Hierarchical decomposition (HD) of resting-state EEG in recovery following severe brain injury identifies causal influence of high frequency activity (beta band) over anterior forebrain

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Motivation
The normal background electroencephalogram (EEG) typically shows a dominance of high frequency (15-30Hz, ‘beta band’) activity over the anterior forebrain (frontal/prefrontal cortices) in the awake state. Restoration of this high-frequency power as characterized in the power spectrum (PS) of the EEG is a common finding among patients who show recovery after a severe brain injury across a wide range of etiologies and patterns of structural injury (Conte et al., 2010; Williams et al., 2009). This activity has been suggested as a general marker for the recovery process and likely reflects changes in overall cerebral background activity and the afferent input to neocortical neurons within the anterior forebrain mesocircuit (Schiff 2010). To examine the possible causal role of recovered high-frequency activity over anterior forebrain structures, we applied hierarchical decomposition analysis (HD) of the EEG (Repucci et al., 2001) to EEG data obtained from a single patient subject studied longitudinally over an 18 month period and 6 normal subjects. In contrast to principal component or within the anterior forebrain mesocircuit (Schiff 2010). To examine the background activity and the afferent input to neocortical neurons

Data Acquisition

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Multitaper method; 19 tapers
Selection of 30 artifact-free epochs, 10 sec each
Bandpass filtering, 1 - 55 Hz

Hierarchical Decomposition

Hierarchical Decomposition of resting-state EEG in recovery following severe brain injury

Results - Normal Subjects
Hierarchical Components (HC1 or HC2) at the causal end of the hierarchy for all normal subjects
Normal 01 - HC1
Normal 02 - HC1
Normal 03 - HC2
Normal 04 - HC1
Normal 05 - HC1

Results - Patient IN356W
Comparison of Power Spectra - Epochs 1:5
Patient IN356W - sample 10-sec epoch

Patient IN356W
The patient subject (40 yr. old male) demonstrated a spontaneous recovery of consciousness 19 years after sustaining a severe traumatic brain injury.

Between evaluations, functional & behavioral improvements were documented including: Neurological: Some functional recovery of left upper extremity motor function.

Behavioral: Increase in baseline arousal level

Improvement in attentional focussive-sustained persistence

Improved speech, more intelligible

no paroxysmal or dysrhythmic activity
no errors in confrontation naming

Corresponding evidence of structural and metabolic change (Voss et al., 2008) and prominent increases in 15-35 Hz power over the anterior forebrain (Conte et al., 2010) were observed.

Hierarchical Decomposition Analysis

HC1 - 2004
HC1 - 2005

Comparison of Power Spectra - Epochs 1:5

Power (dB)

Frequency (Hz)

5 Principal Components
5 Hierarchical Components

10-20 Bipolar montage
Digitization at 200 - 1024 Hz
Bandpass filtering, 1 - 55 Hz
Selection of 30 artifact-free epochs, 10 sec each from eyes-open, awake state

Steps of HD analysis

Principal components

Hierarchical Decomposition

Projection into first 5 principal components
Downsampling to 100 – 128 Hz
Lags selected by Akaike Information Criterion (AIC)

Spectral Analysis
Multi taper method; 19 tapers carried out in MATLAB with Chronux Toolbox

Summary and Conclusions
Hierarchical decomposition analysis of both normal subject and patient EEG records reveals a consistent finding of a component with strong alpha (~5-11Hz) and beta (~15-35Hz) peak in the power spectrum that is at or near the origin (causal side) of the hierarchy resolved by this analysis method.

The analysis highlights the distinction between decompositions based on accounting for variance, and decompositions based on identifying causal relationships.

An apparent similarity in the spatial weighting of the first (or second) hierarchical component for all subjects suggests a common biological generator, possibly related to the default mode network. Further characterization using source localization methods is necessary to test this possibility.

Collectively, these findings suggest the utility of HD analysis to resolve global EEG dynamics and further development of the technique’s use in the study of recovery of brain function following severe injuries (see Drover et al., SFN2012, 553.15).

References


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