# Physiologically Informed Sensor Fusion for Cognitive Impairment Prediction from Polysomnography

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**Aims:** This study aimed to develop a physiologically informed multimodal fusion model to predict future cognitive impairment from overnight PSG. The approach was based on the hypothesis that risk related patterns are distributed across neural, cardiorespiratory, and motor systems and require structured integration of heterogeneous signals.

**Methods:** PSG channels were standardized and grouped by physiological modality. Sampling rates and light filtering were selected to preserve relevant temporal dynamics, including fast neural activity and slower respiratory patterns. Each channel was processed independently using a dedicated convolutional encoder to extract features prior to fusion. Channel level features were concatenated and integrated using a fully connected network to combine complementary physiological information. Missing channels were explicitly encoded, and stochastic channel masking was applied during training to improve robustness to heterogeneous recordings. Each study was represented using multiple 2 minute windows sampled across the night, including windows guided by sleep stage annotations. Window level predictions were averaged to obtain a patient level estimate. Demographic variables and summary features from algorithmic annotations were included as auxiliary inputs.

**Results:** In nested cross-validation, the model achieved mean AUROC 0.80 $\pm$ 0.03, area under the precision recall curve 0.79 $\pm$ 0.05, balanced accuracy 0.81 $\pm$ 0.01, sensitivity 0.80 $\pm$ 0.07, and specificity 0.82 $\pm$ 0.09. Discrimination remained stable across folds, while variation was observed in the trade off between sensitivity and specificity.

**Conclusion:** Physiologically informed sensor fusion provided a practical framework for integrating heterogeneous PSG signals for longitudinal cognitive risk prediction. By preserving temporal structure and combining signals across modalities, the model captured complementary physiological information and remained robust to missing channels and sensor variability. These findings support this method as a reliable tool for estimating future cognitive impairment risk.

Heterogeneous PSG
↓
25 / 100 / 200 Hz streams
↓
2-min windows + sleep stages
↓
Channel-wise CNN + covariates
↓
Mean pooling
↓
Patient-level risk

Figure 1. Physiologically informed sensor fusion pipeline.