

Bidirectional Control Energy (BiCE): An EEG Biomarker of Neural Efficiency Relevant to Alzheimer's Disease in a Photobiomodulation Study

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WHY NEURAL EFFICIENCY MATTERS



AD trajectories are heterogeneous



Amyloid/tau alone do not explain decline



Reduced neural efficiency may increase energetic cost



Scalable biomarkers are needed for cognitive resilience



BiCE quantifies the energetic cost of brain-state control.



Intranasal + Transcranial Photobiomodulation (PBM)

1

BiCE framework



EEG



State dynamics



Network control theory

Control energy

2

Experimental conditions



Baseline



Meditation



PBM + meditation



Sham



Post

3

Interpretation



Lower BiCE = lower energetic demand



for stable, optimized brain states



KEY FINDINGS



Meditation reduced BiCE vs baseline



PBM + meditation reduced BiCE further vs sham



BiCE separated experimental conditions



TRANSLATIONAL RELEVANCE



EEG-derived biomarker of neural efficiency



Sensitive to neurometabolic perturbation



Potential endpoint for MCI and early AD studies



Human EEG study



Baseline + meditation



PBM, sham, post



Permutation testing + ROC



Biomarker for MCI / early AD



TAKE-HOME MESSAGE

BiCE is a **quantitative EEG-derived biomarker of neural efficiency** that is sensitive to **meditation** and non-invasive **photobiomodulation**. **Lower BiCE suggests reduced energetic cost** for maintaining optimized brain states, supporting its potential as a translational endpoint in MCI and early Alzheimer's disease research.

