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Integrative Insomnia Screening: Application of Resting-State EEG Frontal Alpha Asymmetry and Machine Learning

A five-minute resting-EEG marker, combined with anxiety and depression inventories, predicts one-year insomnia stability with approximately 90% accuracy.

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A single baseline session — two self-report inventories and a five-minute resting EEG — predicted persistent insomnia status one year later.

89.6% ACCURACY · 43/48

.908 AUC · +.04 FROM FAA

01 — BACKGROUND

A gap in objective screening

Insomnia disorder affects an estimated **10–20% of adults** and is associated with daytime impairment, cognitive decline, and elevated risk of comorbid depression and anxiety.

Current screening relies largely on self-report inventories, which capture subjective symptom burden but not the underlying neurophysiological state — constraining objective, early detection.

Frontal alpha asymmetry (FAA), derived from resting EEG as $\ln(F4_\alpha) - \ln(F3_\alpha)$, indexes lateralized frontal cortical activation. Following sleep deprivation, FAA shows a left-lateralized shift linked to hyperarousal and elevated state anxiety (Hao et al., 2025), supporting its candidacy as a neurophysiological marker of insomnia vulnerability.

Objective. To develop and validate a machine-learning model integrating anxiety, depression, and resting-state FAA for insomnia screening, and to quantify the incremental contribution of FAA.

48	12 mo	14	34
participants	follow-up	stable insomnia	healthy controls

02 — METHODS

A 12-month longitudinal design

Forty-eight community-dwelling adults (18–65 yr; *M* = 26.2, *SD* = 8.1; 17 M / 31 F) were followed for approximately 12 months.

At baseline (T1) participants completed the Beck Anxiety Inventory (BAI; Beck et al., 1988), Beck Depression Inventory–II (BDI-II; Beck et al., 1996), and Insomnia Severity Index (ISI; Bastien et al., 2001), and underwent a 5-min eyes-closed resting EEG. The ISI was re-administered at two follow-ups ~6 months apart (T2, T3).

Stable insomnia was defined as ISI ≥ 9 at all three assessments (*n* = 14); **healthy controls** as ISI < 9 at all three (*n* = 34). Requiring consistency across 12 months minimized state-dependent misclassification.

Frontal alpha power (F3, F4; 8–13 Hz) was extracted to compute FAA. Two feature sets — **Model 1** (BAI + BDI) and **Model 2** (BAI + BDI + FAA) — were compared across **eight classifiers** using 5-fold stratified cross-validation and leave-one-subject-out (LOSO); SHAP was used for feature attribution.

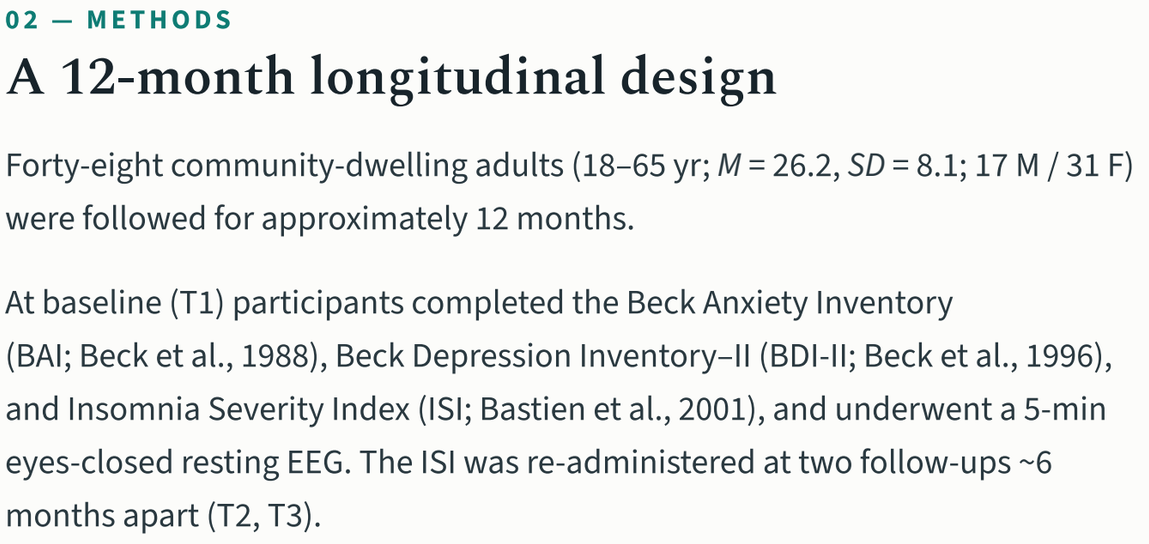

Figure 1. Longitudinal study design and machine-learning pipeline.

03 — RESULTS

FAA improved prediction

The inclusion of FAA improved classification performance across **nearly all classifiers**. The best-performing model (**Naive Bayes**) achieved AUC = **0.908** (5-fold CV) and 0.903 (LOSO), with **89.6% accuracy (43/48)** — an increase of +0.04 AUC over the questionnaire-only model.

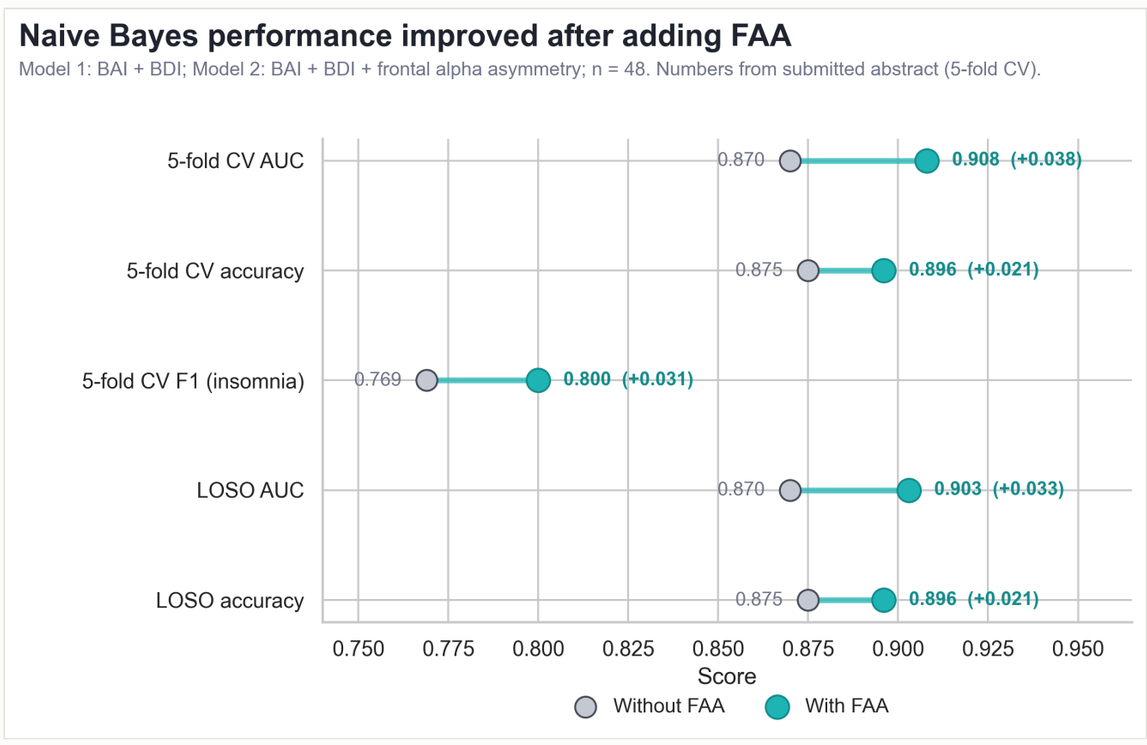

Figure 2. Naive Bayes performance before vs. after adding FAA (5-fold CV and LOSO).

Cross-validation and LOSO estimates differed by ≤ 0.02, indicating limited overfitting despite the modest sample. SHAP analysis identified **FAA as the strongest single predictor**, followed by BDI and BAI.

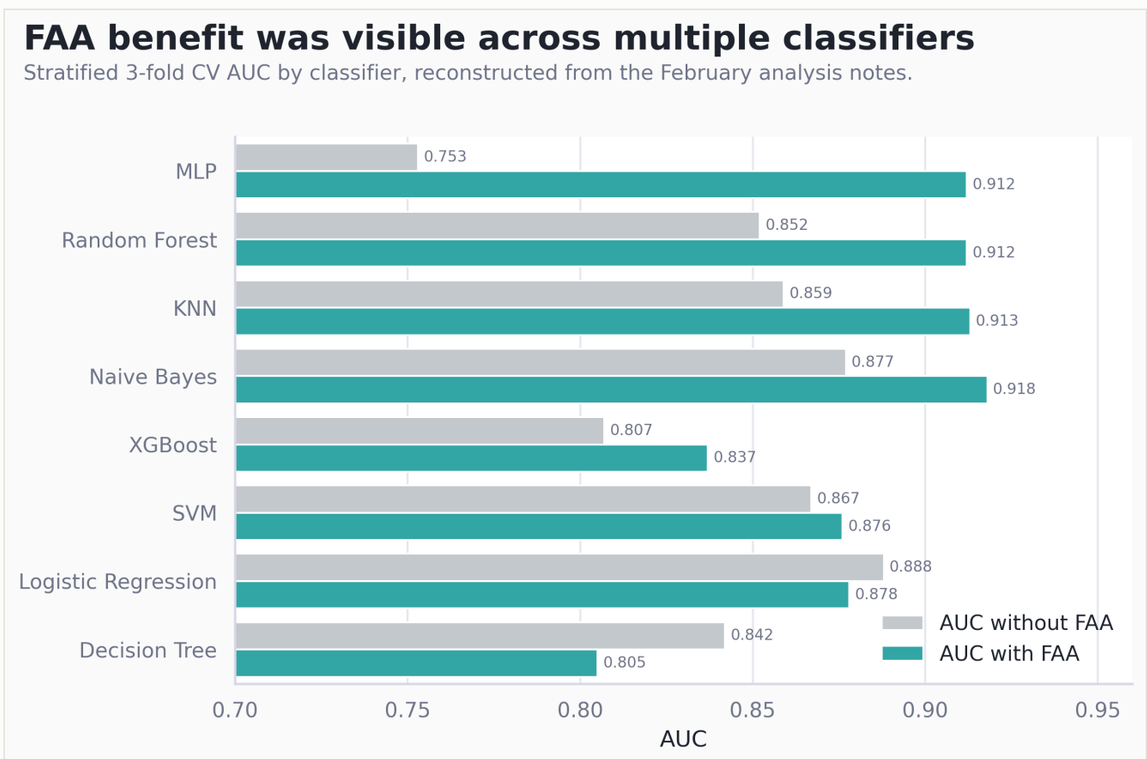

Figure 3. AUC improvement after adding FAA across all classifiers.

04 — DISCUSSION

Interpretation & limitations

Neurophysiological contribution. A brief resting-state measure provided non-redundant predictive information beyond self-report, consistent with a hyperarousal account of insomnia vulnerability.

Label stability. Three-wave ISI assessment yielded temporally stable class definitions, reducing the misclassification associated with single-session, cross-sectional designs.

Clinical translation. A single baseline session predicted insomnia status 12 months later, supporting a low-cost, single-visit early-screening approach.

Limitations. The sample was small and imbalanced (14 vs. 34) and relatively young; replication in larger, older, and clinically diverse cohorts is warranted.

CONCLUSION

A five-minute resting-state EEG measure, combined with two brief self-report inventories, identified persistent insomnia with ~**90% accuracy** — an objective, low-cost approach suitable for large-scale screening evaluation.

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