A dissociation between EEG entropy at slow and fast timescales in non-pharmacological altered states of consciousness

ASSC 26, 2023 | New York, NY, USA

Joel Frohlich[1,2], Ninette Simonian[1], Nicco Reggente[1]
[1]Institute For Advanced Consciousness Studies, Santa Monica, California, USA
[2]Institute for Neuromodulation and Neurotechnology, University Hospital and University of Tübingen, Germany

Scan the QR code for a PDF

SHORT ON TIME? HERE'S THE SUMMARY

We examined EEG actiity during stroboscopic stimulation and breath-focused meditation. Brain wave complexity takes a surprising twist during altered states: fast signals increase in complexity, as expected, while slower rhythms surprisingly reduce their complexity, adding nuance to our understanding of brain activity and consciousness.

Background

The entropy or "complexity" of electroencephalography (EEG) signals decreases during states of unconsciousness and increases during psychedelic states relative to ordinary wakefulness (Sarasso et al. 2021). However, it is uncertain how EEG entropy changes during non-pharmacological altered states of consciousness (npASC), though prior work suggests similar changes as seen in psychedelics (Schwartzmann et al. 2019).

Methods

- We induced non-pharmacological altered states of consciousness (npASC) induced by 1) stroboscopic stimulation with binaural beats and 2) breath-focused meditation, while recording 64-channel EEG.
- Participants in the stimulation group received either STRONG (high frequency) or WEAK (low frequency) stroboscopic stimuli (see Table 1).
- The stroboscopic stimulation causes geometric, kaleidoscopic perceptions similar to those experienced with psychedelic substances.
- We calculated the permutation entropy (Bandt and Pompe, 2002) of the EEG signals at various time lags, providing a measures of complexity at different frequencies.
- Results were analyzed with linear mixed models and log-likelihood ratio tests to infer effects of timepoint and condition.

Breath-focused meditation

Stroboscopic stimulation

Acknowledgements

This work was funded by a Research Services Agreement between IACS and IN.TO. IN.TO had no input on the design nor analysis of this study, apart from supplying the stropboscopic hardware and software.

References

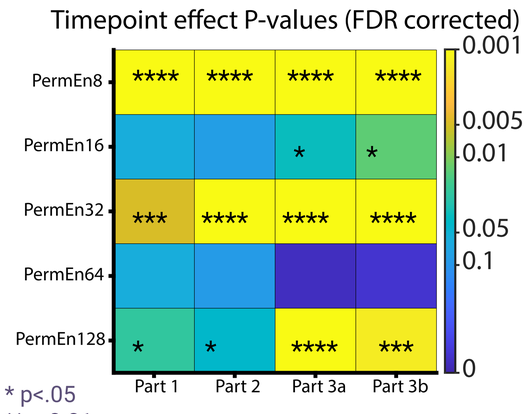
1. Sarasso, Simone, et al. "Consciousness and complexity: a consilience of evidence." Neuroscience of Consciousness 7.2 (2021): 1-24.
2. Schwartzman, David J., et al. "Increased spontaneous EEG signal diversity during stroboscopically-induced altered states of consciousness." BioRxiv (2019): 511766.
3. Bandt, Christoph, and Bernd Pompe. "Permutation entropy: a natural complexity measure for time series." Physical review letters 88.17 (2002): 174102.
4.Carhart-Harris, Robin L. "The entropic brain-revisited." Neuropharmacology 142 (2018): 167-178.

Results

- After preprocessing and data cleaning, we retained:
  - **N = 74 datasets for weak stimulation**
  - **N = 72 datasets for strong stimulation**
  - **N = 69 datasets for meditation**
  - **N = 215 datasets total**
- We found **increases in entropy at fast timescales** (8 - 40 Hz) but **decreases in entropy at slow timescale**s (2 - 10 Hz).
  - **Weak stimulation appears more similar to meditation as judged by PermEn16** (8 - 20 Hz):
    meditation < weak stimulation < strong stimulation
  - **Strong stimulation appears more similar to meditation as judged by PermEn8** (16 - 40 Hz):
    meditation < strong stimulation < weak stimulation

Conclusions

Our results show a dissociation between EEG entropy at fast and slow timescales during npASC. In particular, our finding of diminished 2 - 10 Hz entropy during npASC, including a visually rich experience of stroboscopic stimulation, is surprising given that neural entropy generally scales with the richness of conscious content (Carhart-Harris, 2018).



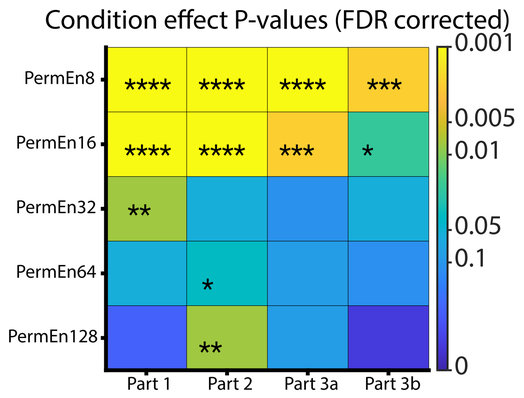
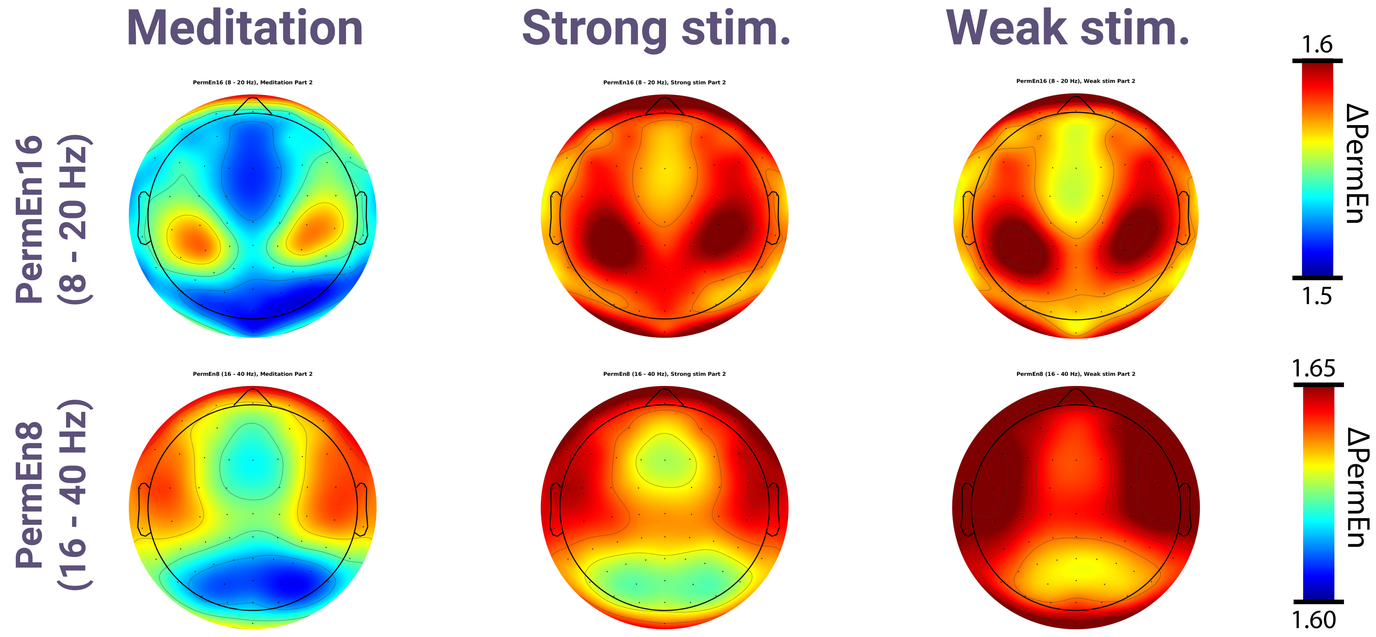


Table 1: Stimulation frequencies

Stage		Part1	Part2	Part3a	Part3b
STRONG	Light pulse A freq (Hz)	7.5 - 12.5	13.5 - 18.5	4.5 - 12	8.0 - 14.0
STRONG	Light pulse B freq (Hz)	NA	NA	40.0 - 79.5	40.0 - 79.5
STRONG	Binaural Beat freq (Hz)	7.5 - 12.5	13.5 - 18.5	4.5 - 12	8.0 - 14.0
WEAK	Light pulse A freq (Hz)	0.2	0.2	0.2	0.2
WEAK	Light pulse B freq (Hz)	0.5	0.5	0.5	0.5
WEAK	Binaural Beat freq (Hz)	7.5 - 12.5	13.5 - 18.5	4.5 - 12	8.0 - 14.0

Part 2 (shows consistant effects)



Here, we substract pre-experience resting (top row) and post-experienc resting (bottom row) to reveal what happens during the experience ...