Unpacking Hidden Resting State Dynamics in Hallucination-Prone Individuals using a Hidden Semi-Markov Model

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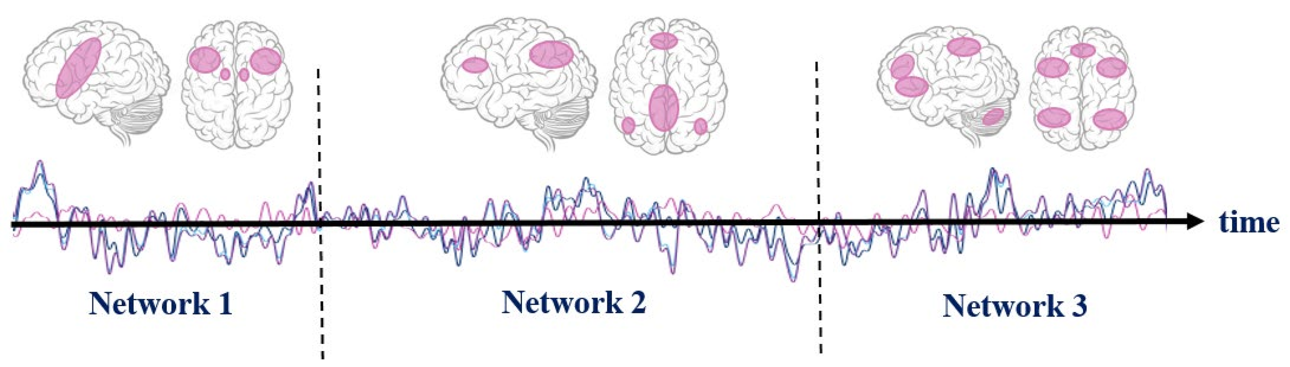
INTRODUCTION

Hallucination Proneness (HP) Continuum

non-clinical → clinical

- Symptom severity and underlying neural changes increase as a function of HP [1].
- Alpha & theta are most dominant during resting state (RS) EEG → are associated with different aspects of cognitive control and error monitoring [2].
- Cognitive control is involved in the neural underpinnings of (auditory verbal) hallucinations [1].

RSN activity is transient, sequential, and dynamic



Recurrent patterns of RS activity can be clustered into "brain states" [3], which can elucidate frequency-specific alterations in brain dynamics.

RQ: Does HP in a non-clinical sample relate to changes in brain state dynamics?

METHODS

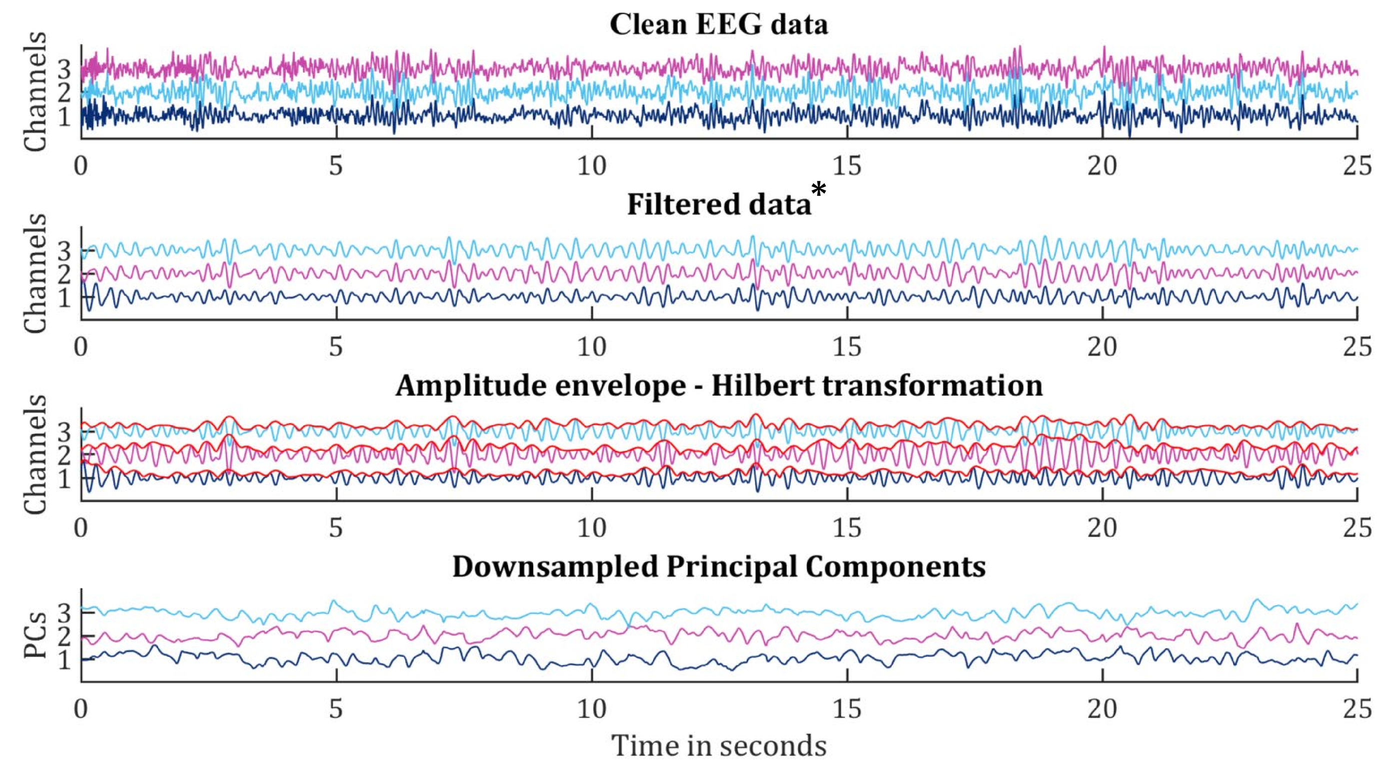
Data acquisition

- 24 individuals from the general population.
- 128-channel actiCHAMP active system sampling freq. 1000 Hz; Sound-proof EEG booth.
- 5 min. eyes-closed RS EEG.
- Self-report Launay-Slade Hallucination Scale (LSHS) measuring HP in a non-clinical sample [4].

EEG data pre-processing

- MATLAB-based EEG data analysis toolbox EEGLAB.
- Band-pass filter 1-40 & resampling to 512 Hz.
- Artifact Subspace Reconstruction (ASR) EEGLAB plugin.
- ICA/PCA; artifact rejection related to eye-movement, line noise, channel noise, and muscle activity.

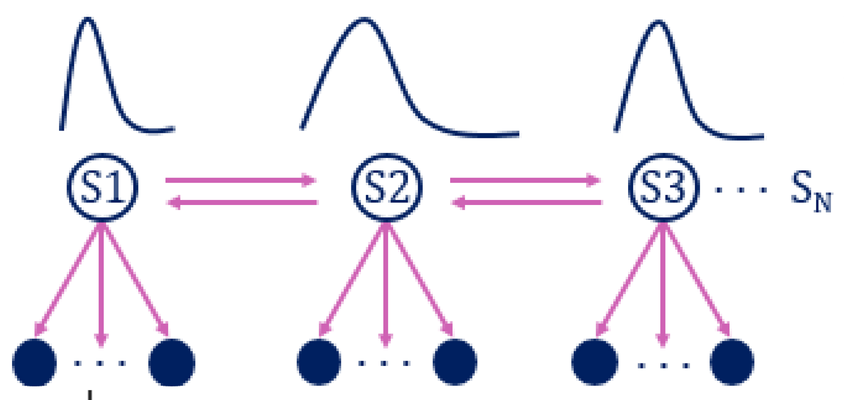
EEG data post-processing



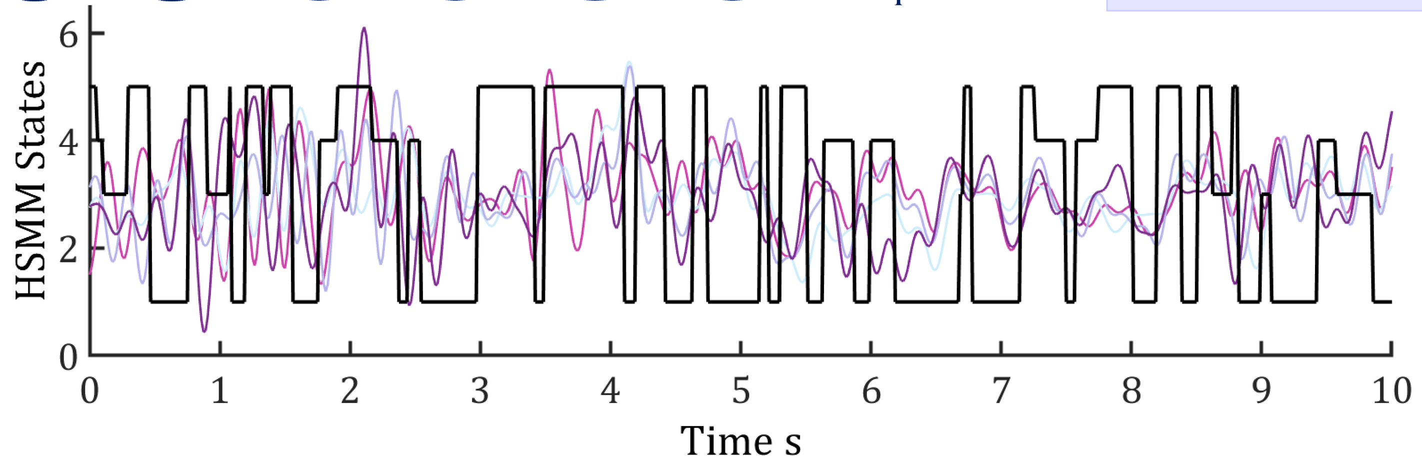
*Frequency bands of interest: Alpha (8 – 12 Hz) and theta (3 – 7 Hz)

Data modelling & statistical analysis

The HsMM models RS EEG data as a sequence of **recurrent hidden states of functional connectivity (FC)**, here based on **amplitude coupling** [3].



- S_1 to S_N are characterized by unique statistical properties of the data (variances & covariances).
- Filled circles: random number of observations, i.e., the observed EEG time-series
- The states' durations are explicitly modeled by the duration model as lognormal probability distributions [3].
- Two HsMMs (alpha & theta modeled separately) were trained with **k = 6 states**.
- Using the state sequence, the dynamic properties of the states were calculated for each subject and statistically analyzed in relation to HP.



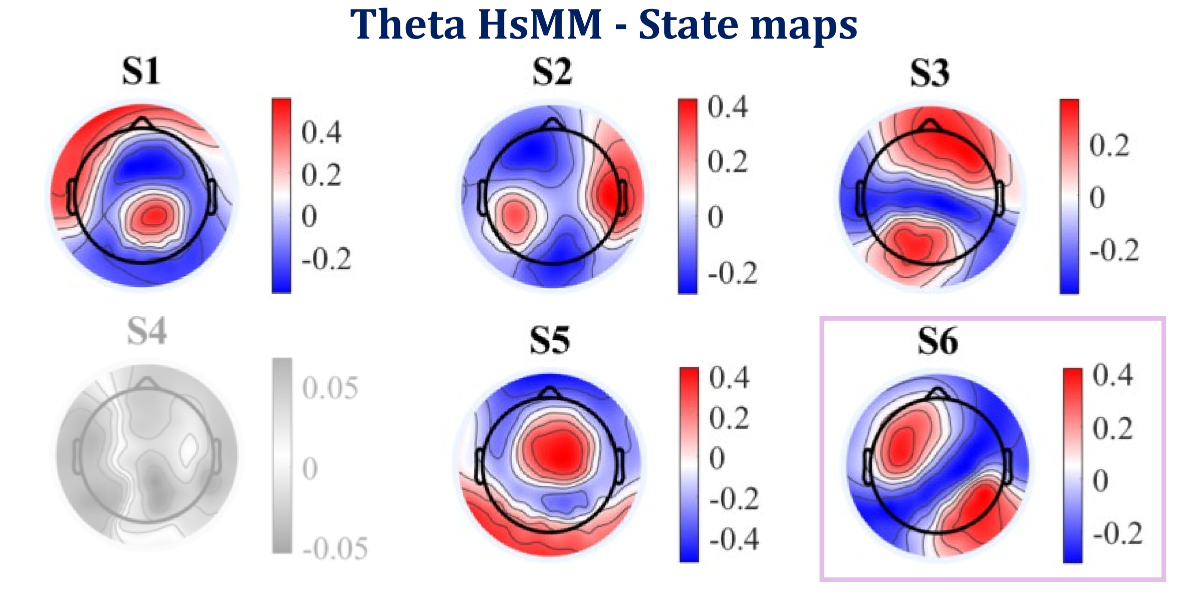
State dynamics of interest:

- State fractional occupancy (FO), i.e., relative time spent in each state.
- State duration mean and variance.
- Total number of transitions.

RESULTS

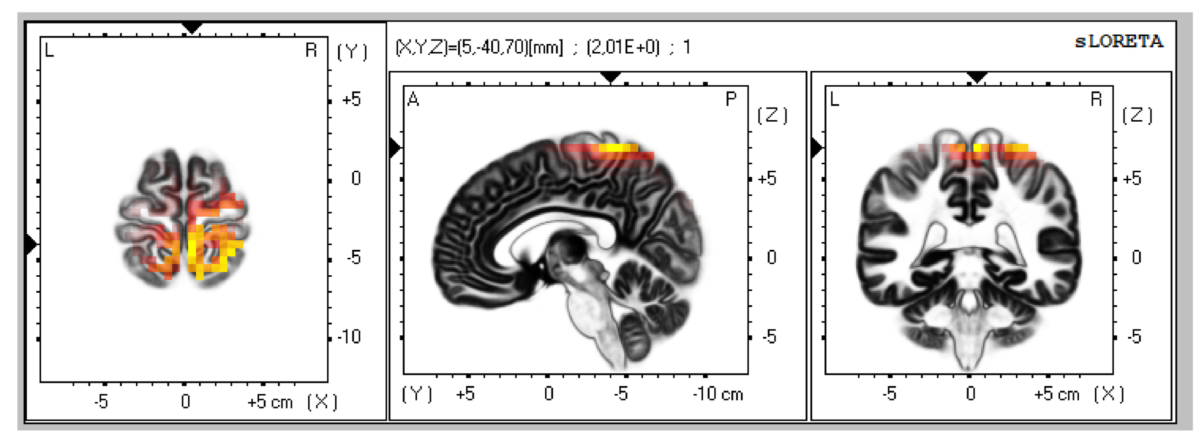
Alpha HsMM: NO significant relationship with HP.
→ Resuts of the **theta HsMM are presented** here in more detail.

Theta HsMM - State maps



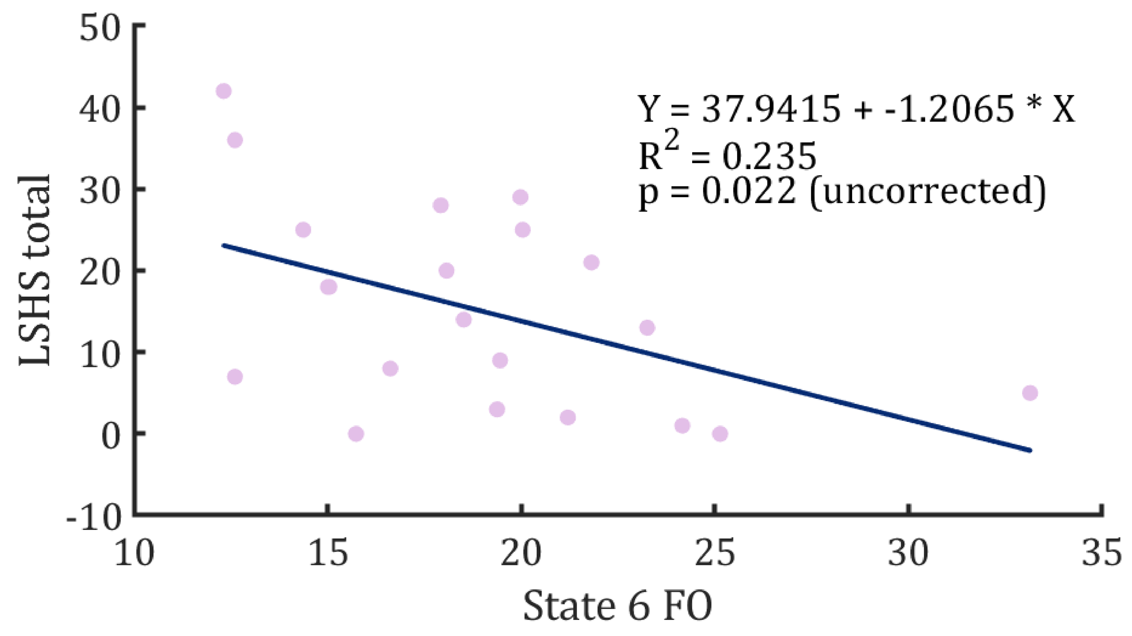
State 4 considered noise, i.e., excluded from further analyses

Source of state 6



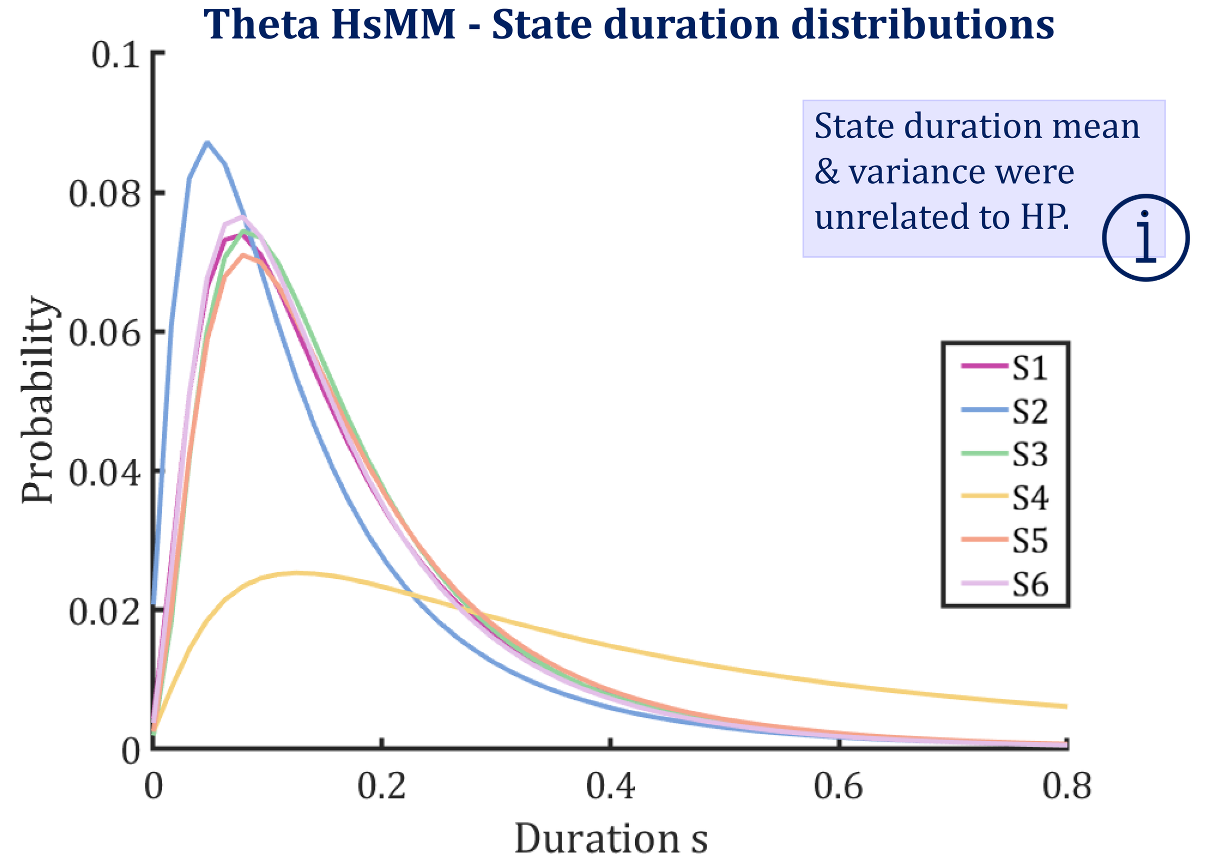
Maximum activity localized in
i) medial frontal gyrus and ii) post-central gyrus, both implicated in (auditory verbal) hallucinations [5].

Theta HsMM - Regression of state 6 FO & LSHS total score



State 6 FO shows a **negative linear relationship** with the LSHS total score (general HP), the LSHS-5 subscale (auditory HP), and the LSHS-3 subscale (auditory-verbal HP).

Theta HsMM - State duration distributions



State duration mean & variance were unrelated to HP.

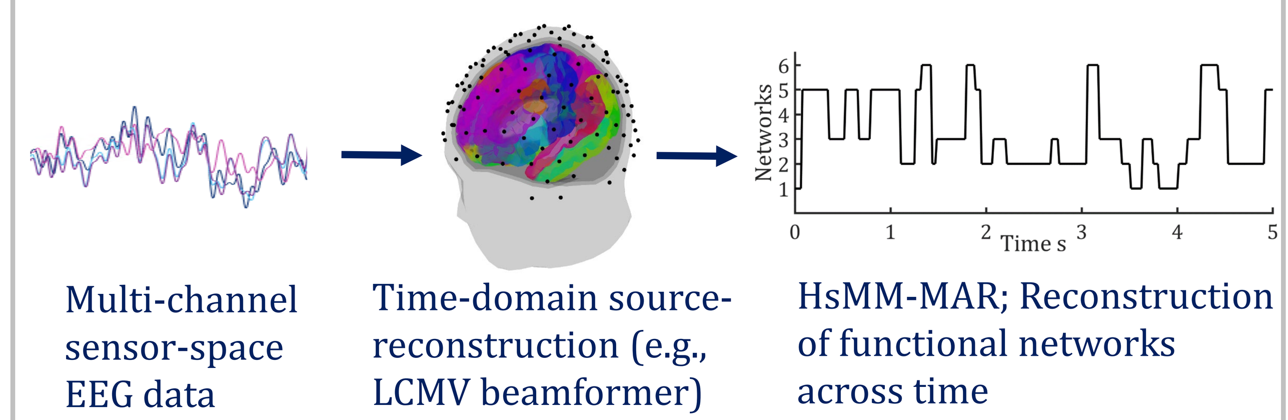
Main findings:

- High HP relates to less time spent in state 6.
- Brain state dynamics of different frequency bands are differently related to cognition and behavior.
- Theta brain state temporal dynamics are sensitive to individual differences in HP and related cognitive function in a non-clinical sample.

CONCLUSION & FUTURE DIRECTIONS

- The HsMM characterizes brain state dynamics on a **sub-second time-scale →** relevant for cognition and behavior
- **Deficient active suppression of (internal memory-related or external sensory) intrusions** may underlie (auditory verbal) hallucinations [1].
- Low RS theta power linked to poor conflict-related (reactive) cogntitive control, i.e., decreased resistence to interference [6].
- Theta-band dynamics may reflect neural signatures of trait-like **individual differences in reactive control and error monitoring** → may inform about **hallucinatory predisposition** in a non-clinical sample.
→ provides support for the **continuity of psychotic experiences** [7].

- Application of the **HsMM-Multivariate Autoregressive Model (HsMM-MAR)** [8] to source-space EEG data
- Interpretation on the level of RSNs, including their spectral properties and FC.



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