Time-frequency analysis of MEG data

Alex Clarke

UNIVERSITY OF CAMBRIDGE

Centre for Speech, Language and the Brain
Department of Experimental Psychology

CSLB

Oscillations in the brain

- Brain oscillations show power changes in response to events
  - Changes linked to distinct frequency bands

Name:	Frequency:	Example association:
Delta	0-4 Hz	Sleep, clinical disorders
Theta	4-8 Hz	Working memory
Alpha	8-12 Hz	Sensory stimulation, memory, attention
Beta	12-30 Hz	Motor actions, planning
Gamma	30-80 Hz	Binding, consciousness, attention

Herrmann, Grigutsch & Busch (2005)

However, oscillations recorded in MEG contain confluence of information from different frequencies

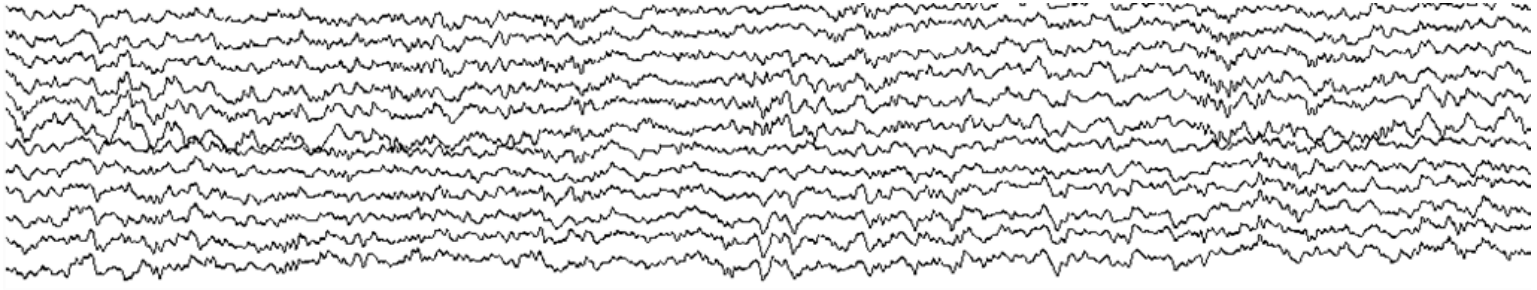
- Need specialised analysis techniques

Oscillations in the brain

Techniques allow us to ask:

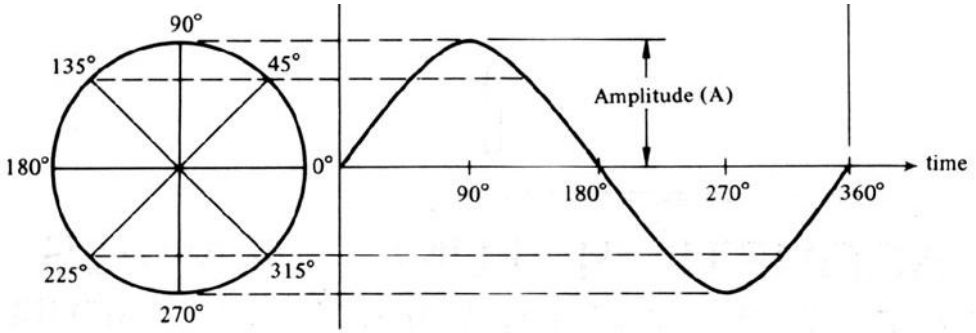
- Are different frequencies more tuned to different sensory/cognitive functions?
- Is different information about a stimulus encoded in different frequency bands?

Oscillations in the brain

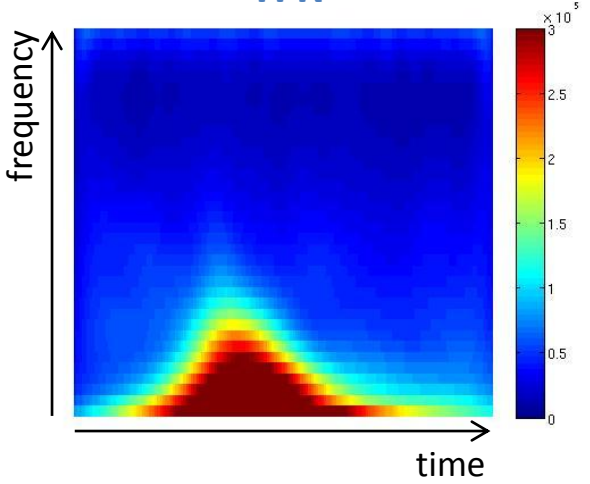


- Complex oscillations we record can be decomposed into different frequencies
- The frequency-tuned **power** and **phase** can then be extracted for each time-period
- Power used to construct TFR

Phase

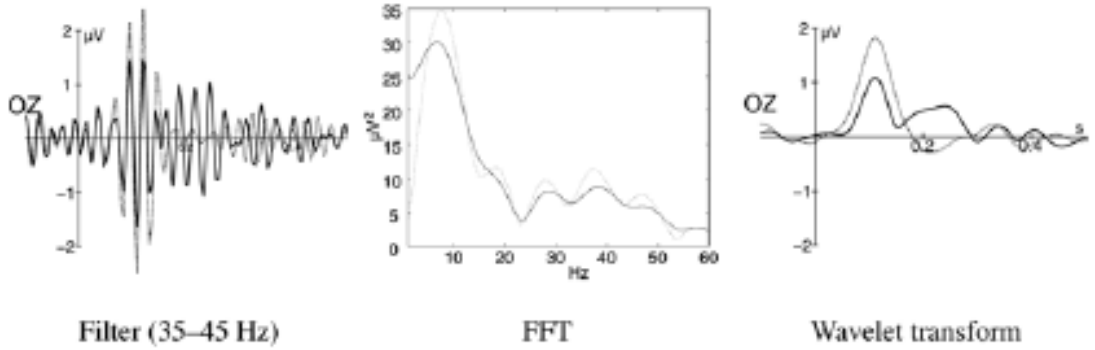


TFR



Decomposing the oscillations

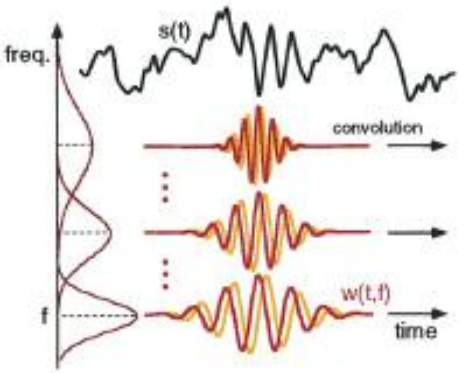
- Methods to extract freq-tuned oscillations:
  - Filtering
  - FFT
  - Multi-tapers
  - **Wavelets**

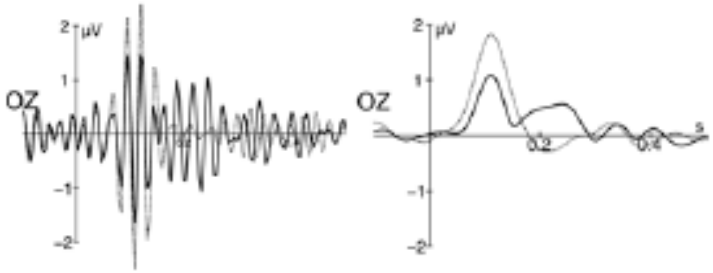


Filter (35–45 Hz) FFT Wavelet transform

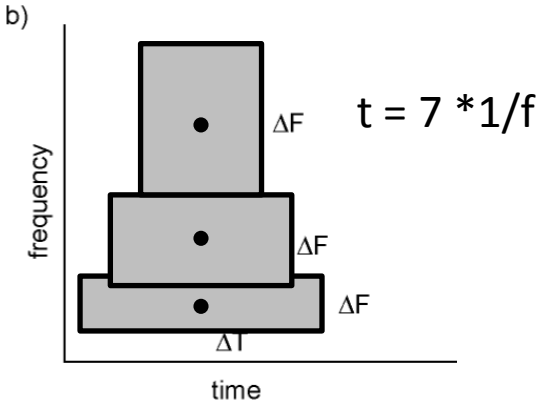
Wavelets

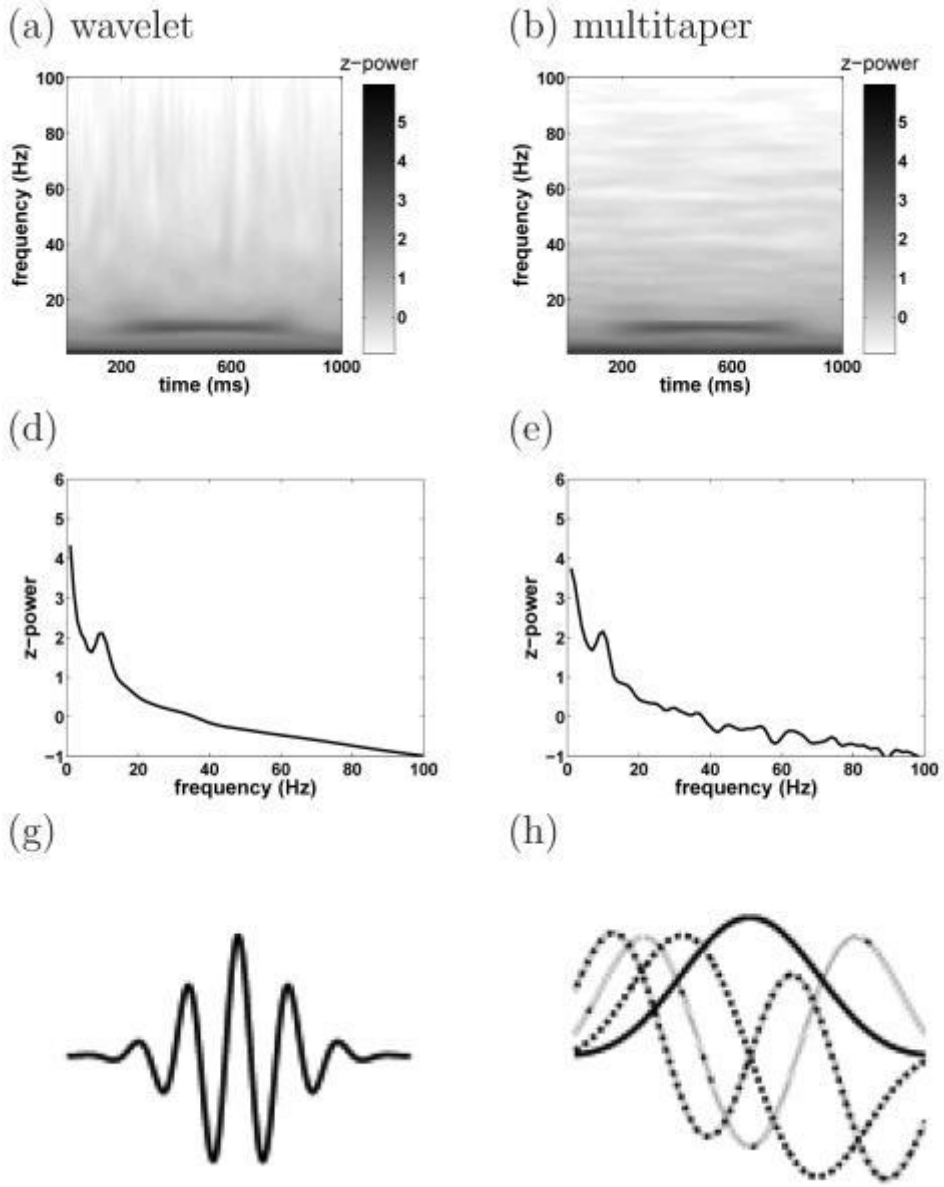
- Extract power and phase centred at *t* and *f*
- Morlet wavelet transformation of the signal
  - Signal convolved with frequency-specific wavelet function
  - Shifted, scaled version of mother wavelet
  - Though of as envelop of filtered signal





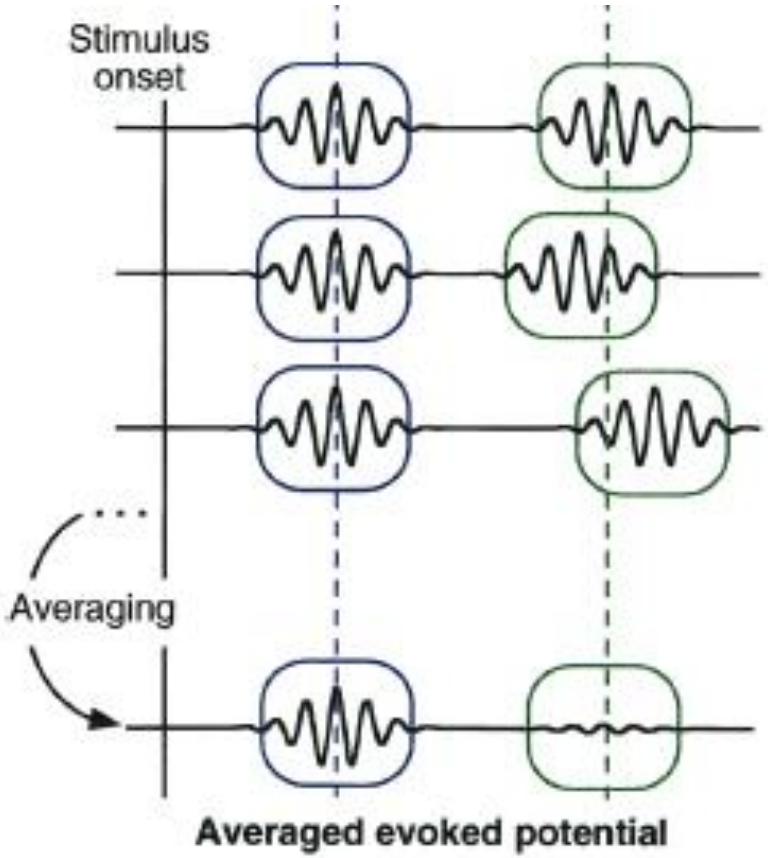
- Reveals freq-specific power (and phase)
  - But temporal/frequency resolution variable
  - No. cycles/window
    - <u>Cycles go up:</u> Time res goes down, Freq res goes up
    - Typical 5 - 7 cycles





Vugt et al (2007). Journal of Neuroscience methods

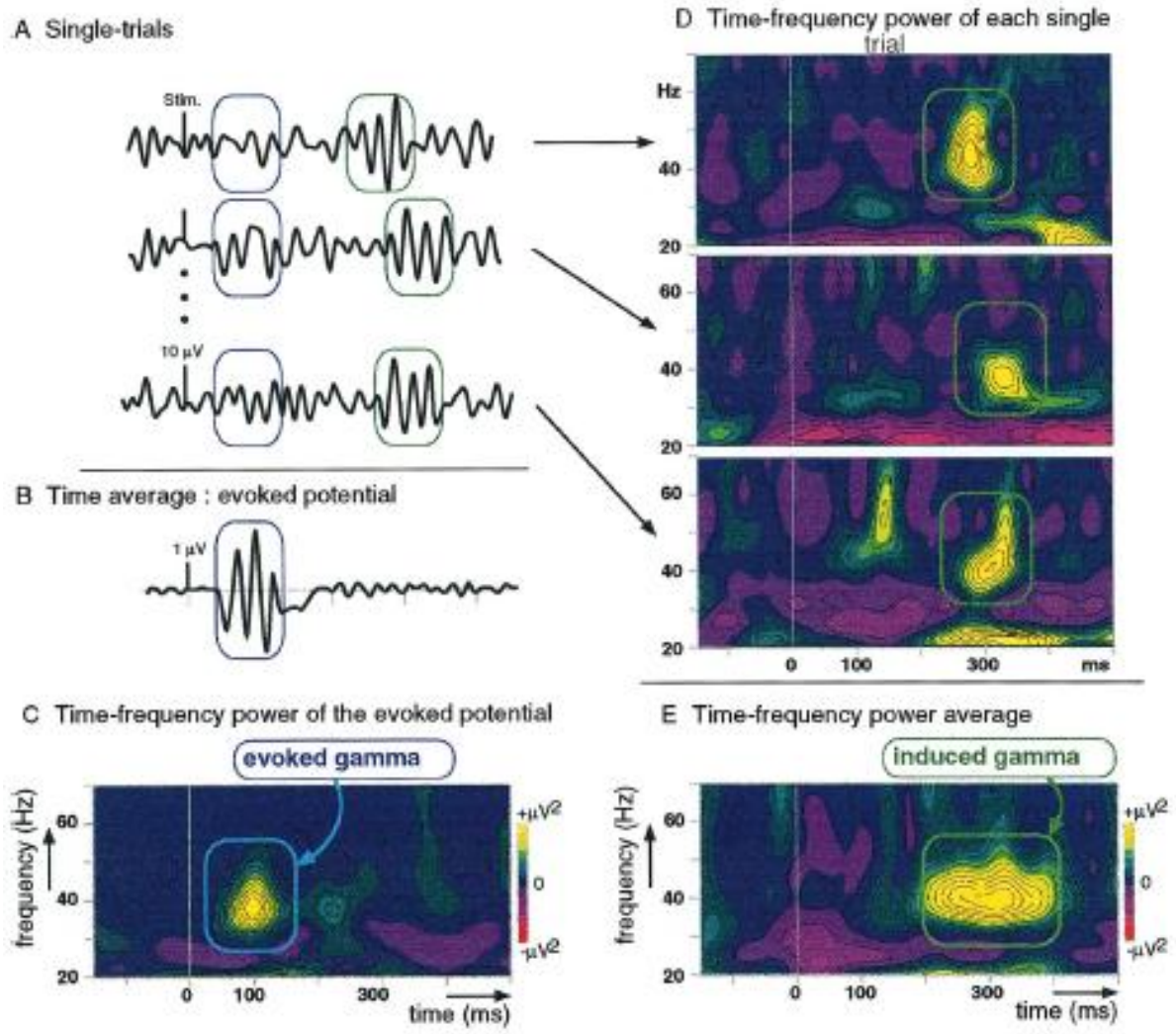
Data analysis



Tallon-Baudry & Bertrand (1999)

Data analysis

Evoked **Induced**

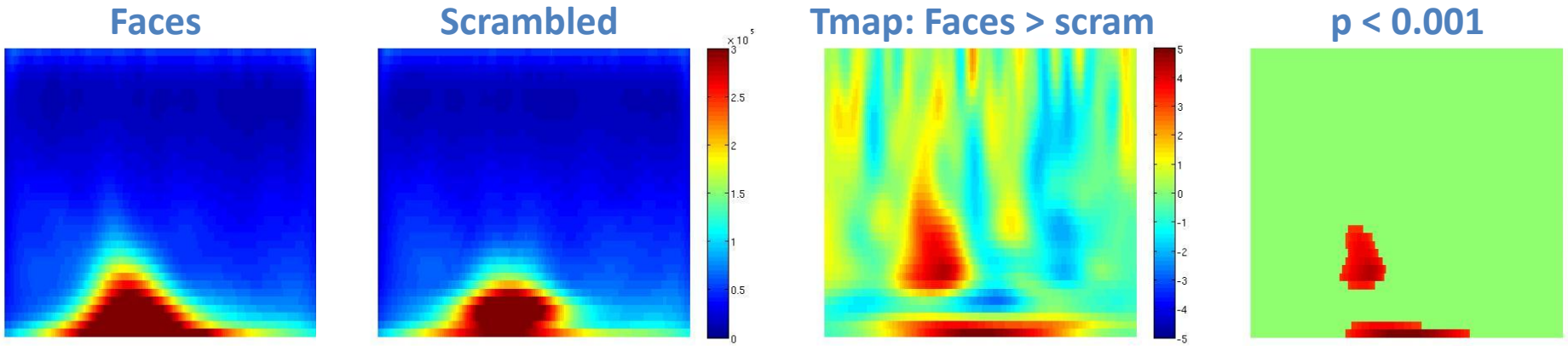


Tallon-Baudry & Bertrand (1999)

Example

Faces vs. scrambled faces

- Epoched, downsampled, artefact rejection
  - TFR of trials, averaged within condition (total)
  - SPM stats showing faces > scrambled
    - 110 ms, 13 Hz
    - 190 ms, 5 Hz

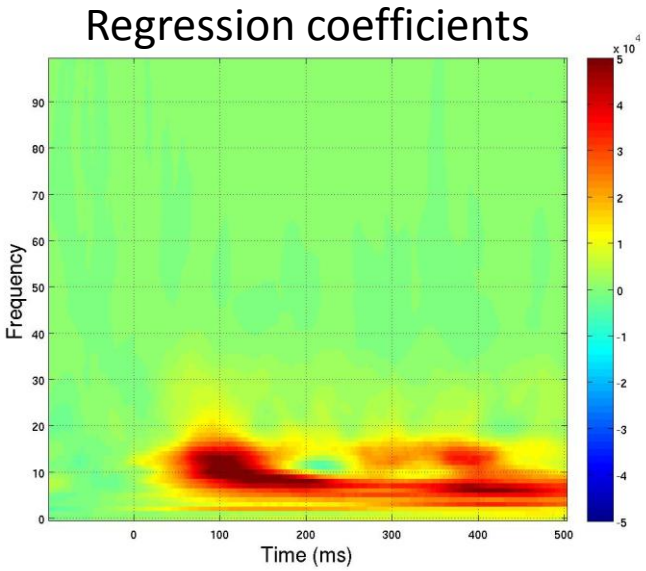


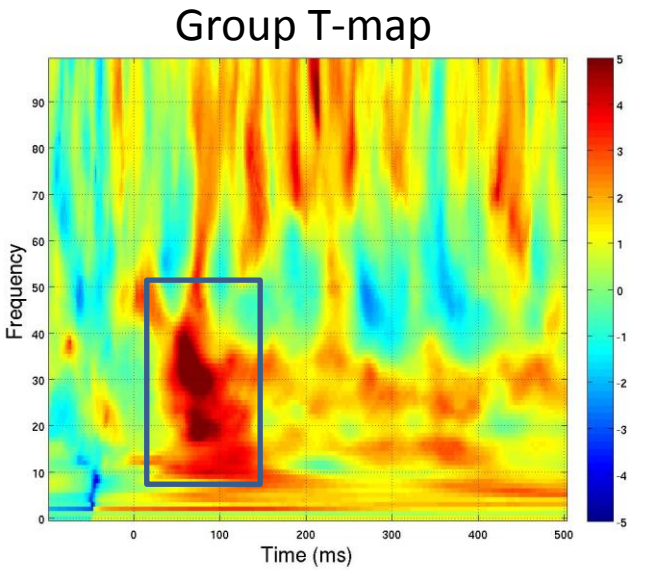
SPM8 multimodal face data: http://www.fil.ion.ucl.ac.uk/spm/data/

Advanced 1: Regression

- Regression between single-trial power and stimulus properties
  - At each time/frequency point
- Reveal TFR increases/decreases with varying linear stimulus properties

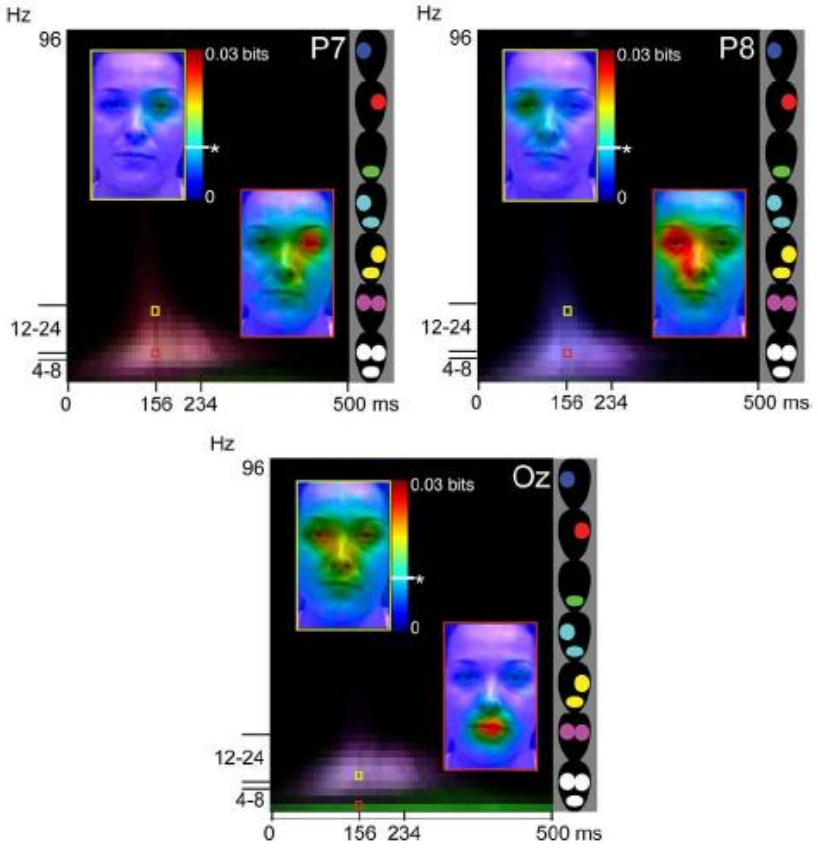
- Here, shows increased power with increasingly complex visual images
  - 10-50 Hz, 50-150 ms





Advanced 2: MI

- Mutual information (MI) between presence of pixels and power (& phase)
- Shared info between facial features and frequency-specific power/phase

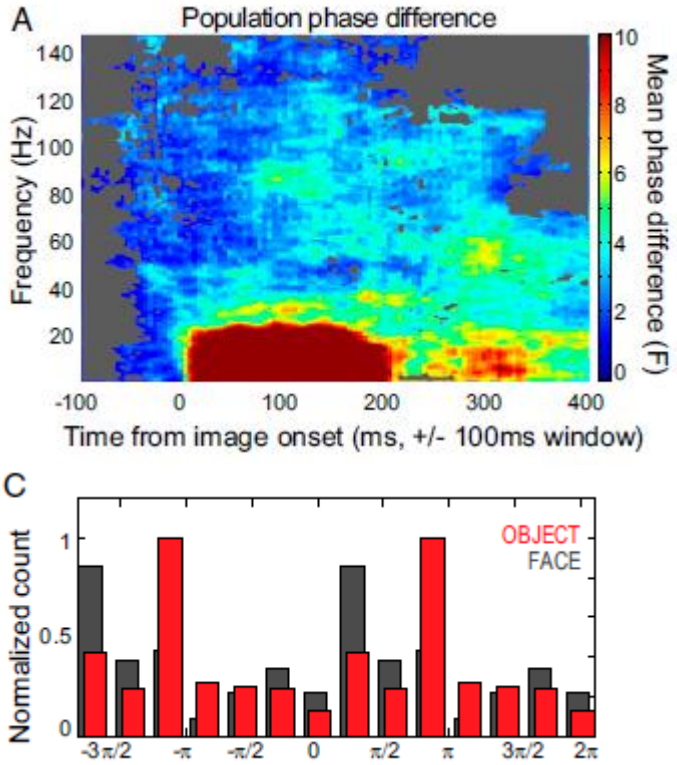


- Multiplexing
  - Mouth: Theta
  - Eyes: Beta

Schyns, Thut & Gross (2011). PLoS biology

Advanced 3: Phase

- Category-specific phase responses in non-human primate STS
  - Phase of oscillations tied to type of image (face vs. object)
- Systematic differences in phase not due to firing rates
- Evidence that phase coding could support rapid object recognition



Turesson, Logothetis & Hoffman (2012). PNAS

Tutorials

- SPM8
  - Multimodal face data
  - http://www.fil.ion.ucl.ac.uk/spm/data/
  - Chapter x of manual
- Fieldtrip
  - http://fieldtrip.fcdonders.nl/tutorial/timefrequencyanalysis
- MNE
  - http://mne-tools.github.com/mne-python-intro/

Reading

- Herrmann, Grigutsch & Busch (2005). EEG oscillations and wavelet analysis. In *Event related potentials: A methods handbook.*
- Tallon-Baudry & Bertrand (1999). Oscillatory gamma activity in humans and its role in object representation. Trends in cognitive science.
- Pfurtschellar & Lopes da Silva (1999). Event-related EEG/MEG synchronization and desynchronization: basic principles. Clinical Neurophysiology.
- Roach & Mathalon (2008). Event-related EEG time-frequency analysys: An overview of measures and an analysis of early gamma band phase locking in Schizophrenia. Schizophrenia bulletin.
- Mitra & Pesaran (1999). Analysis of dynamic brain imaging data. Biophysical journal.