Sedentary behavior intervention effect measurement from wearable sensors through self-supervised deep learning model

Howon Ryu, PhD Candidate

Division of Biostatistics and Bioinformatics, University of California San Diego

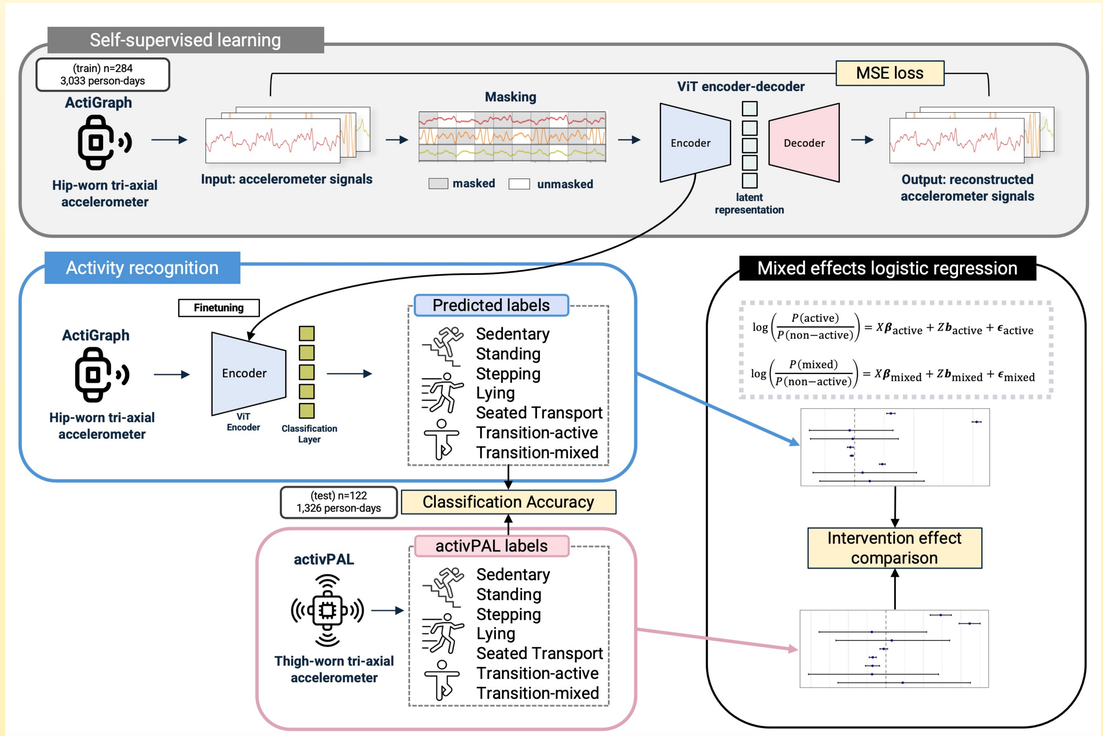
Abstract

Accurate measurement of free-living sedentary behavior is central to evaluating behavioral interventions, yet most accelerometer classifiers rely on generic labels that do not align with intervention targets. We develop a fine-tuned version of our previously developed self-supervised deep learning model, Multi-modal Cross-masked Autoencoder (MoCA), to learn activity states explicitly linked to the goals of the Rise for Health randomized trial, which aims to reduce sitting and increase sit-to-stand transitions among postmenopausal women. Using hip-worn ActiGraph time series, the adapted MoCA model produces clinically meaningful sedentary-related classifications that directly quantify intervention-relevant behavior change. We estimate changes in sedentary behavior at the 3-month visit using these MoCA derived outputs and compare them with measurements from activPAL, the thigh-worn reference device. The results illustrate the feasibility of adapting foundation sensor models for intervention-specific phenotyping and their potential to scale objective behavior assessment in digital health research.

Introduction

- Accurate measurement of free-living sedentary behavior is integral to intervention effect evaluation.
- Currently there is lack of wearable sensor foundation model for such activity recognition that is tailored to study-specific behavioral intervention effect measurement.
  - There exists a need to eliminate reliance on activPAL, which is conventionally thought to produce the “gold standard” activity label, due to lower participant adherence.
- We improve upon our previously developed *MoCA*, a masked autoencoder model for activity recognition with self-supervised learning framework, to tackle this problem.
- Rise for Health study is a 3-month three-arm (control, less sitting, more sit-to-stand) randomized trial investigating sedentary behavior and health outcomes of postmenopausal women.
- Our model provides activity recognition for intervention effect measurement, specifically designed to discern transition movement to measure behavioral intervention effect for Rise for Health study.

Methodology



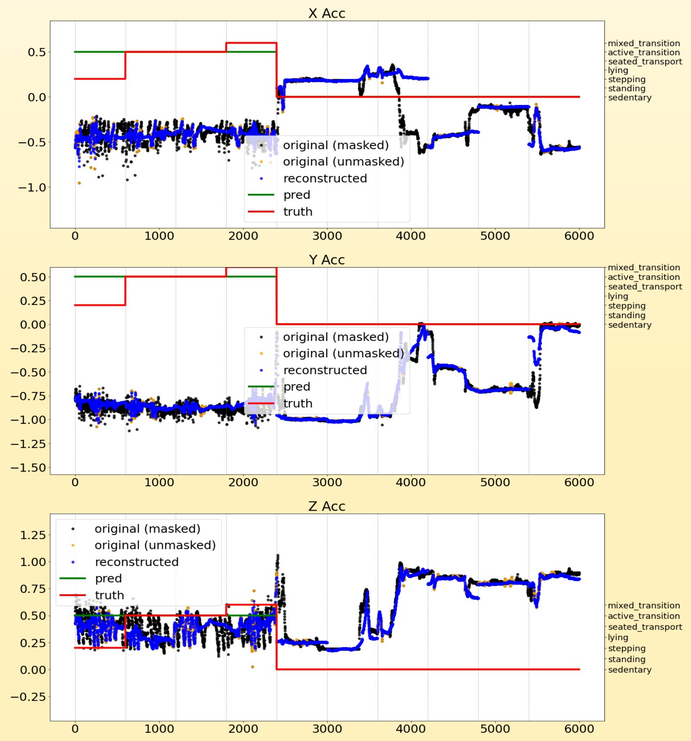


Figure 1: Reconstruction visualization example

Results

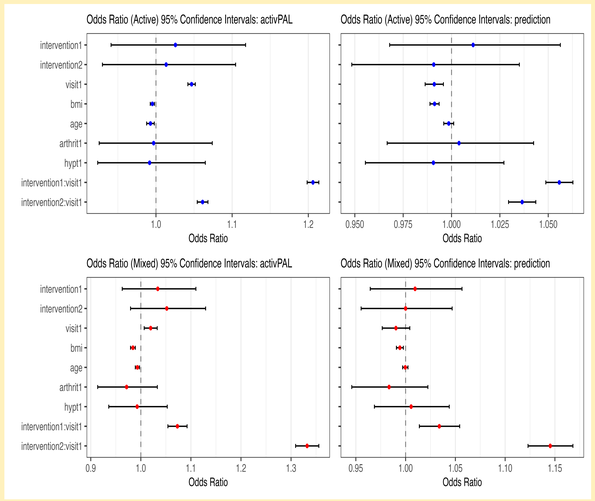


Figure 2: fixed effects 95% CI comparison

model	Final Label	Final Label (collapsed)
MoCA with RISE (no augmentation)	77.66%	90.31%
MoCA with RISE (mix up and warp)	78.18%	90.67%
MoCA with RISE (mix up only)	77.60%	90.62%
MoCA with RISE (warp only)	77.58%	90.59%

Table 1: Activity classification result

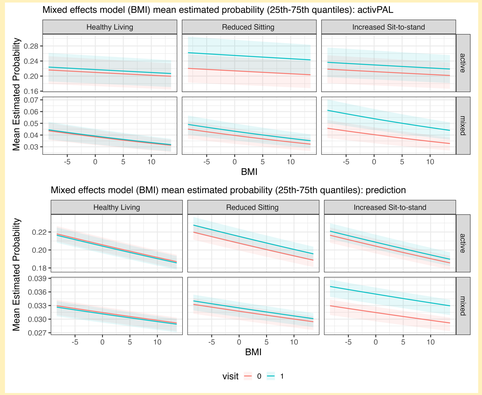


Figure 3: mean estimated probability per intervention

Conclusion

- With 7 activities (sedentary, standing, stepping, lying, seated transport, transition-active, transition-mixed), our model achieved **78.2%** classification accuracy; with collapsed labels (non-active, active, mixed) the accuracy is **90.7%**.
- With logistic mixed effects model, intervention coefficients show consistent significance across activPAL and predicted labels.
- The result illustrates feasibility of adapting self-supervised deep learning model for intervention effect evaluation.