Predicting Self-Reported Stress and Affective States Using Wearable Sensor Data

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BACKGROUND / OBJECTIVES

Traditional mental health assessment relies on retrospective surveys and subjective interviews, which can delay diagnosis and miss critical intervention windows. Wearable biosensors provide continuous, non-invasive physiological monitoring. However, few solutions leverage temporal patterns for personalized moment-to-moment emotional forecasting. Connecting real-time physiological measurements to subjective mental health states creates opportunity for translational informatics innovations in surveillance and equitable care delivery.

STUDY OBJECTIVES:

- Predict self-reported stress, anxiety, and negative affect using electrodermal activity (EDA) and heart rate variability (HRV).
- Compare performance of static vs. time-series models for psychological state prediction.
- Identify key physiological predictors driving model performance.

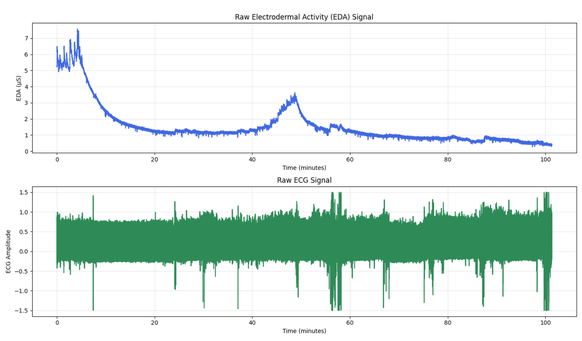
DATA

Wearable Stress and Affect Detection (WESAD):

- 15 participants (12 male, 3 female), aged 24-35
- 2 Wearable devices
  - Chest : ACC, ECG, EDA, EMG, RESP, TEMP
  - Wrist : ACC, BVP, EDA, TEMP
- 4 Experimental Conditions:
  Baseline, Stress, Amusement, Meditation
- Self-report Questionnaires: PANAS, STAI, SAM

RESEARCH DESIGN

FEATURE EXTRACTION

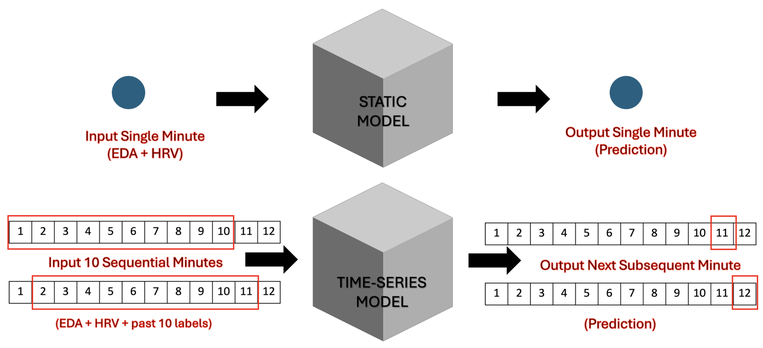


EDA and HRV features were extracted at one-minute intervals using Neurokit2.

LABELING

Stress (mapped from PANAS)	0 = No stress, 1= Low stress, 2= High stress
Anxiety (mapped from STAI)	0 = No to low anxiety, 1 = Moderate anxiety, 2 = High anxiety
Negative Affect (calculated from PANAS)	Ranges from 10-50

MODEL DESIGN



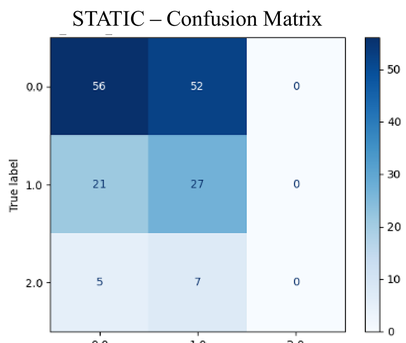
ALGORITHMS & METRICS

- Algorithms: Logistic/Linear Regression, Decision Tree, Random Forest, XGBoost, LightGBM, AdaBoost, SVM
- Metrics: Accuracy, F1, AUC-ROC, R^2, MSE

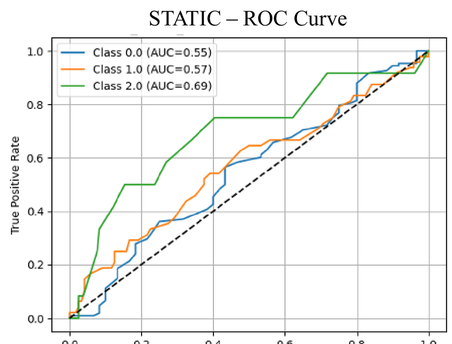
RESULTS

STRESS RESULTS

STATIC – Confusion Matrix

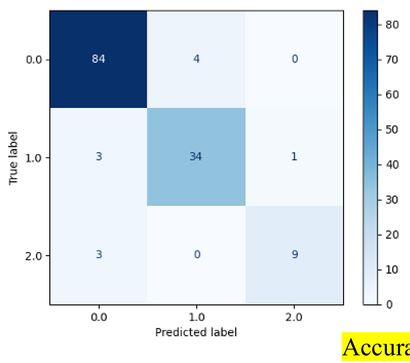


STATIC – ROC Curve

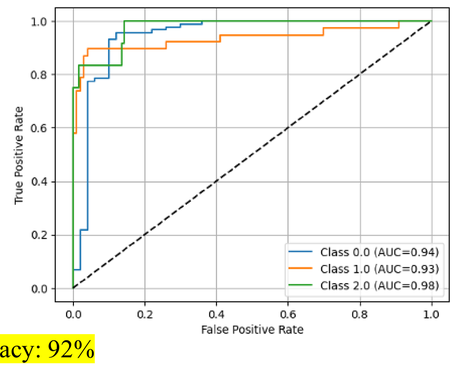


Accuracy: 49%

TIME-SERIES – Confusion Matrix



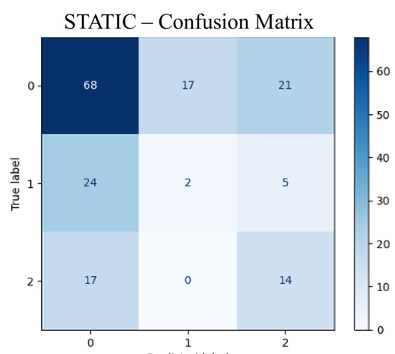
TIME-SERIES – ROC Curve



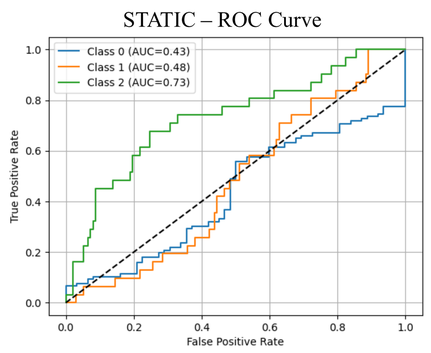
Accuracy: 92%

ANXIETY RESULTS

STATIC – Confusion Matrix

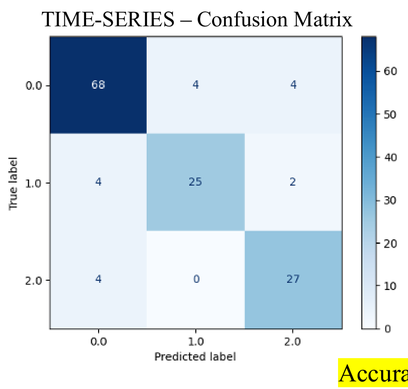


STATIC – ROC Curve

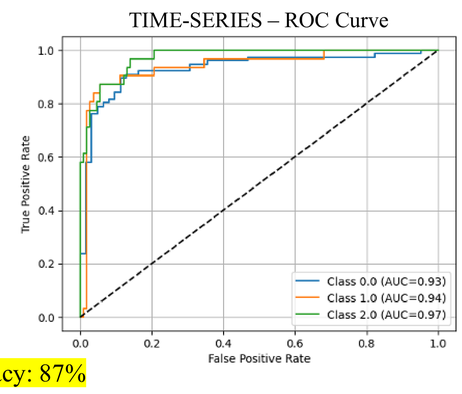


Accuracy: 50%

TIME-SERIES – Confusion Matrix



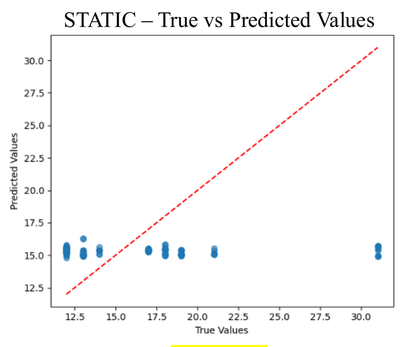
TIME-SERIES – ROC Curve



Accuracy: 87%

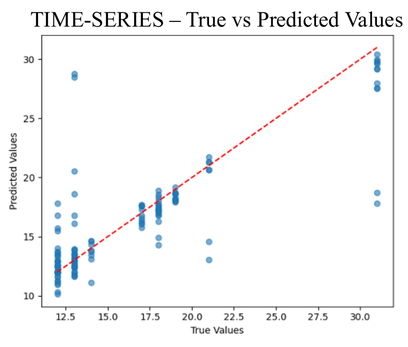
NEGATIVE AFFECT RESULTS

STATIC – True vs Predicted Values



R^2 : -0.03

TIME-SERIES – True vs Predicted Values



R^2: 0.68

FEATURE IMPORTANCE

	Stress Prediction		Anxiety Prediction		Negative Affect Prediction	
Feature Ranking	**Static**	**Time-Series**	**Static**	**Time-Series**	**Static**	**Time-Series**
1	SCL_Mean	HRV_HF_t-1	SCL_Mean	HRV_HF_t-1	SCL_Mean	HRV_HF_t-1
2	HRV_MedianRR	SCL_STD_t-2	HRV_pNN50	SCL_STD_t-2	HRV_HF	SCR_Peaks_Count_t-1
3	HRV_MeanRR	HRV_MedianRR_t-2	HRV_HF	SCL_Mean_t-10	HRV_MeanRR	SCL_Mean_t-1
4	SCL_STD	HRV_SampEN_t-3	HRV_SampEN	SCL_Mean_LF_HF_Ratio_t-4	HRV_RMSSD	HRV_LF_HF_Ratio_t-8
5	HRV_RMSSD	HRV_LF_t-2	HRV_MedianRR	HRV_MedianRR_t-10	HRV_SDNN	HRV_pNN50_t-9

DISCUSSION / CONCLUSIONS

Time-series models outperformed static approaches for all psychological state predictions. The time-series model achieved an accuracy of 92% (AUC 0.95) for stress, 87% for anxiety (AUC 0.95), and a R^2 of 0.68 for negative affect, surpassing static model results. Feature importance analysis found SCL_Mean (mean skin conductance) and HRV_HF (high-frequency HRV) as the top predictors. Visual summaries confirm the improved performance and interpretability of time-aware modeling.

Key Takeaways

- Temporal data improve prediction of stress, anxiety, and affective states.
- Single moment EDA/HRV features are not sufficient predictors.
- Skin conductance and high frequency HRV are top features for mental health modeling.
- Wearable biosensors have great potential for supporting personalized mental health care.

FUTURE PLANS

- Test on **larger, more diverse datasets** to improve generalizability and support fairness analyses across demographic subgroups.
- Evaluate model performance in **real-world environments** by testing across diverse everyday settings and conditions.
- Explore **alternative scales for real-time affect** measurement, especially for positive affect.
- Incorporate **additional physiological signals** (respiration, temperature, accelerometer) and **advanced deep learning methods**.
- Explore **real-time deployment frameworks** for wearable-based mental health monitoring systems using mobile platforms.

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REFERENCES

1. Schmidt P, Reiss A, Duerichen R, Marberger C, Van Laerhoven K. Introducing WESAD, a multimodal dataset for wearable stress and affect detection. Proc ACM Int Conf Multimodal Interact. 2018:400–8.