EVALUATION OF A GALVANIC VESTIBULAR STIMULATION SYSTEM TO REDUCE CYBERSICKNESS IN VIRTUAL REALITY

C. da Costa C. *, E. Chouin, M. Denoual, R. G. P. Moura, R. P. S. Leão, R. F. Sampaio, G. C. Barroso, D. R. Jaguaribe, Y. Jezequel, H. Pochat

* Presenter
CIFRE PhD student in Electronics and Microelectronics at ENSICAEN

clarice.dacosta-correa@unicaen.fr

IARIA

GREYC Electronics and Computer Science Laboratory

ENSI CAEN ÉCOLE PUBLIQUE D'INGÉNIEURS CENTRE DE RECHERCHE

NBI®

gre GRUPO DE REDES ELÉTRICAS INTELIGENTES

VIRTVS VNITA FORTIOR UFC

Clarice da Costa Corrêa

CIFRE PhD Student – ENSICAEN / GREYC – NBI

Electrical engineer from the Federal University of Ceará (UFC), Brazil (2024). Currently a doctoral student with the startup Neural Balance Innovation (NBI), majoring in Electronics and Microelectronics at the National School of Engineering of Caen (ENSICAEN), within the GREYC research laboratory at Université Caen Normandie.

Her research focuses on the development of galvanic and electromagnetic stimulation systems for vestibular rehabilitation.

Aims and contribution of the paper

Aims

1. Validate a Galvanic Vestibular Stimulation (GVS) system
2. Enhance the learning experience of students using VR

Contributions

1. Enhance the sense of immersion
2. Reduce cybersickness in virtual reality environments

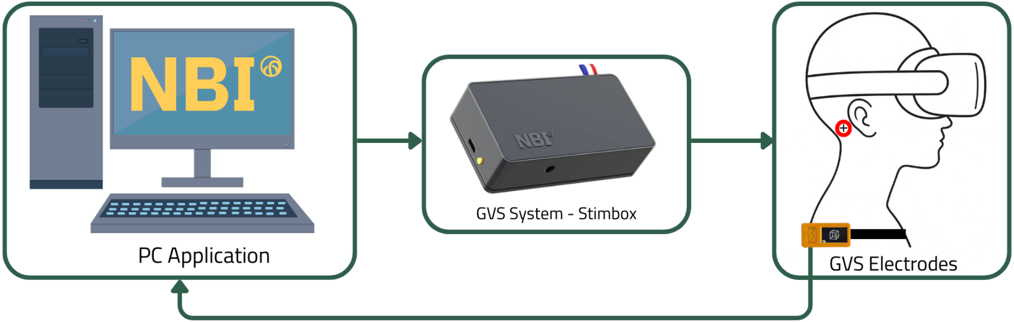
State of the Art

VR use → Senses mismatch → Cybersickness

Most reported symptoms:

- Disorientation
- Nausea
- Oculomotor disturbances
- Headache
- Dizziness

System montage



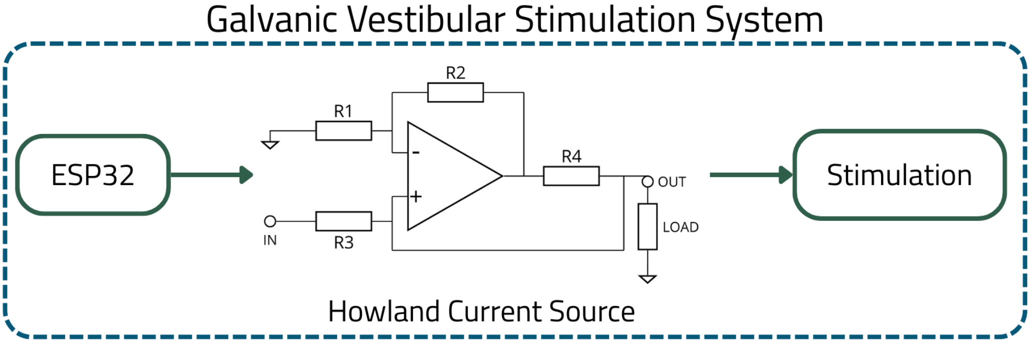
Firmware (ESP32 – PlatformIO)

- Control of amplitude, frequency, waveform
- Independent electrode management
- Simultaneous stimulation patterns

User Interface

- Dedicated application
- Real-time parameter configuration
- Designed for future industrial deployment

System Specifications



Control Unit

- ESP32 microcontroller
- Digital signal generation
- Independent GPIO control

Current Generation

- Two independent Howland current sources
- Voltage-to-current conversion
- Independent electrode pair control

User safety

Protection Mechanisms	Current Limitation	Impedance Adaptation
Electrical + Software Prevents leakage current	$\pm$2.6 mA Below $\pm$4 mA guideline [11]	Up to 9 kΩ Accounts human variability

Designed to ensure safe operation during startup and stimulation, while maintaining stable current delivery under physiological impedance variations.

[11] A. Antal et al., “Low intensity transcranial electric stimulation: Safety, ethical, legal regulatory and application guidelines,” Clin. Neurophysiol., vol. 128, no. 9, pp. 1774–1809, 2017, doi:10.1016/j.clinph.2017.06.001.

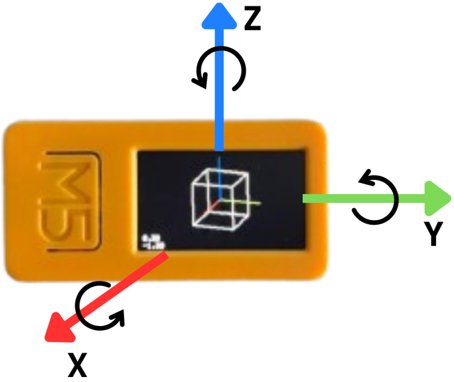
Motion Data Acquisition

IMU Sensor: MPU6886

- 3-axis gyroscope
- 3-axis accelerometer
- 16-bit ADC

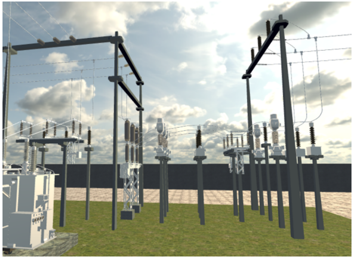
Configuration

- Gyroscope: ±1000 °/s (32.8 LSB/°/s)
- Accelerometer: ±8 g (4096 LSB/g)
- Sampling frequency: 200 Hz

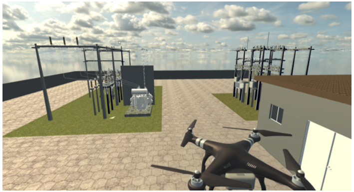


Virtual Reality Application

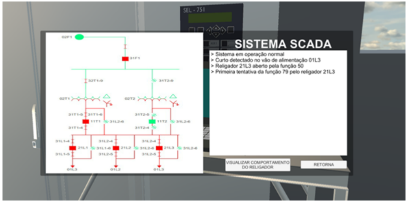
Virtual Reality Substation Laboratory (VRSL)
VR environment designed to accurately reproduce the power distribution substation located on the university campus



First-person
Navigation



Outdoor Yard
Drone piloting



Control House
Event and accident simulation

Experimental Design

Research Questions

- Does GVS improve the sense of immersion?
- Can GVS combined with VR reduce cybersickness symptoms?

Participant Screening

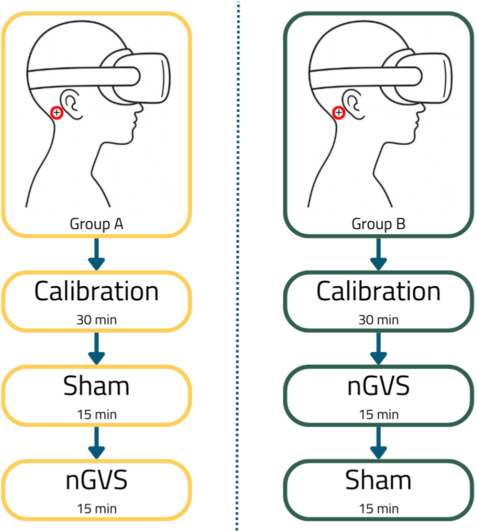
- Health questionnaire
- Exclusion of participants with relevant medical conditions or medication use

Questionnaires

- System Usability Scale [12]: usability of the VRSL + Stimbox
- Simulator Sickness Questionnaire [13]: sickness symptoms and subscale scores
- Immersion tolerance

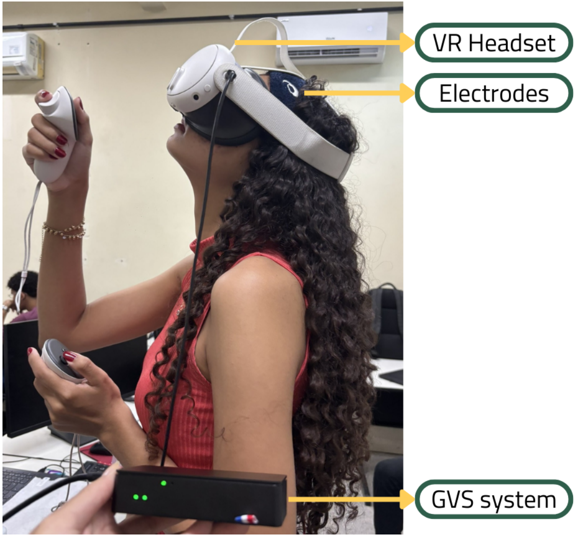
[12] Brooke, J. (1986). SUS - - A quick and dirty usability scale.
[13] R. S. Kennedy, N. E. Lane, K. S. Berbaum, and M. G. Lilienthal, "Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness," Int. J. Aviat. Psychol., vol. 3, no. 3, pp. 203–220, 1993, doi:10.1207/s15327108ijap0303$_3$.

Testing Procedures



Randomized crossover design

Test Environment



- 20 participants
- 1h 10min per participant
- Data collection over 16 days

Scan to access the NBI website

Analysis

Outcome Measures

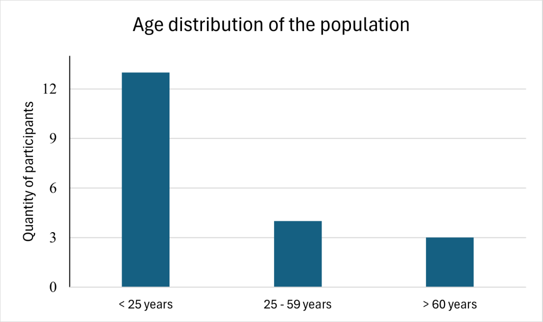
- Cybersickness: SSQ total score + subscales (nausea, oculomotor, disorientation)
- Immersion tolerance: time spent in VR (max. 15 min)

$$SSQ_{\text{total}} = \frac{(9.54 \times \text{nausea}) + (7.58 \times \text{oculomotor}) + (13.92 \times \text{disorientation})}{3.74}$$

Statistical Analysis

- Continuous (asymmetric): Wilcoxon signed-rank test
- Ordinal: Sign test or Bowker's test of symmetry
- Binary: McNemar's exact test

Quantitative Results



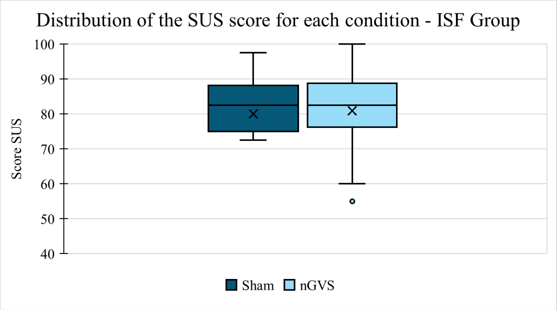
Immersion tolerance

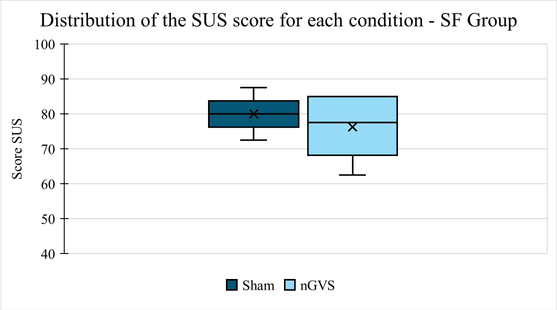
Condition	Did not complete	Completed
Sham	3 (15%)	17 (85%)
nGVS	0 (0%)	20 (100%)

Washout groups

Group	Participants
ISF ($\leq$ 1h)	13
SF ($>$ 1h)	7

SUS Results – Usability Analysis

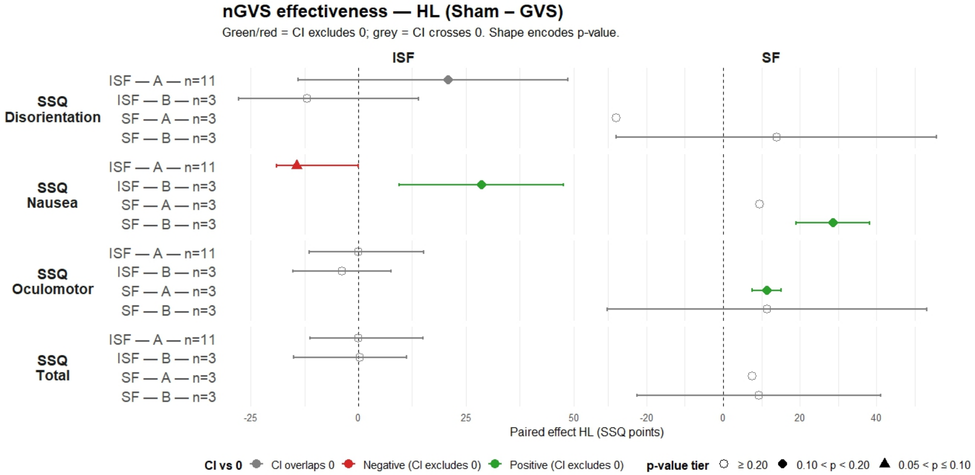




Key observations

- High usability scores in both conditions (80).
- No statistically significant difference (Wilcoxon test).
- Greater dispersion in the SF group under nGVS.

SSQ Results – Effect of Exposure Order



- Reduction trend in nausea under nGVS
- Carryover effect observed in short washout group

Conclusion and Future Work

Conclusion

- nGVS demonstrates a preventive effect on nausea during VR immersion.
- Increased tolerance to VR exposure under stimulation.
- Washout duration is critical for reproducibility to avoid potential carryover effects.

Future Work

- Inclusion of a larger and more heterogeneous sample.
- Implementation of multi-day protocols with controlled washout intervals.
- Extension to different VR applications to reduce the requirement for prior domain-specific knowledge.

Thank You

Any Questions ?

clarice.dacosta-correa@unicaen.fr