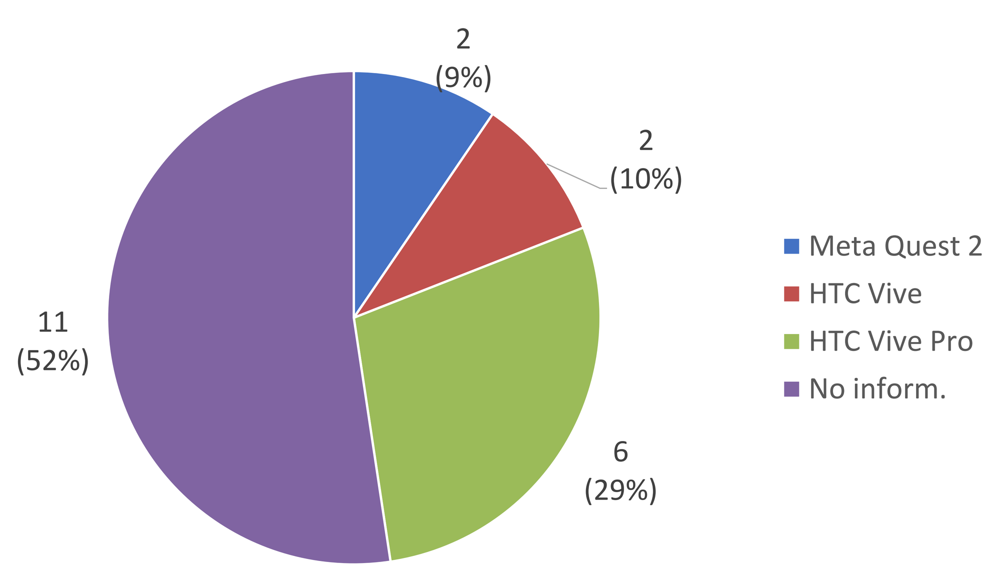
- As a result, 21 articles were found to be consistent with the purpose of this study.

Result

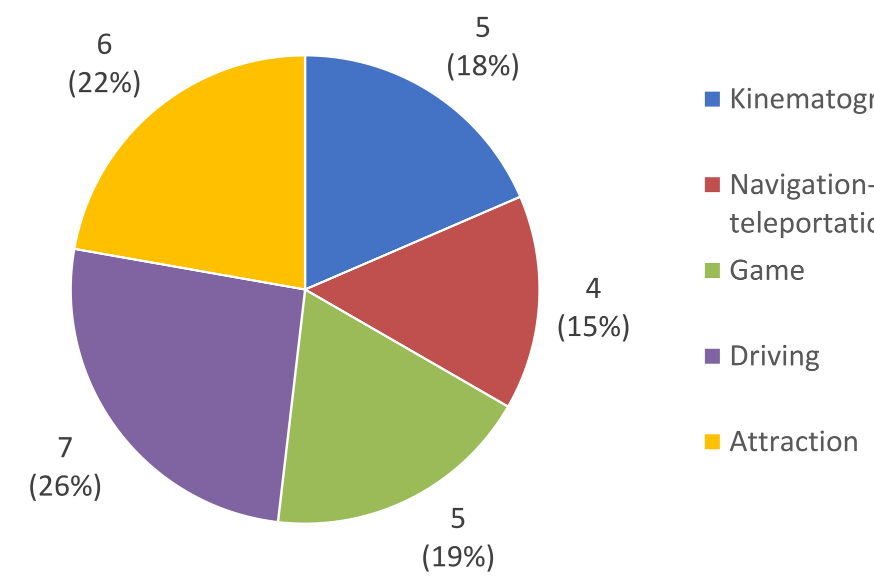
Classification of studies by no. of Subjects



Classification of studies by mean age of Subjects



Classification of studies by VR contents



The classification of studies by user postures and tasks

Main categories	Sub categories	No. of case
Posture	Sitting	15
	Standing	3
	Sitting/Standing	2
Task type	Passive - Watching	11
	Active – Navigating / Selecting / Manipulating	7
	Passive / Active	3

The classification by measurements and extracted features

Main categories	Sub categories	No. of case
Motion analysis	Eye-tracking: Blink, Saccade, Attention weight	8
	Head-tracking: Angular velocities, Accelerations, Jerks	6
	Postural sway/Balance: Angular velocities, Accelerations	2
Bio-signal analysis	Electroencephalogram (EEG): Cz, F7, O2, P3, P4	6
	Electrodermal Activity (EDA): Skin conductance	4
	Electrocardiogram (ECG): HR	2
	Photoplethysmography (PPG): HRV	2

The classification of studies by predictive models

Main categories	Sub categories	No. of case
Deep Learning (DL)	SNN, TL, CNN, LSTM, FCN	12
Machine Learning (ML)	Tree, SVR, kNN, NN, Regression	6
DL + ML	-	3

Future research direction

Categories	Future research direction
Deployable real-time and personalized prediction systems	• Develop cybersickness models that run in real time using only sensors available in consumer HMDs and simple wearables (head/eye tracking, basic PPG/EDA). • Use meta-learning, transfer learning, or few-shot adaptation so that models quickly personalize to each user based on a small amount of individual data and background info. • Connect prediction models to VR engines so that motion, FOV, locomotion mode, or visual effects are automatically adapted to prevent or reduce cybersickness in real time.
Data, labels, and populations for robust generalization	• Build shared, standardized, and publicly available VR–cybersickness datasets with common tasks, hardware metadata, and consistent experimental protocols. • Move beyond single post-exposure scores toward continuous, multi-dimensional labels (e.g., symptom subtypes, time-to-onset) and multi-horizon prediction. • Extend studies beyond young healthy adults to older adults, children, clinical populations, and real industrial/rehab settings with longer-term, repeated VR use.
Mechanisms, biomarkers, and intervention strategies	• Design explainable models (e.g., attention, feature importance, network analysis) to identify key physiological and behavioral markers that drive cybersickness. • Use model outputs to guide concrete interventions (e.g., graded exposure, customized content tuning, neuromodulation like tDCS) and test how these change symptoms and underlying biomarkers.

Conclusion

- This paper conducted a systematic review for the studies that proposed prediction model of cyber sickness in VR system.
- The PRISMA methodology was conducted, and a total of 21 papers were selected to be reviewed.
- The future research direction were suggested into three main categories: 1) Real-time, user-adaptive cybersickness prediction, 2) Standardized datasets and rich evaluation across diverse users, and 3) Explainable models and model-driven interventions.

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