Content-Specific Virtual Reality Sickness: Validation Research

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Abstract

Cybersickness remains a major challenge in virtual reality (VR), with individual susceptibility influenced by factors such as sex, movement patterns, and physiological responses. To investigate these relationships, we analyzed data from ***APAL 2019* (Wang et al., 2023)** and ***Dataset for Cybersickness* (Curry, 2021)**, which include motion tracking and electrodermal activity (EDA) measurements. We normalized and extracted key data points, examining gender-based differences in motion classification and leveraging Simulator Sickness Questionnaire (SSQ) scores to categorize cybersickness susceptibility into high, medium, and low groups. Using the WEKA machine learning toolkit, **we applied multilayer perceptron and other classifiers** to model cybersickness risk based on physiological and motion-related features. Our findings highlight gender-specific variations in motion patterns and their correlation with cybersickness susceptibility, reinforcing prior research on sex differences in VR experiences. The predictive models developed in this study serve as a foundation for future work on adaptive mitigation strategies, such as real-time motion adjustments tailored to individual physiological thresholds. By refining predictive modeling techniques, we aim to enhance VR accessibility, extend user engagement, and contribute to the development of intelligent systems capable of dynamically responding to cybersickness risks.

1. Description

- Investigated cybersickness in VR using physiological and motion-based data.
- Focused on demographic differences, especially among women and passive viewers.
- Used *APAL 2019* and *Dataset for Cybersickness*.
- Extracted head and torso movement (**max/min values on X, Y, Z axes**).
- Analyzed electrodermal activity (**EDA**) spikes as physiological markers.
- Classified users into high, medium, or low susceptibility via SSQ scores.
- Applied machine learning (e.g., **multilayer perceptron**) in WEKA.
- Found patterns linking motion and EDA to cybersickness risk.
- Proposed real-time, personalized mitigation strategies to enhance VR accessibility.

2. Workflows

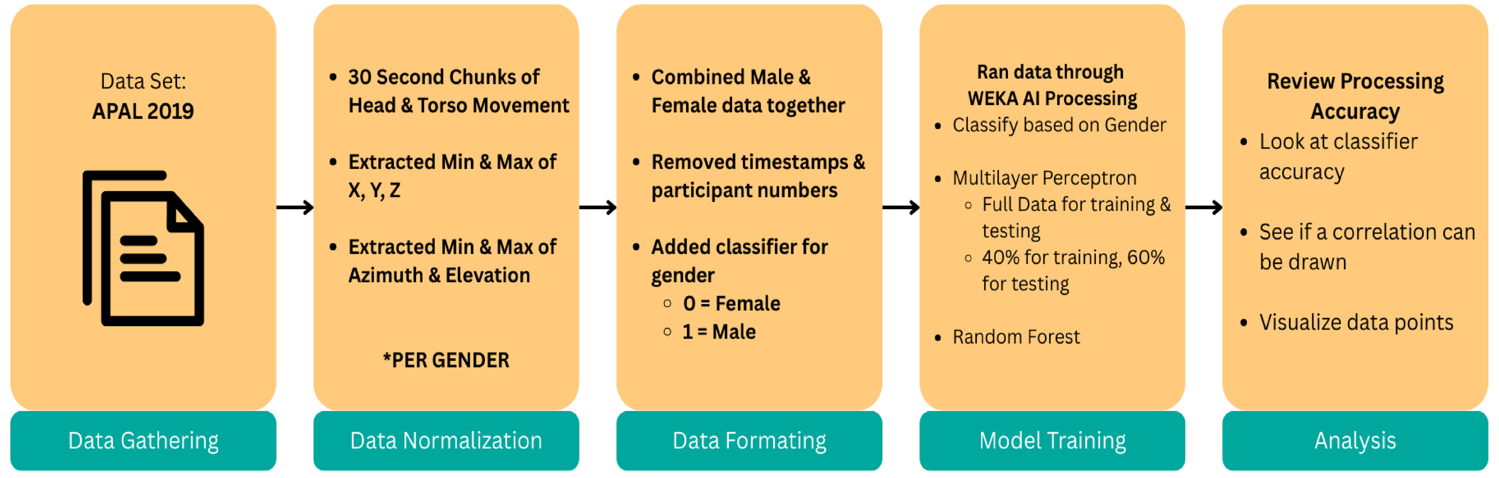

Figure 1.1 - Workflow for the APAL 2019 Dataset – How we interpreted and modified data for our research

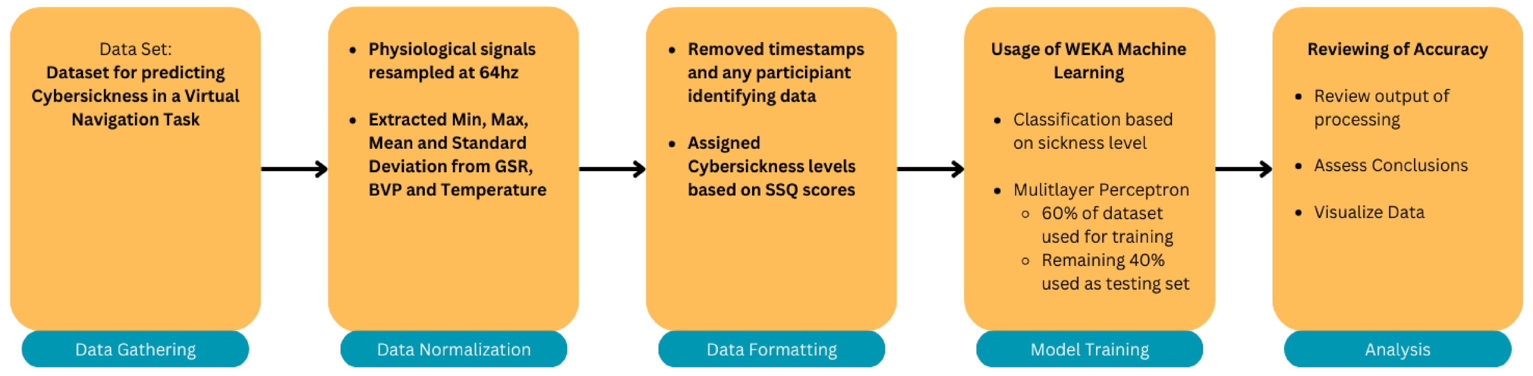

Figure 1.2 - Workflow for the Cybersickness Dataset – How we interpreted and modified data for our research

3. Results

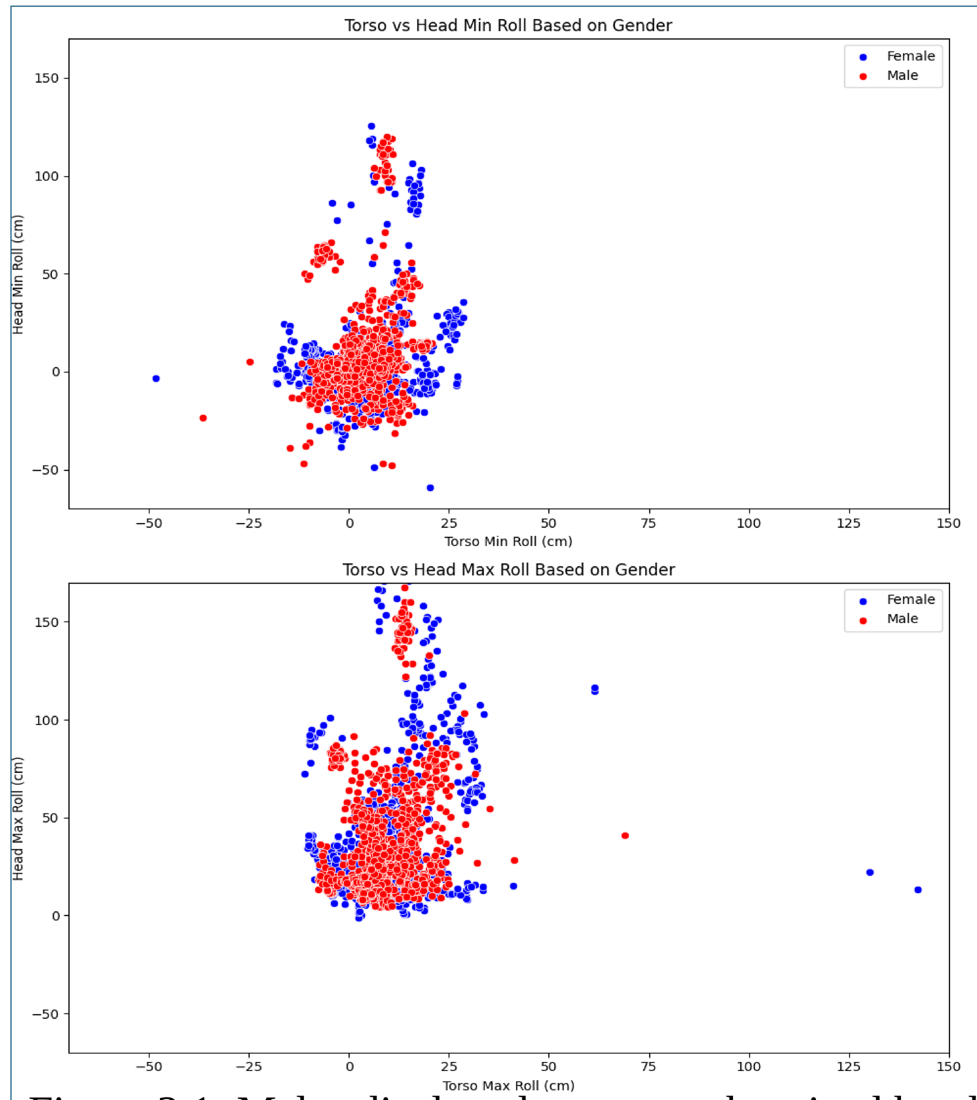

Figure 2.1: Males displayed more synchronized head and torso roll, whereas females showed greater discrepancies between the two. This misalignment **may indicate compensatory movements**, which could contribute to **increased cybersickness susceptibility** in female participants.

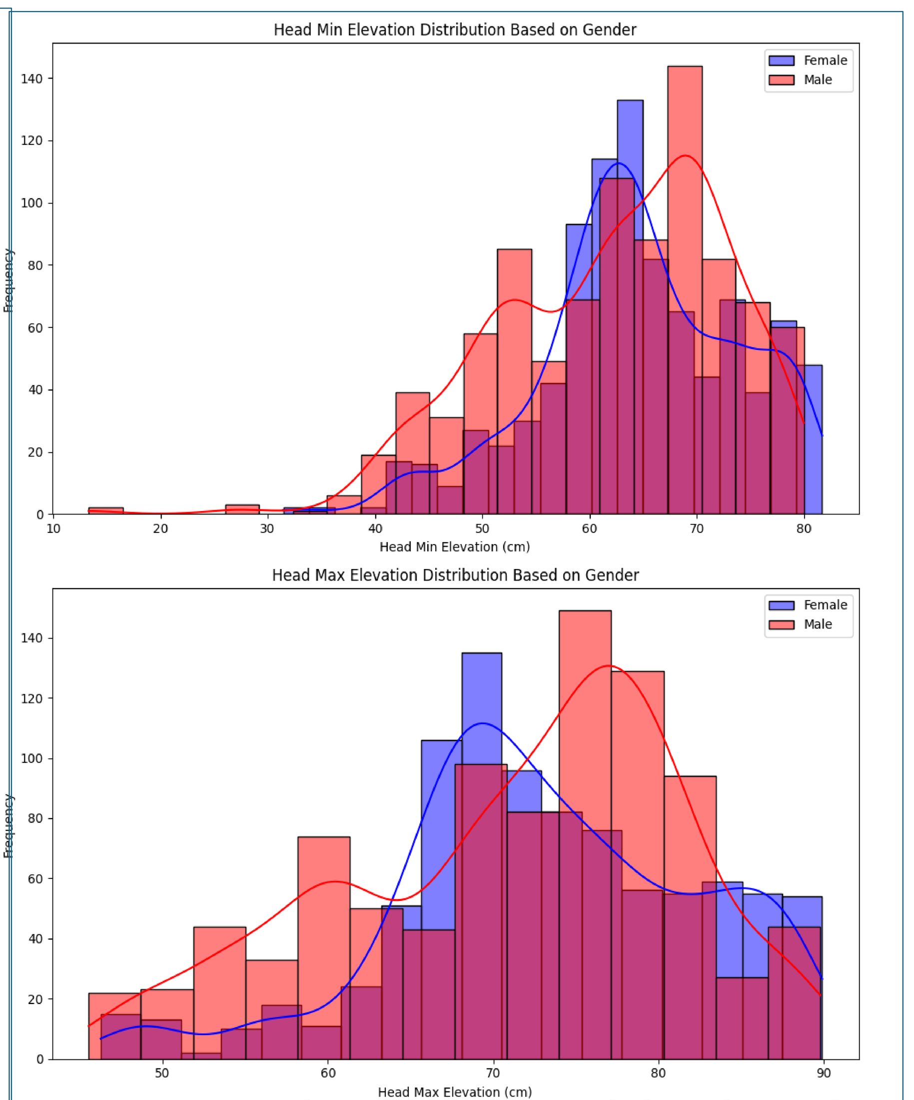

Figure 2.2: Male participants exhibited a wider range of elevation changes, while female participants showed more constrained movement. This suggests differences in navigation strategies, with restricted elevation shifts potentially correlating with higher cybersickness susceptibility in female users.

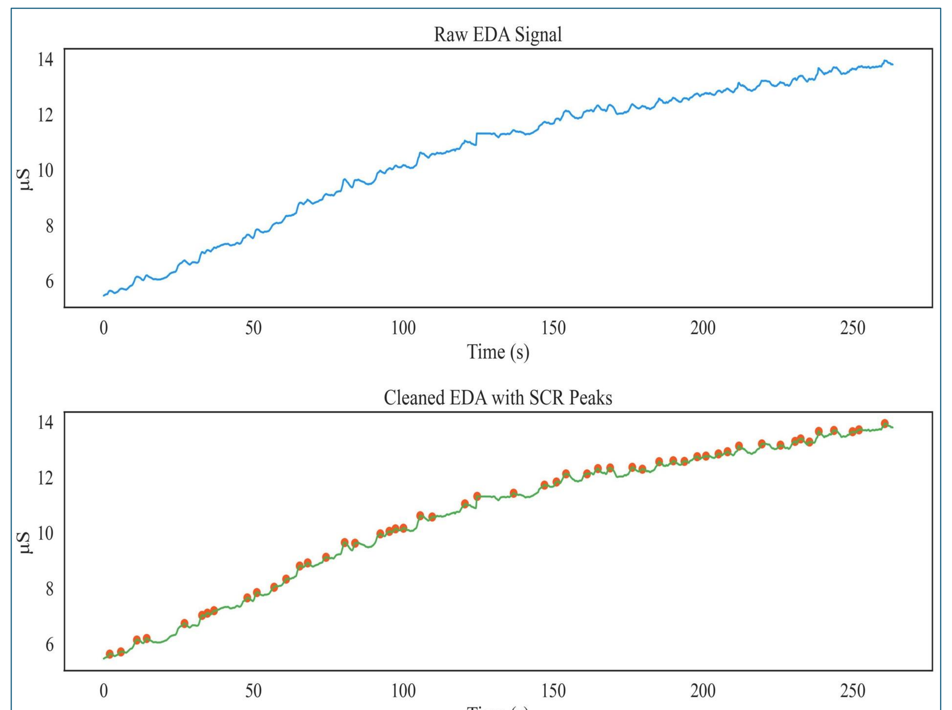

Figure 3.1: Raw GSR signal for a single sample, followed by cleaned signal with peaks marked. Features were extracted to be used for data processing.

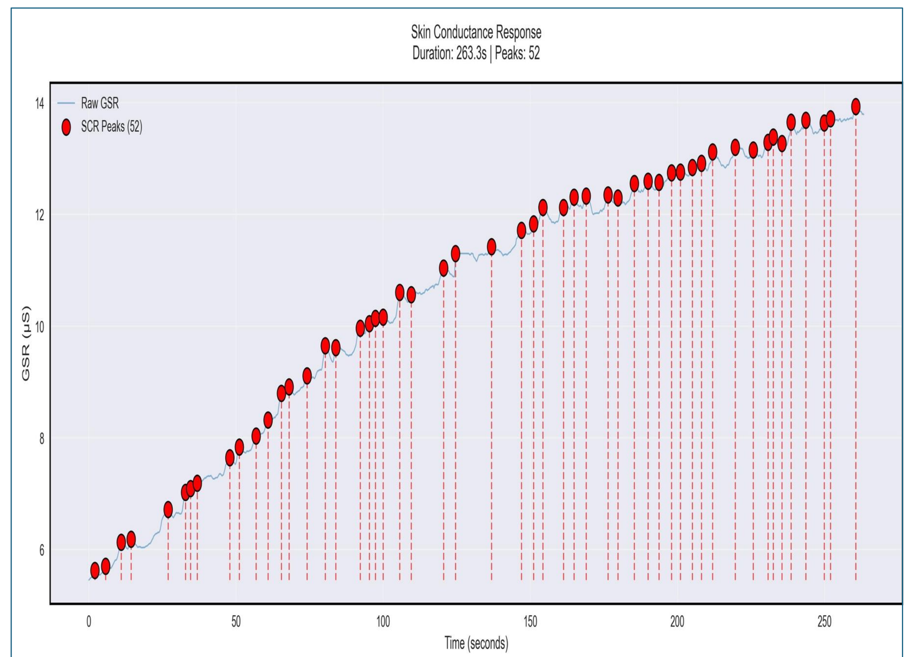

Figure 3.2: More prominent depiction of peaks on GSR . Shows the **Skin Conductance Response** during measurement. As well as number of peaks recorded

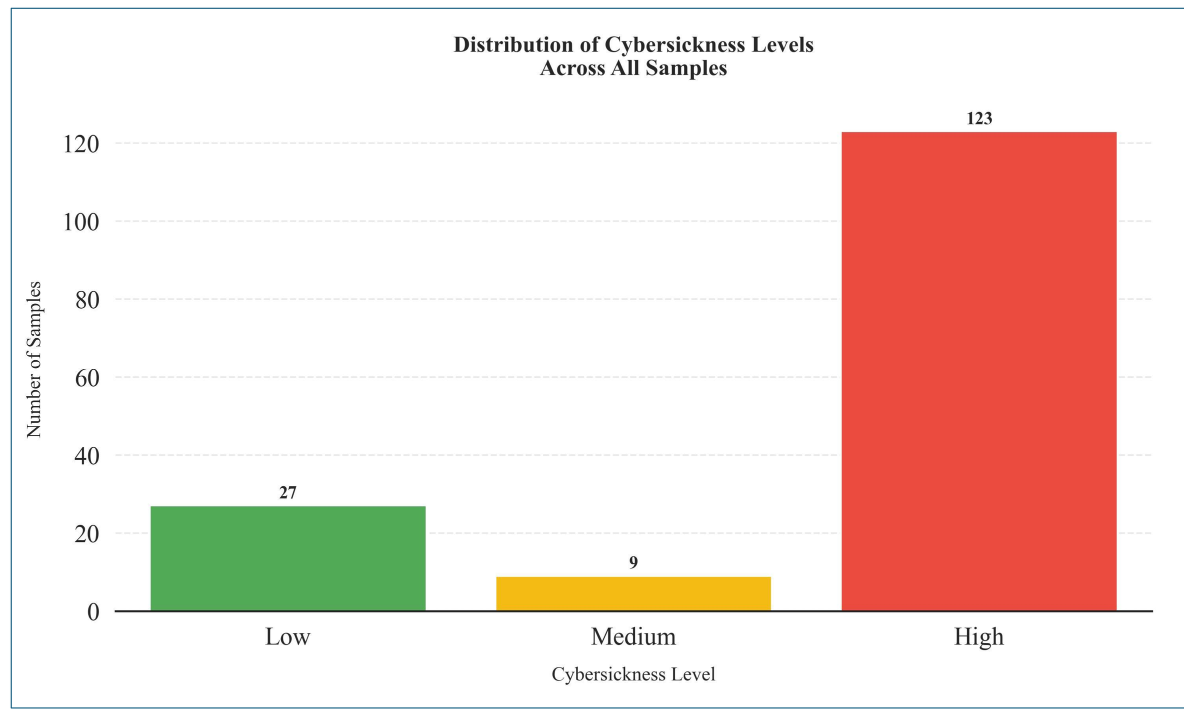

Figure 4.1:
Bar plot showing the distribution of samples across the cybersickness dataset, showing the skew toward mostly high sickness datapoints

```
Correctly Classified Instances        1078      98.1785 %
Incorrectly Classified Instances        20       1.8215 %
Total Number of Instances             1098

=== Detailed Accuracy By Class ===

     TP Rate  FP Rate  Precision  Recall  F-Measure  MCC    ROC Area  PRC Area  Class
     0.987    0.023    0.976      0.987   0.982      0.964  0.995     0.994     0

=== Confusion Matrix ===

   a    b   <-- classified as
 535    7 |   a = 0
  13  543 |   b = 1
```

Figure 4.1
Multilayer Perceptron –
40% trained, 60% test data split

On APAL Data

```
Correctly Classified Instances          46      71.875 %
Incorrectly Classified Instances        18      28.125 %
Total Number of Instances               64

=== Detailed Accuracy By Class ===

     TP Rate  FP Rate  Precision  Recall  F-Measure  MCC    ROC Area  PRC Area  Class
     0.860    0.714    0.811      0.860   0.835      0.160  0.709     0.899     High

=== Confusion Matrix ===

  a  b  c   <-- classified as
 43  7  0 |   a = High
  8  3  0 |   b = Low
  2  1  0 |   c = Medium
```

Figure 4.2
Multilayer Perceptron –
60% trained, 40% test data split

On Cybersickness Data

4. Problem Solved/Lessons Learned

- This research examines cybersickness in VR using the APAL 2019 and Dataset for Cybersickness.
- **Gender differences emerged in motion analysis**: women showed more head roll and less torso movement, potentially increasing susceptibility.
- Electrodermal activity (EDA) spikes, classified via the Simulator Sickness Questionnaire (SSQ), linked physiological responses to motion variability.
- Machine learning models, including multilayer perceptron in **WEKA**, were trained to predict cybersickness levels.
- These findings support advancements in predictive models and targeted mitigation strategies for VR.

5. Future Research Possibilities

- Our team plans to develop an innovative solution for VR motion sickness inspired by **Apple's Vehicle Motion Cues** technology.
- Drawing from Apple's research on sensory conflicts as a cause of motion sickness, our VR solution will:
- Incorporate visual cues at the periphery of the user's field of view to represent physical movement within virtual environments.
- Help harmonize the brain's perception of motion with the body's vestibular system, reducing discomfort during extended VR sessions.
- By leveraging VR headsets' built-in sensors to detect head movement and position changes, our system will:
    - Dynamically adjust peripheral cues to match the user's physical motion.
    - Create a more natural and comfortable VR experience.

Referenced Works

Curry, C. (2021, May 1). *Cybersickness in virtual reality head-mounted displays: Examining the influence of sex differences, vehicle control and postural precursors*. University Digital Conservancy Home. https://conservancy.umn.edu/items/34dbc74c-2d9c-4ce3-bb9b-fe984999eb8b

Wang, Y., Chardonnet, J.-R., & Merienne, F. (2023, March 29). *Modeling online adaptive navigation in Virtual Environments based on PID control*. arXiv.org. https://arxiv.org/abs/2303.16635