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Comparative Analysis of Deep Learning Techniques for Diagnosing Cybersickness in Virtual Reality Using the Simulator Sickness Questionnaire

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ABSTRACT

Rapid VR adoption across a variety of industries has improved user immersion while also posing problems like cybersickness, which has a substantial negative impact on user satisfaction and retention. Although the Simulator Sickness Questionnaire (SSQ) and other traditional measures have been used for a long time to assess symptoms, new technologies are opening up new assessment options. This study compares state-of-the-art models, such as Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), and Autoencoders, to examine recent developments in deep learning methods for detecting cybersickness. The paper also highlights gaps in present research methodologies and charts the evolution of algorithmic development.

Keywords: Cybersickness, deep learning, diagnostic techniques, SSQ, virtual reality

INTRODUCTION

Virtual Reality (VR) technology has emerged as a transformative force in a variety of industries, enabling immersive experiences that enhance user engagement in gaming, education, and therapeutic applications. Nonetheless, the immersive nature of virtual reality may cause cybersickness, a type of motion sickness characterised by symptoms such as nausea, dizziness, and disorientation, significantly reducing user experience and adoption. The SSQ is frequently employed to evaluate and quantify symptoms, highlighting the significance of efficient cybersickness diagnostic instruments. This paper examines contemporary deep learning methodologies employing the SSQ to identify cybersickness in virtual reality.

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The analysis includes a variety of deep learning architectures, such as CNNs, RNNs, and Autoencoders, and we evaluate their performance as well as implementation challenges related to VR cybersickness.

LITERATURE REVIEW

Table 1 shows that numerous research projects have been conducted to study various techniques for predicting and managing cybersickness in virtual reality settings. These studies include methodology that includes machine learning algorithms like SVMs and XGBoost, as well as complex approaches like transformers and cross-modal integration.

Table 1
Recent works on FDD using DL and MO

Reference	Description	Outcomes & Efficacy	Limitations
Zaidi et al. (2023)	Applies AI with ML algorithms (SVMs, DTs, KNNs) to predict CS outcomes in VR, focusing on minimizing user discomfort and enhancing VR design. DT and SVM showed higher accuracy than KNN.	DT and SVM demonstrated high accuracy in predicting CS, with DT performing better in training. Effective for guiding VR development to reduce CS risk.	The study is limited by its focus on specific algorithms without exploring the full potential of combining various data attributes that could enhance prediction accuracy.
Sameri et al. (2024)	Integrates physiological signals with SSQ scores using XGBoost and XAI for clearer model interpretation in VR Cybersickness assessment.	Achieved 86.66% accuracy in detecting Cybersickness, with strong correlation between physiological data and SSQ scores.	Limited by the static VR setting and the opaque nature of XGBoost, complicating deeper physiological understanding.
Ramaseri-Chandra et al. (2024)	Uses easily accessible demographic data (age, gender, VR exposure) and machine learning classifiers to predict VR cybersickness, offering a non-invasive alternative to biomedical approaches.	Showed that demographic variables can effectively predict cybersickness, challenging the reliance on biomedical data.	Constrained by dataset diversity and size, which affects generalizability and real-world applicability.
Kourtesis et al. (2024)	Implements CSQ-VR with pupillometry to enhance cybersickness assessment in VR, improving on SSQ and VRSQ measures.	Proven to be more reliable and consistent than SSQ and VRSQ, with effective use of pupil size to predict cybersickness severity.	Limited by the specific VR settings used, which may not represent all VR scenarios.
Zhu et al. (2025)	Uses a transformer for bio-signal and a PP-TSN for video feature extraction, with cross-modal fusion for cybersickness prediction.	Achieved 93.13% accuracy, demonstrating effective real-time performance in VR environments.	Limited by dataset specificity, potentially affecting broader VR applications.

COMPARATIVE ANALYSIS

The comparative study of cybersickness assessment and prediction methodologies indicates significant advancements in evaluation tools and machine learning models intended to improve user experience in VR situations (Yalcin et al., 2024). The investigation of cybersickness evaluation tools is shown in Figure 1.

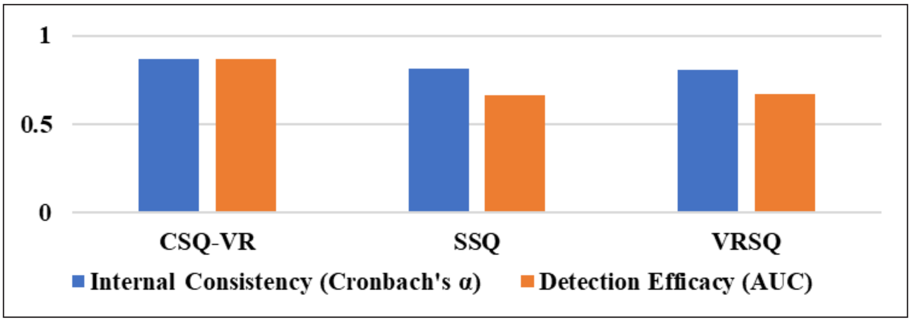

Figure 1. Comparison of cybersickness assessment tools

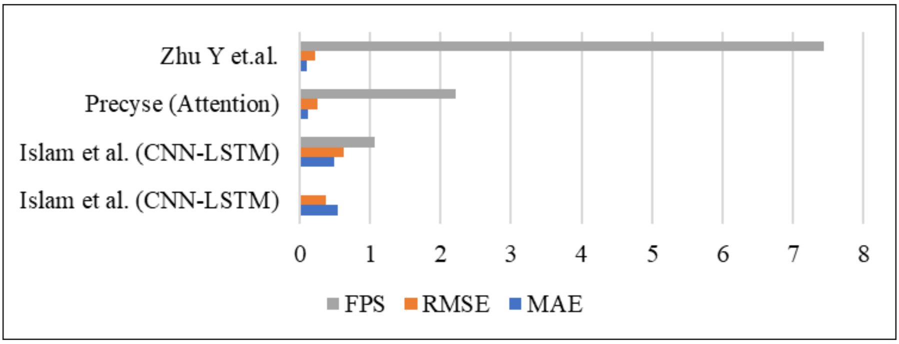

Figure 2. Performance comparison of cybersickness prediction models

Figure 2 compares machine learning prediction models based on their Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and Frames Per Second (FPS) (Zhu et al., 2025). The Sparse-Att model Zhu et al. (2025) demonstrated excellent performance, with the highest FPS for real-time processing, as well as the lowest MAE and RMSE, ensuring exceptional prediction accuracy. In contrast, the Precyse (attention-based) model performed modestlybut had high MAE and RMSE values. The CNN-LSTM models (Islam et al., 2021) had the highest values for both MAE and RMSE, indicating low prediction accuracy and low computational performance. These results underline the strengths of transformer-based architectures with cross-modal fusion, affirming Sparse-Att as the best-performing model for predicting cybersickness in real time with virtual reality (Zhu et al., 2025).

Last but not least, the custom methodologies shown in Figure 3influence the predictions of cybersickness. The results indicate that DeepTCN with Early Shaping exhibits the smallest RMSE and the best predictive accuracy. Additionally, transfer learning improves all the models, namely, DeepTCN and CNN-LSTM. Whereasthe highest RMSE, signifying the worst performance, is reported by models evaluated using sample weighting.

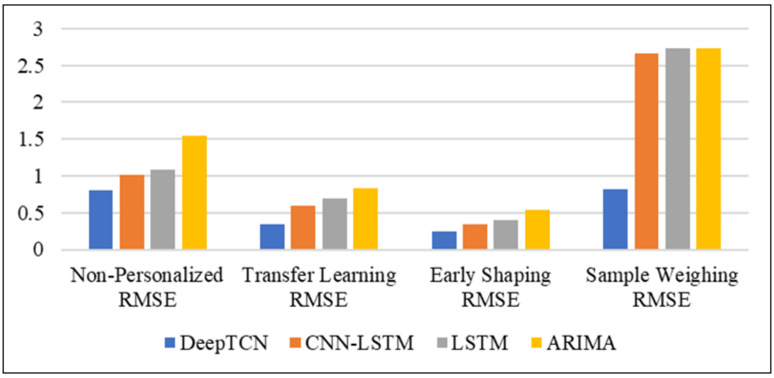

Figure 3. Impact of personalization strategies on cybersickness prediction

CONCLUSION

This thorough examination of cybersickness prediction and detection approaches showed how quickly both objective machine-learning algorithms and subjective assessment tools demonstrated in virtual reality settings. Enhanced questionnaires like the CSQ-VR, evidencing better internal consistency and detection sensitivity as compared with conventional tools like the Simulator SSQ and VRSQ, were regarded as a landmark development in self-reported metrics. Models such as the Sparse-Att Network have attained high accuracy and responsiveness, proving in great measure the workability of the traditional methods, namely, CNN-LSTM.

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