Machine Learning-powered Wearables for Adaptive Electrical Vestibular Stimulation Balance Therapy for Older Adults

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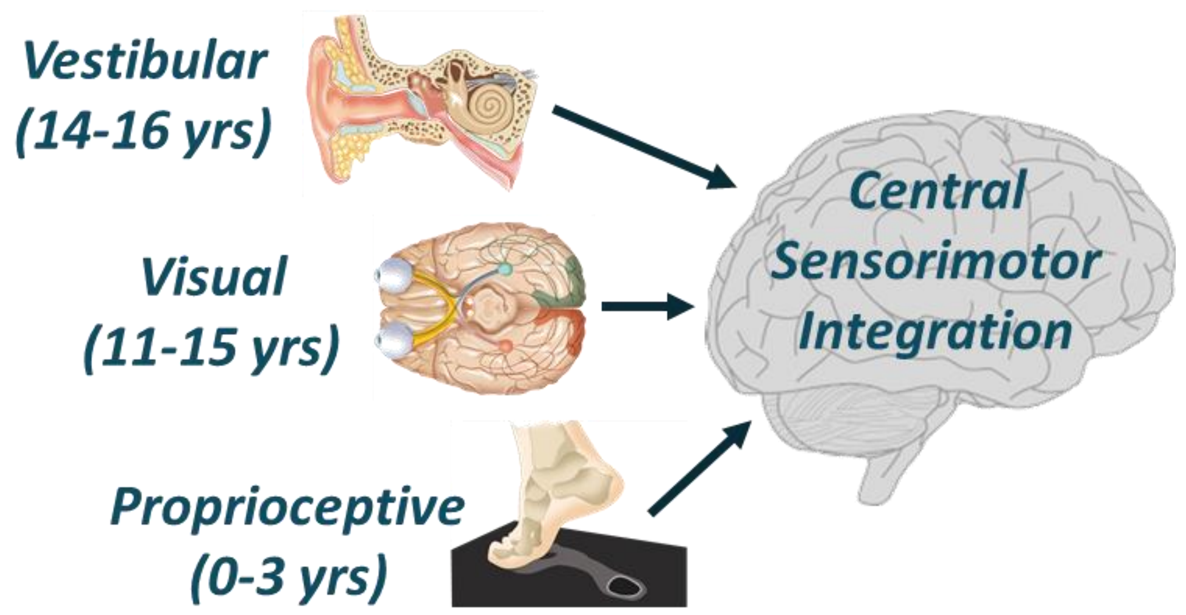
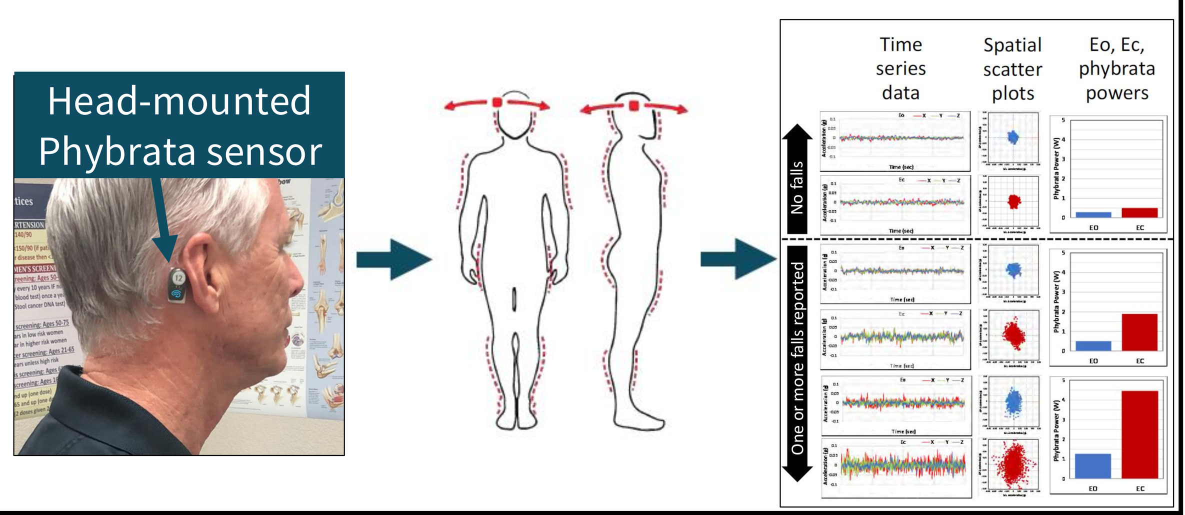
MassAITC Aging Focus Pilot Core

Motivation

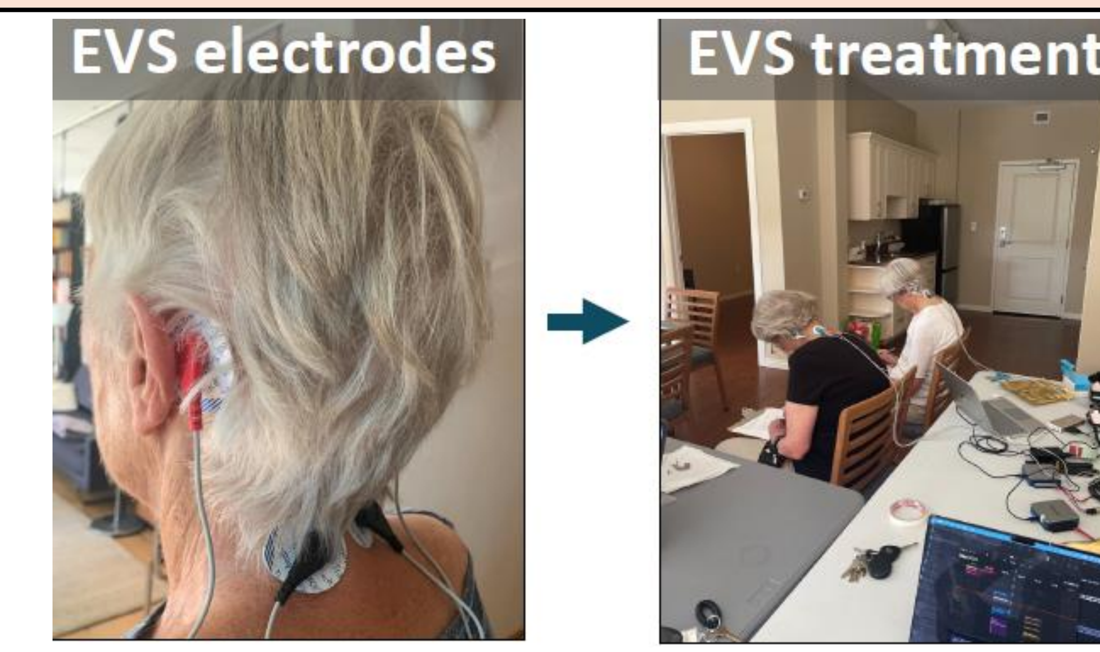
- Human balance system doesn't fully mature until teenage years and begins to **decline after age 40** [1].
- Currently, the only method to restore disrupted balance is a **vestibular implant**.
- The Central Nervous Systems (CNS) performs **sensory reweighting** on our visual, vestibular, and proprioceptive sensory inputs to maintain postural stability [2].
- **Electrical vestibular stimulation (EVS)** is a bioelectronic intervention that stimulates vestibular nerves to reduce balance and gait impairments and related fall risks [3, 4].
- The head-mounted wearable **phy**siological vi**brat**ion **a**cceleration (Phybrata) sensor developed by *Neursantys* detects and analyzes microscopic involuntary motions of the body to assess balance and gait impairments [5-7].
- Phybrata data can be used to monitor response to EVS and personalize stimulation parameters to optimize treatment

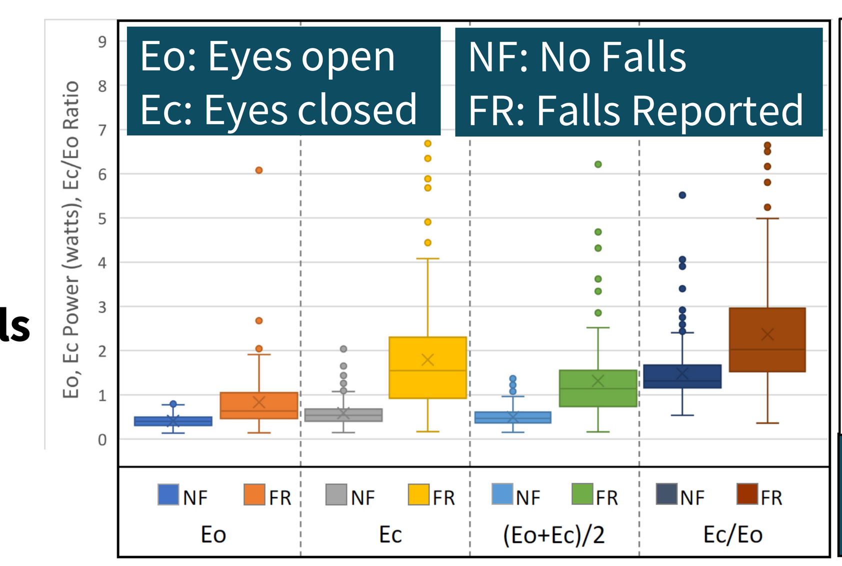


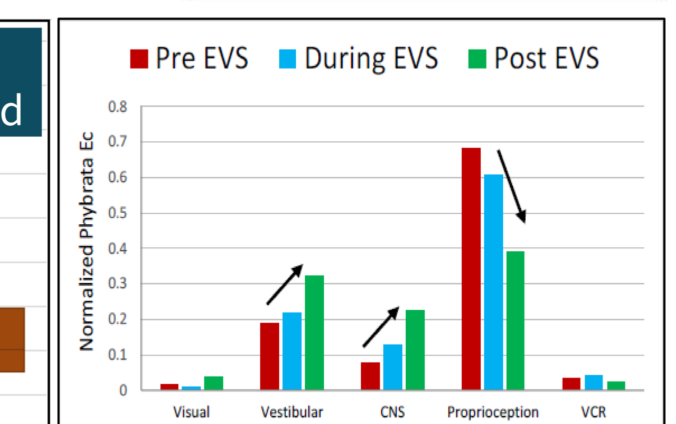


Background Work

- **Fifty** adults (50-90 years) without diagnosed balance impairments were randomly assigned to **STIM** (EVS therapy) or **SHAM** (control) groups.
- The STIM group received a proprietary subthreshold wideband stochastic EVS (swsEVS) during each treatment session, while the SHAM group received no stimulation current during each session.
- Both groups underwent three 20-minute swsEVS sessions per week for six weeks, with balance, gait, and fall risk assessments completed before and after each session.
- Balance was tested using the Phybrata sensor under three conditions: eyes open/closed, feet apart/together, and hard floor/foam pad.
- Phybrata powers are higher for subjects with **falls reported** than subjects with **no falls**.
- The **Vestibular** contribution to balance control **increases** after an effective EVS session.





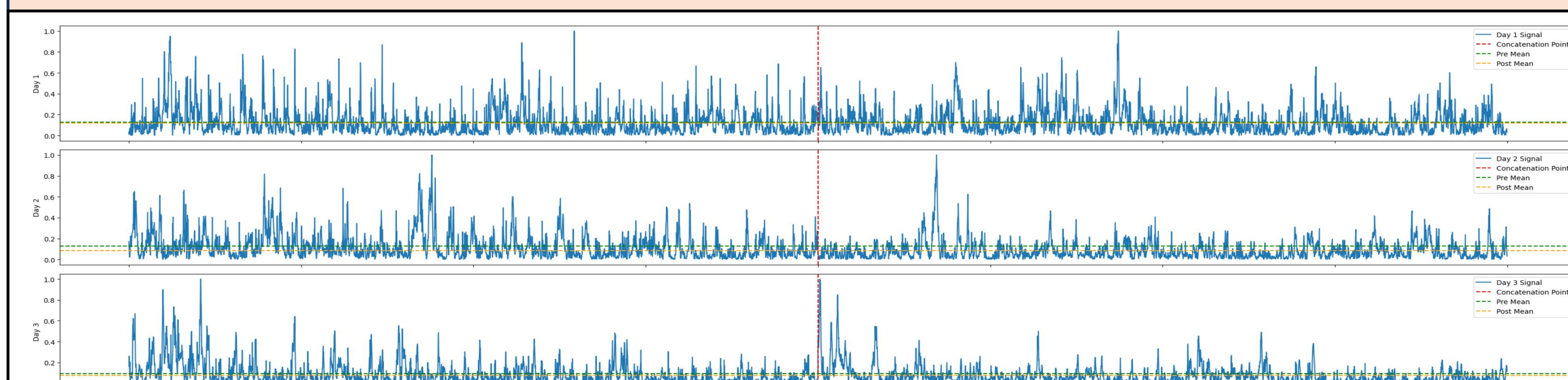


Relative contribution of sensory bands

Objective and Proposed Approach

- Our goal is to determine personalized EVS treatment parameters that minimize the number of treatment sessions required to optimize the magnitude and persistence of balance restoration delivered to each patient.
- Our empirical results show that Phybrata power is higher for subjects with degraded balance and a history of reported falls, allowing us to use the change in phybrata power to determine the effectiveness of each treatment session.
- The relative contribution of the vestibular sensory band to postural control also increases when treatment is effective.
- ***Contribution:*** We have developed a metric that combines Phybrata power and sensory band data to train a 1D-CNN network to accurately classify EVS treatment sessions that are effective in enhancing balance.

Results



- Each of the 864 treatment sessions (48 subjects x 18 sessions, 2 dropped out) was divided into two datasets – effective and ineffective – based on our empirical findings.
- The pre-treatment power signals and the post-treatment power signals for each day were concatenated to create a continuous signal.
- We augmented our dataset using sliding windows of 1-sec.
- The continuous signal is then passed through a 1D-CNN network to train it.
- We applied a weighted loss function to account for the unbalanced labels.
- The results show our model achieves an overall **92.6% accuracy** (87.3% precision classifying ineffective days and 95.3% precision classifying effective days).

The machine learning model achieved an overall accuracy of **92.6%.**

Conclusions & Future Work

- We have developed a metric that combines Phybrata power and sensory band data to train a 1D-CNN network to classify EVS treatment sessions in terms of their effectiveness in enhancing balance.
- The number of effective days was significantly higher for STIM patients (82%) than for SHAM patients (69%) showing the efficacy of the EVS sessions.
- Our machine learning model effectively distinguishes between effective and ineffective EVS balance treatment sessions,
- achieving **92.6% accuracy** with **87.3% precision** classifying ineffective sessions and **95.3%** precision classifying
- effective sessions.
- ***FUTURE WORK:*** *The trained model can now be used to classify EVS treatment effectiveness and predict ineffective sessions based on PRE-assessments, enabling personalized parameter adjustments to optimize balance restoration, minimize session numbers, and transform potentially ineffective outcomes into effective ones.*

Acknowledgments

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