Advanced Cognitive Neuroscience

Week 38: Workshop paradigm: Measuring visual subjective experience + MR Recordings

The course plan

Week 36:
Lesson 0: What is it all about?
Class 0: Setting up UCloud and installing MNE-Python

Week 37:
No Teaching

Week 38:
Lesson 1: Workshop paradigm: Measuring visual subjective experience + MR Recordings
Class 1: Running an MEG analysis of visual responses

Week 39:
MEG workshop: Measuring and predicting visual subjective experience

Week 40:
Lesson 2: Basic physiology and Evoked responses
Class 2: Evoked responses to different levels of subjective experience

Week 41:
Lesson 3: Multivariate statistics
Class 3: Predicting subjective experience in sensor space
<u>Deadline for feedback: Video Explainer</u>

Week 42:
Autumn Break

Week 43:
Lesson 4: Forward modelling and dipole estimation
Class 4: Creating a forward model

Week 44:
Lesson 5: Inverse modelling: Minimum-norm estimate
Class 5: Predicting subjective experience in source space

Week 45:
Lesson 6: Inverse modelling: Beamforming
Class 6: Predicting subjective experience in source space, continued

Week 46:
Lesson 7: What about that other cortex? - the cerebellar one
Class 7: Oral presentations (part 1)
<u>Deadline for feedback: Lab report</u>

Week 47:
Lesson 8: Guest lecture: Laura Bock Paulsen: Respiratory analyses
Class 8: Oral presentations (part 2)

Week 48:
Lesson 9: Sensors of the future
Class 9: Oral presentations (part 3)

Week 49:
Lesson 0 again: What was it all about?
Class 10: Oral presentations (part 4)

Guest lecture + MEG NORD

Page limits for report

2) *Report on MEG acquisition and MEG analysis:* **Project group assignment (50 % of grade)**:

- Task: The report must include an **introduction**, based on relevant literature; operationalisable **hypotheses**; a clear **methods** section, which must describe the experiment and the data acquisition procedure; a succinct **results** section with both behavioural data and MEG data; a **discussion** addressing limitations and the suitability of the method for investigating subjective experience. Data from all 8 participants **must** be used and **at least one** analysis **must** be based on multivariate statistics. A maximum of 6 pages per co-author. Code as appendix.
- Evaluation Criteria: to what degree has **relevant** literature been chosen for the introduction; to what degree has **operationalisable** hypotheses been formulated; to what degree has the methods section **clearly** described the experiment and the data acquisition procedure; to what degree are the results **succinctly** described; to what degree are the limitations and the suitability of the method **relevantly** described. (**Remember** to use all participants and to use a multivariate analysis)
- Deadline for receiving feedback: Week 46 (Thursday 23.59)

Linear algebra materials

https://www.3blue1brown.com/

Look for the linear algebra videos

Leon Steven J (2015) Linear algebra with applications., 9. ed., global ed. Pearson, Boston ;

https://cryptpad.fr/doc/#/2/doc/edit/a0pJG0VzkK99GmREvYHR5itk/

CryptPad

5

Online collaboration

- Let’s create a resource together
  - It will become whatever you make it
- So join in the collaboration

Advanced Cognitive Neuroscience 2025 Q&A

WEEK 36: what is it all about?

Q: (Lau) how do I ask questions here?

A: (Lau) you’ve just done it - well done!

Q: how do I ask questions anonymously

A: (Lau) you’ve just done it - well done!

Q: how do I answer questions?

A:(<student_name>): like this, or anonymously if you prefer. You can also write “student” to highlight that it is an answer given by a fellow student

WEEK 38: Workshop paradigm: Measuring visual subjective experience + MR Recordings

WEEK 39: MEG workshop: Measuring and predicting visual subjective experience

WEEK 40: Basic physiology and Evoked responses

Workshop

SUBJECTIVE EXPERIENCE

- September 19th: MR scans (**only** the subjects should show up): sign-up sheet
- September 22-24: 9-17
  - Two subjects the first day
  - Three subjects the other days
  - Subjects can join one other group to observe how things are done from the outside

MR slots

Modality	Date	Time Slot	Full Name	Study Group
MR	19-Sep	09.00-09.15	Sofie Bøjgaard Thomsen	5
MR	19-Sep	09.15-09.30	Ane Iben Lodahl	4
MR	19-Sep	09.30-09.45	Matilda Rhys-Kristensen	3
MR	19-Sep	09.45-10.00	Hannah Mai Højgaard	6
MR	19-Sep	10.00-10.15	Katharina Hellmund	0
MR	19-Sep	10.15-10.30	Christian Westh Stenbro	7
MR	19-Sep	10.30-10.45	Mads Munch Mikkelsen	1
MR	19-Sep	10.45-11.00	Ditlev Kræn Andersen	2

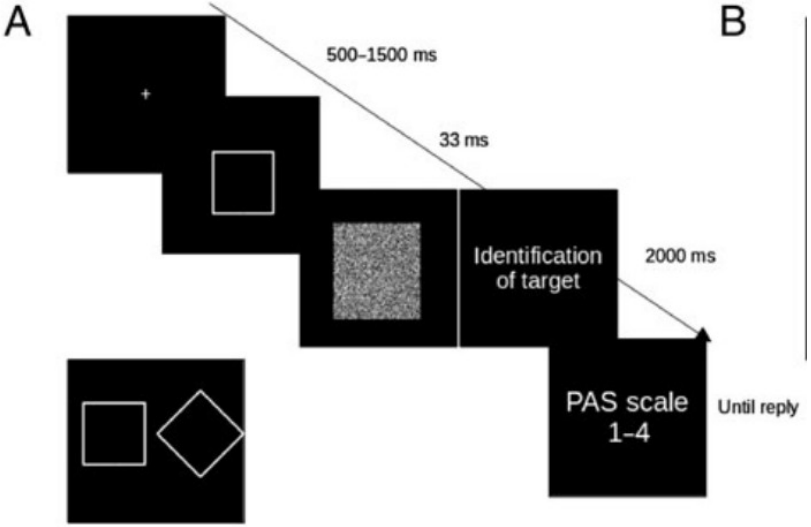
MEG slots

Modality	Date	Time Slot	Full Name	Study Group
MEG	22-Sep	10.00-13.00	Ane Iben Lodahl	4
MEG	22-Sep	13.00-16.00	Katharina Hellmund	0
MEG	23-Sep	09.00-12.00	Hannah Mai Højgaard	6
MEG	23-Sep	12.00-15.00	Ditlev Kræn Andersen	2
MEG	23-Sep	15.00-18.00	Matilda Rhys-Kristensen	3
MEG	24-Sep	09.00-12.00	Christian Westh Stenbro	7
MEG	24-Sep	12.00-15.00	Sofie Bøjgaard Thomsen	5
MEG	24-Sep	15.00-18.00	Mads Munch Mikkelsen	1

Workshop

SUBJECTIVE EXPERIENCE

from Center of Functionally Integrative Neuroscience



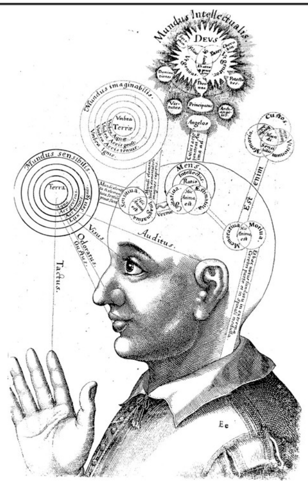
Andersen LM, Pedersen MN, Sandberg K, Overgaard M (2016) Occipital MEG Activity in the Early Time Range (<300 ms) Predicts Graded Changes in Perceptual Consciousness. Cerebral Cortex 26:2677–2688. https://doi.org/10.1093/cercor/bhv108

Workshop

SUBJECTIVE EXPERIENCE

Table 1 The Perceptual Awareness Scale (PAS)

Label	Description [from Ramsøy and Overgaard (2004)]
(1) No Experience (NE)	No impression of the stimulus. All answers are seen as mere guesses.
(2) Weak Glimpse (WG)	A feeling that something has been shown. Not characterized by any content, and this cannot be specified any further.
(3) Almost Clear Experience (ACE)	Ambiguous experience of the stimulus. Some stimulus aspects are experienced more vividly than others. A feeling of almost being certain about one's answer.
(4) Clear Experience (CE)	Non-ambiguous experience of the stimulus. No doubt in one's answer.



Andersen LM, Pedersen MN, Sandberg K, Overgaard M (2016) Occipital MEG Activity in the Early Time Range (<300 ms) Predicts Graded Changes in Perceptual Consciousness. Cerebral Cortex 26:2677–2688. https://doi.org/10.1093/cercor/bhv108

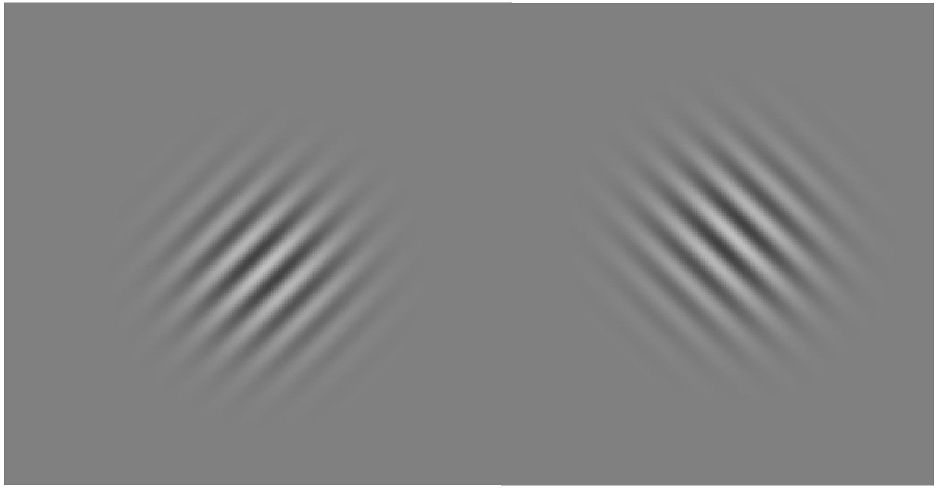
Ramsøy TZ, Overgaard M (2004) Introspection and subliminal perception. Phenomenology and the Cognitive Sciences 3:1–23. https://doi.org/10.1023/B:PHEN.0000041900.30172.e8

By Robert Fludd - Utriusque cosmi maioris scilicet et minoris […] historia, tomus II (1619), tractatus I, sectio I, liber X, De triplici animae in corpore visione, Public Domain, https://commons.wikimedia.org/w/index.php?curid=699073

```
#%% RUN EXPERIMENT

## initalise
experiment = Experiment()

## setting up experiment
experiment.open_GUI()
experiment.set_experiment_parameters()
experiment.check_user()
experiment.write_to_terminal('refresh_rate')
experiment.define_io_files()
experiment.write_to_terminal('setting_path')
experiment.define_texts()
experiment.create_experiment_window()
experiment.define_visual_stimuli()
experiment.present_instructions('welcome')

## practice
experiment.present_instructions('practice')
experiment.run_practice()

## experiment
experiment.set_experiment_parameters()
experiment.present_instructions('experiment')
experiment.run_experiment()

## thank you

experiment.present_instructions('thank_you')
```

Try out the experiment on your own computer

https://github.com/ualsbombe/2025_advanced_cognitive_neuroscience/blob/main/experiment/subjective_experience_v0.py

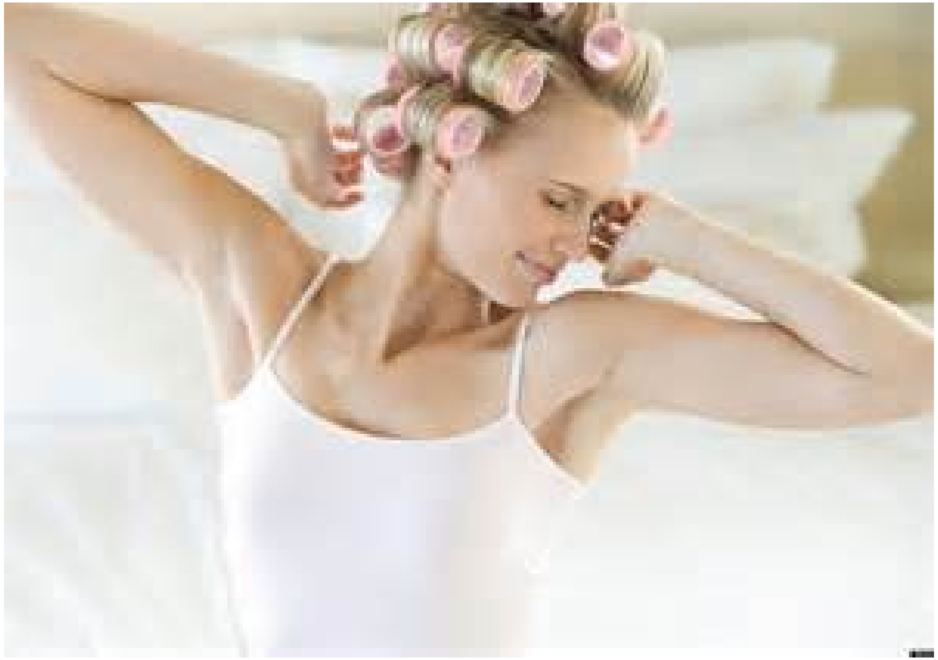


Protocol

https://github.com/ualsbombe/2025_advanced_cognitive_neuroscience/blob/main/experiment/data_acquisition_protocol.pdf

Context of the experiment

State consciousness



Content consciousness

Aim:

Answering where and when in the brain, we can see neural activity correlating with *consciousness of visual content*

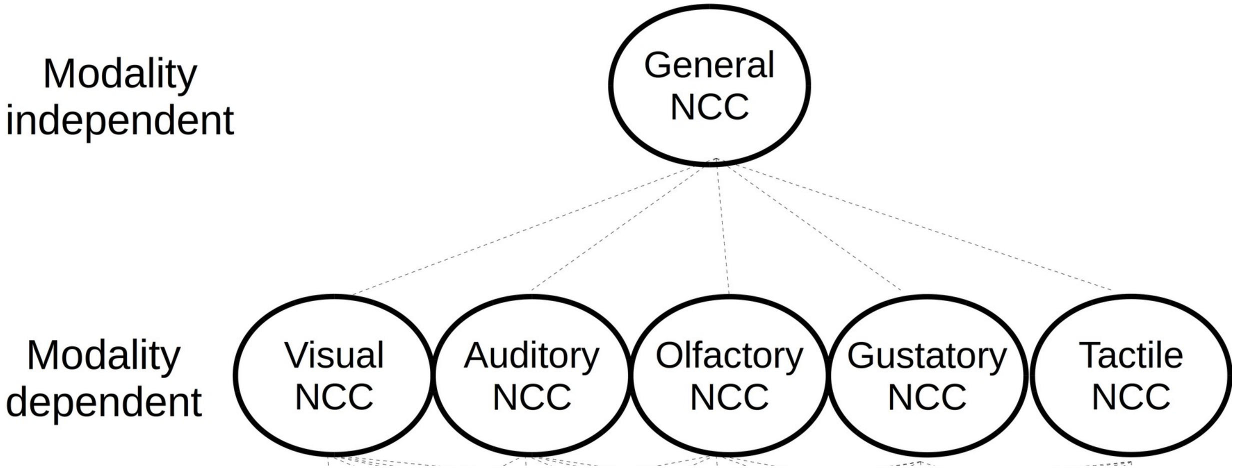
NCC (Neural Correlate of Consciousness)

"An NCC (for content) is a minimal neural representational system N such that representation of a content in N is sufficient, under conditions C, for representation of that content in consciousness."

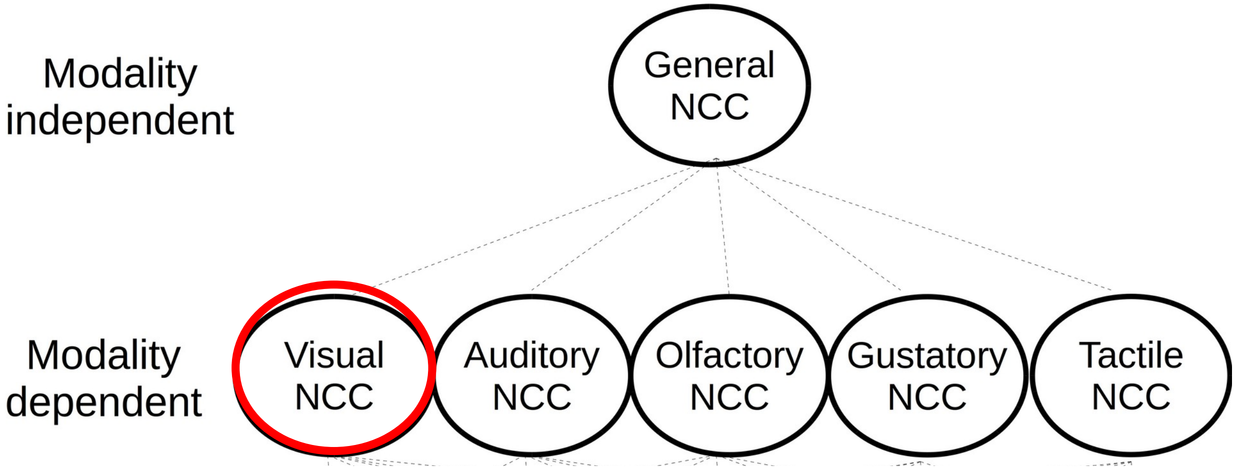
Chalmers, D. J. (2000). What Is a Neural Correlate of Consciousness. In T. Metzinger (Ed.), Neural Correlates of Consciousness

Levels of consciousness

Levels of consciousness

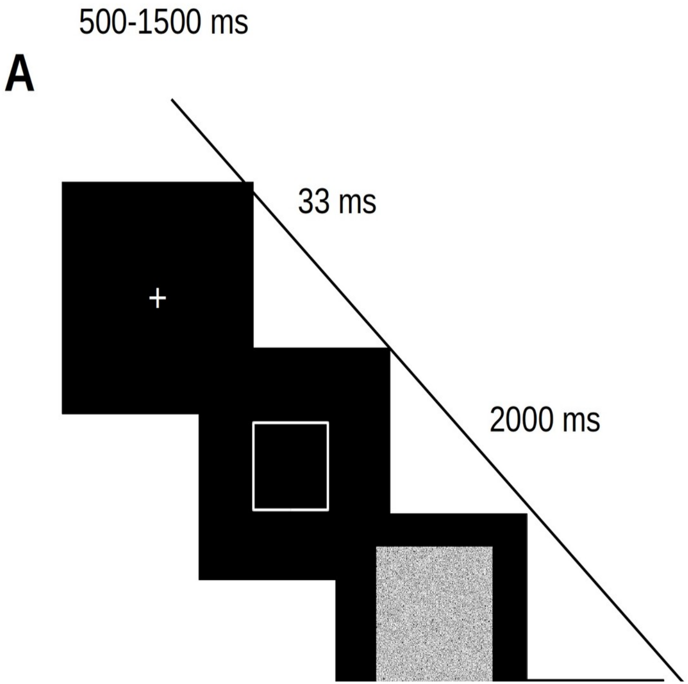


Levels of consciousness

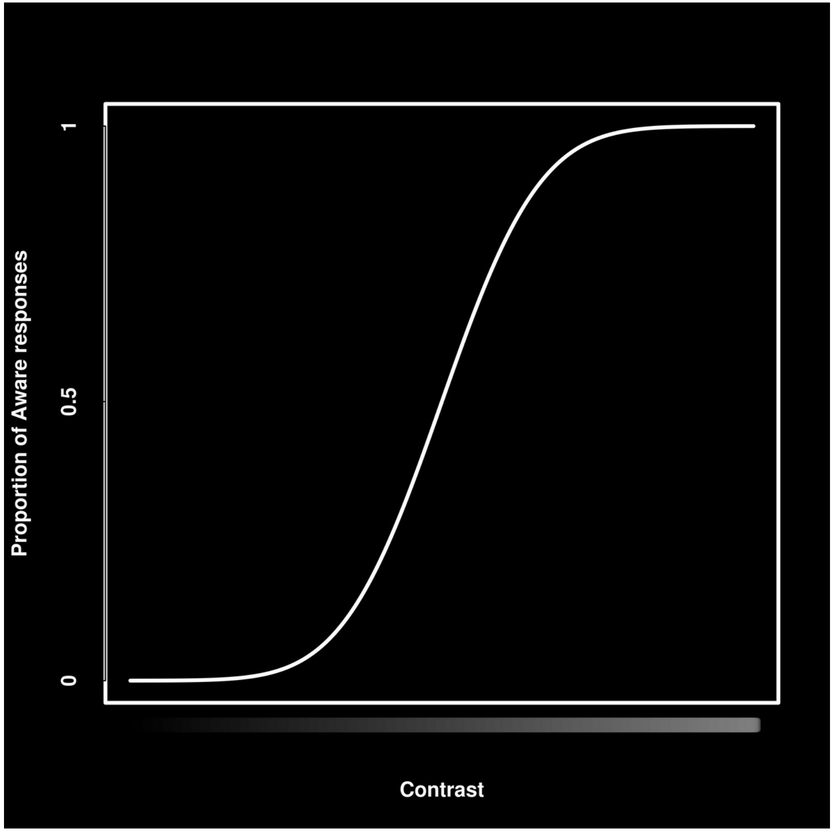


Paradigm and basic MEG

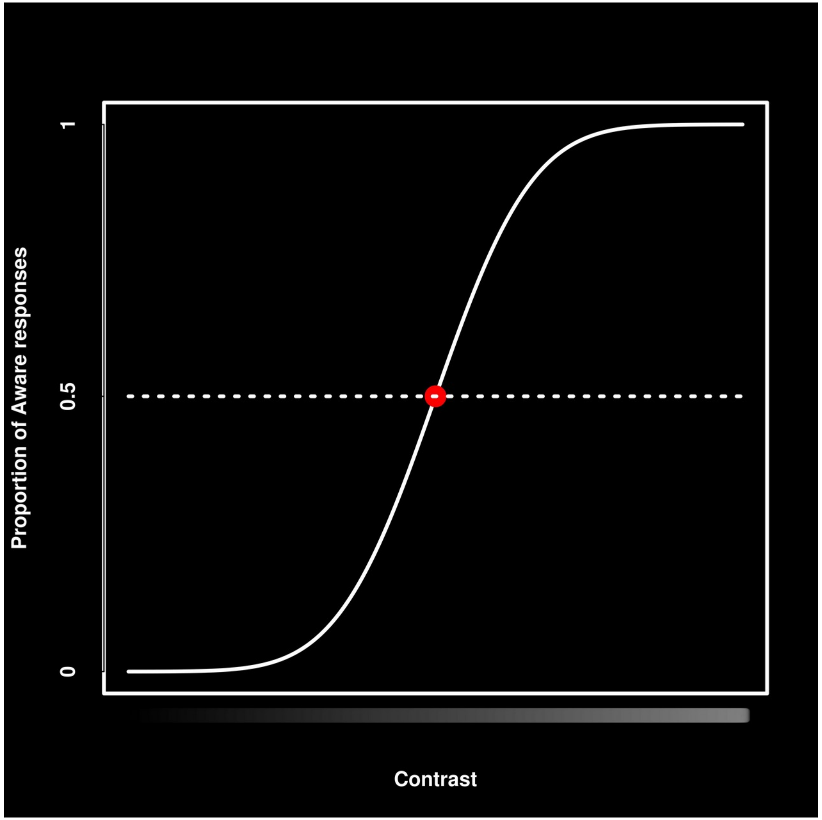
Visual masking



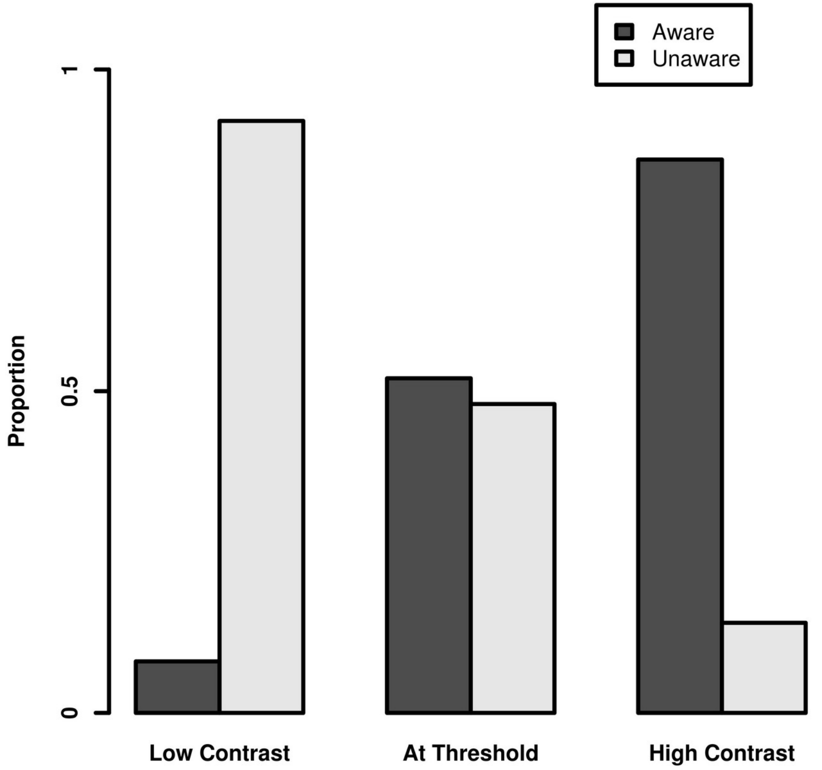
Threshold



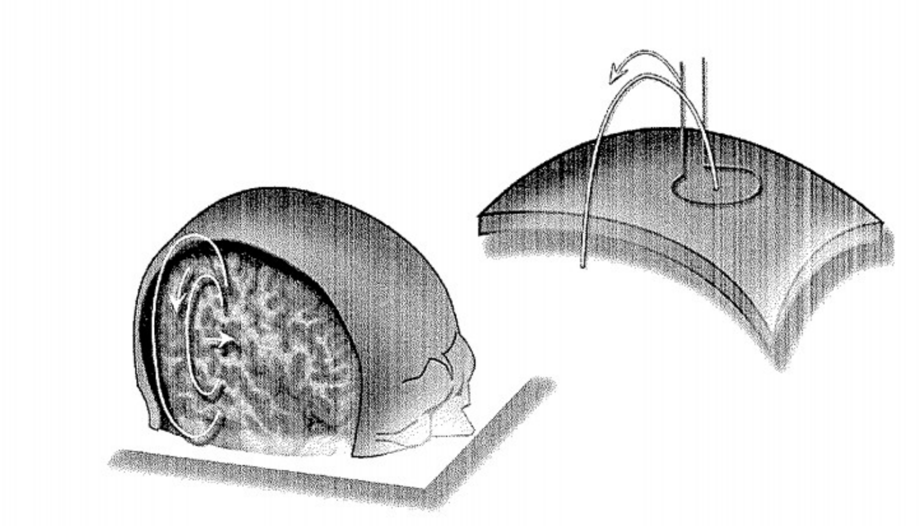
Threshold



Threshold

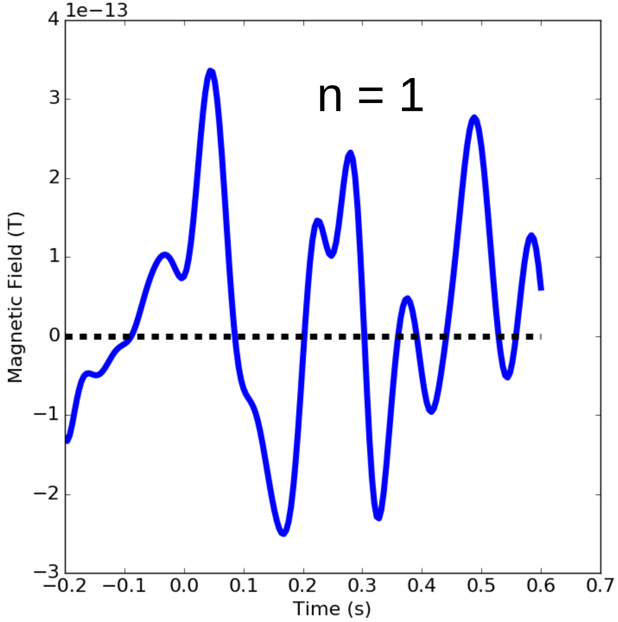

Aware
Unaware
Proportion
1
0.5
0
Low Contrast
At Threshold
High Contrast

Magnetoencephalography

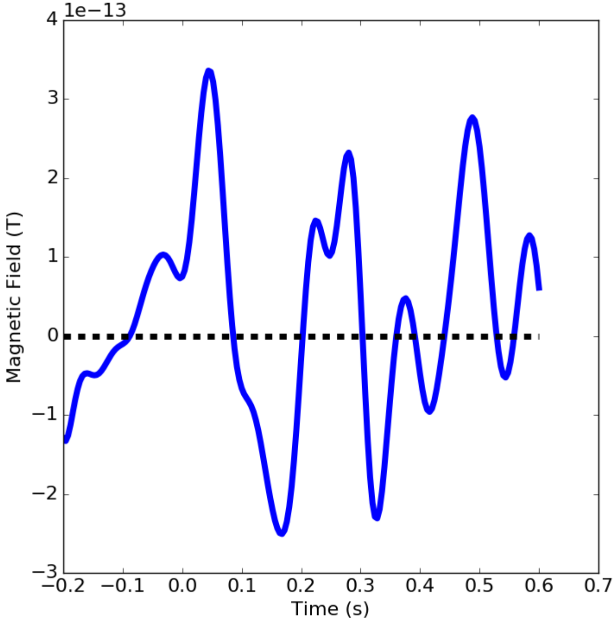


Papanicolaou 2009
Clinical Magnetoencephalography and Magnetic Source Imaging.

Epochs and Evoked Responses

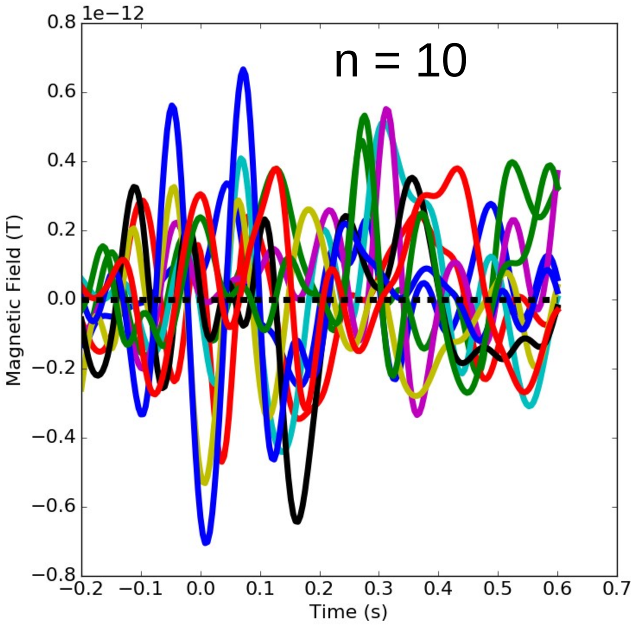


EPOCHS

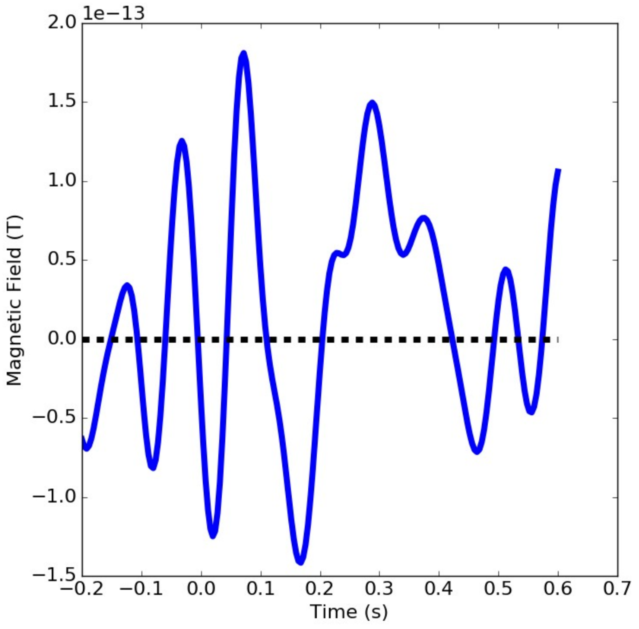


EVENT RELATED FIELD (ERF)

Epochs and Evoked Responses



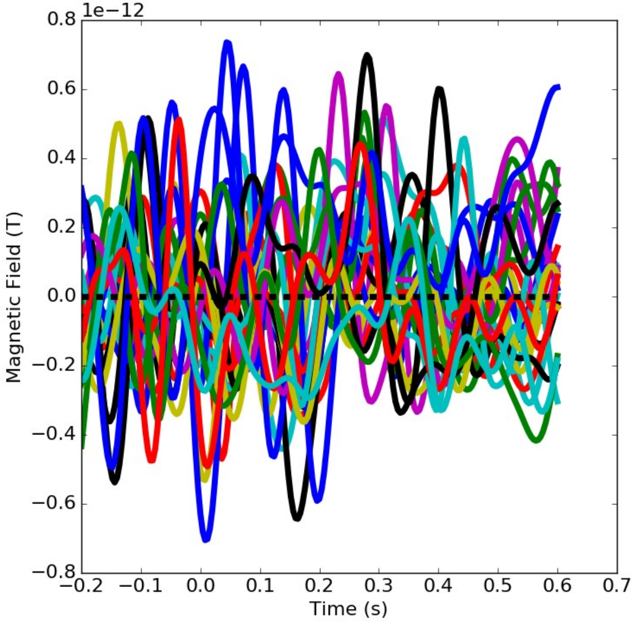
EPOCHS



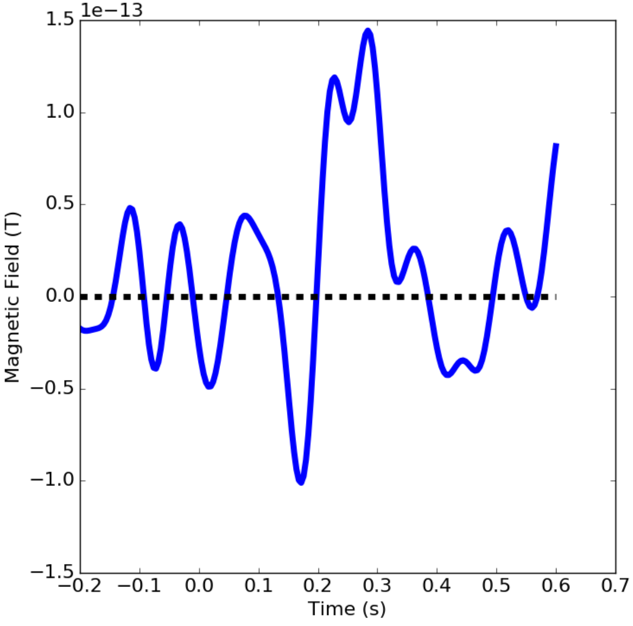
EVENT RELATED FIELD (ERF)

Epochs and Evoked Responses

n = 25



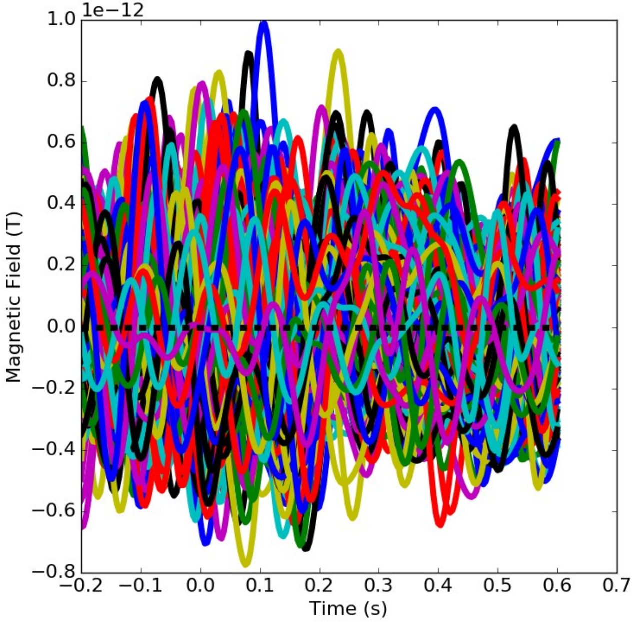
EPOCHS



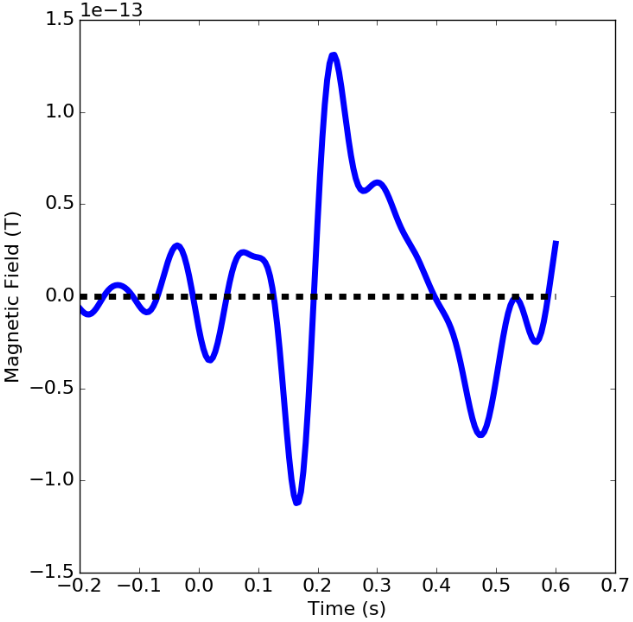
EVENT RELATED FIELD (ERF)

Epochs and Evoked Responses

n = 250

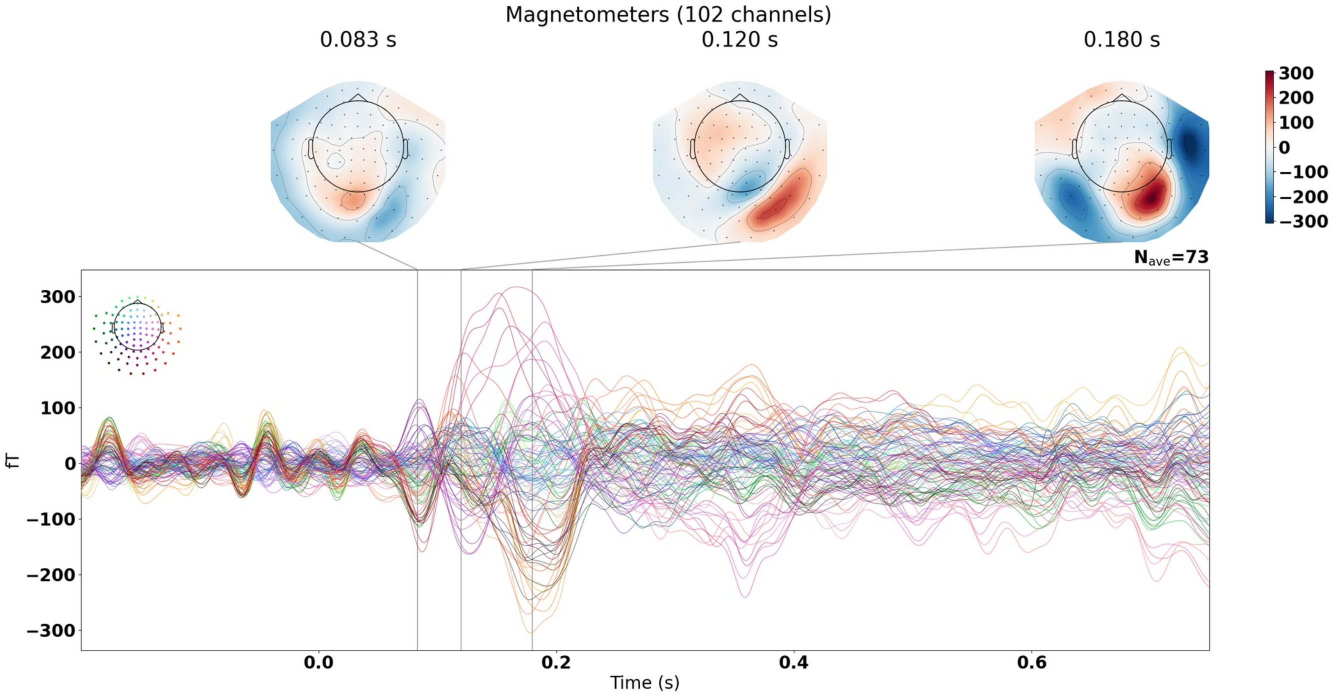


EPOCHS

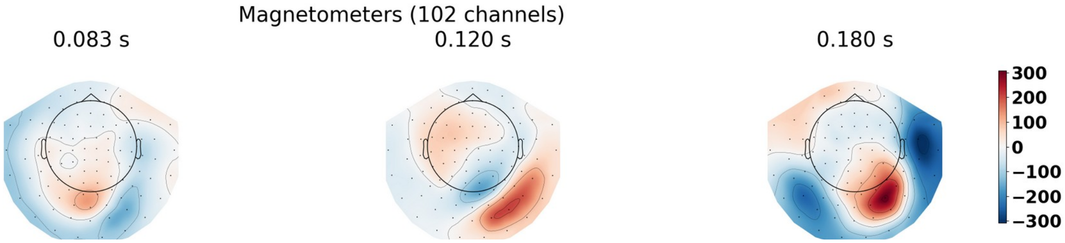


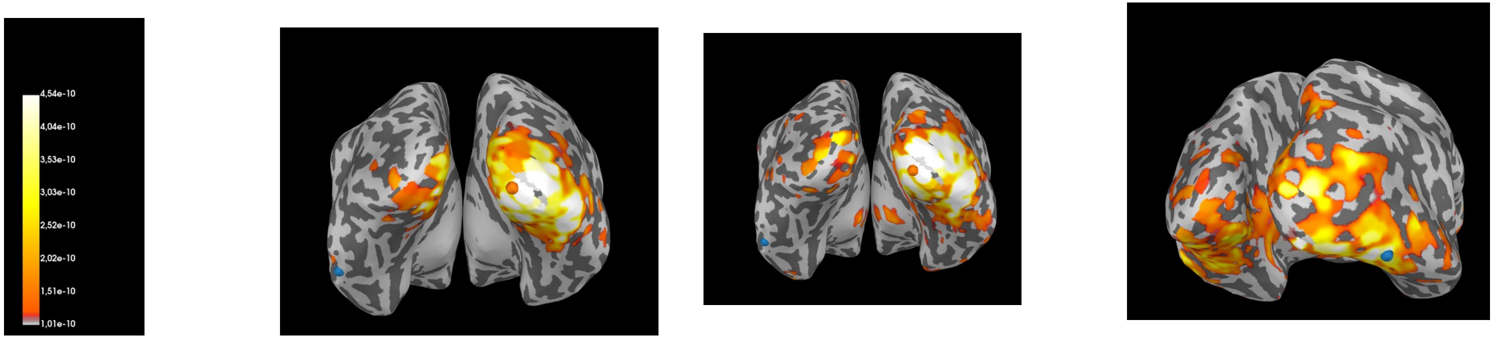
EVENT RELATED FIELD (ERF)

Evoked responses to a left hemifield checkerboard (sample data)

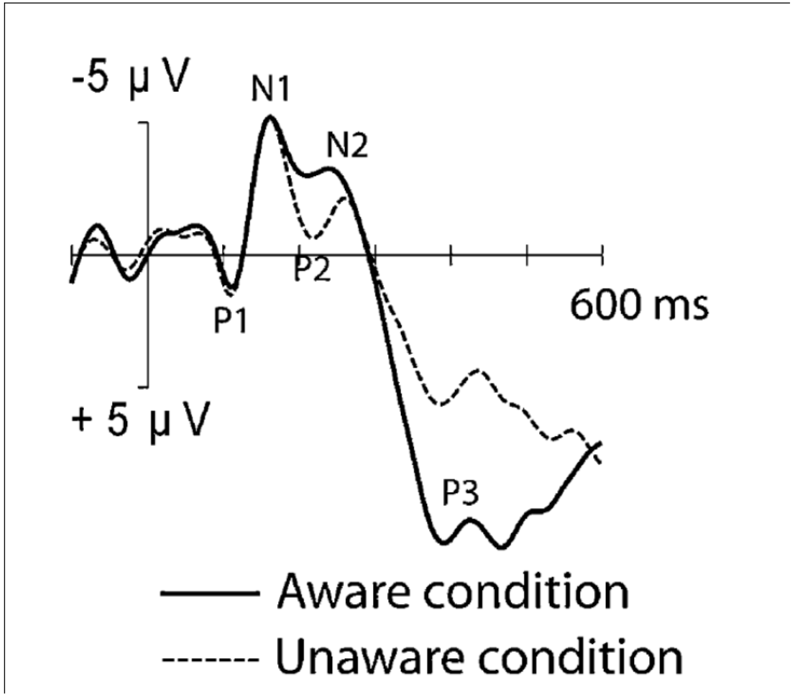


Evoked responses to a left hemifield checkerboard (sample data)



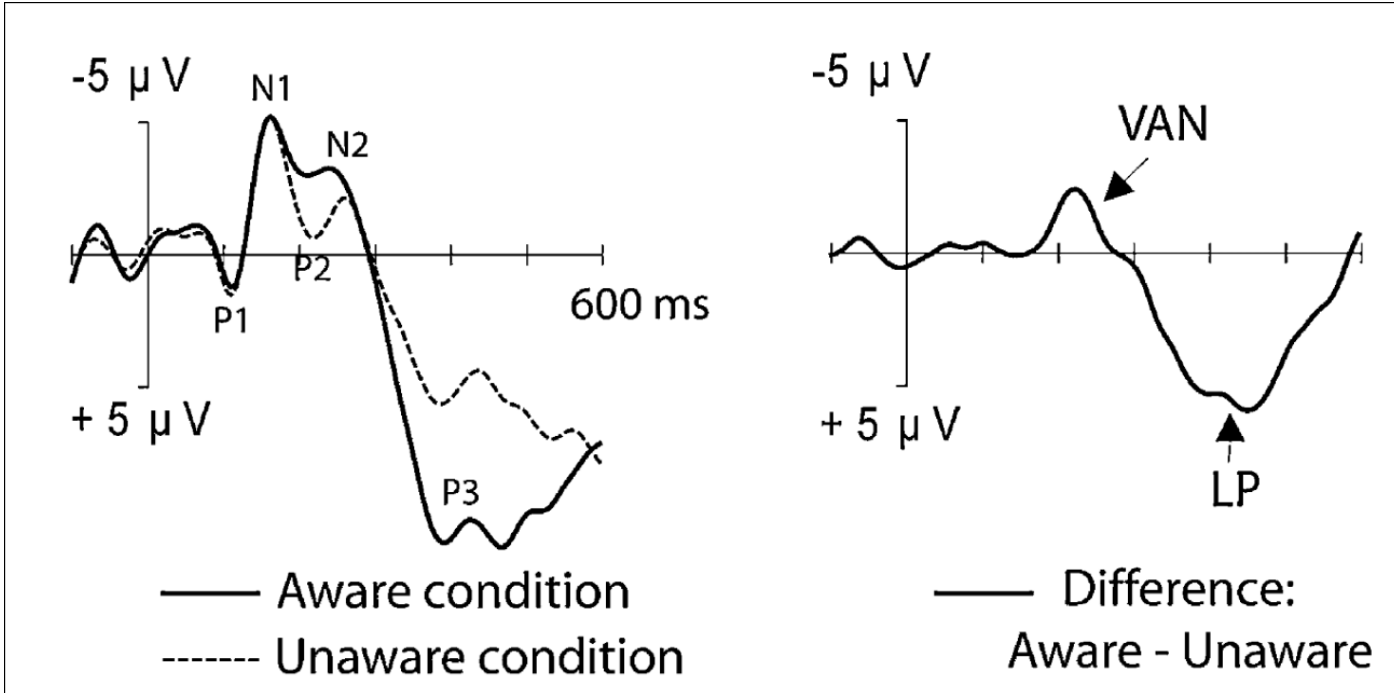


Early and late components (EEG)



Koivisto & Revonsuo 2010, *Neuroscience & Biobehavioral Reviews*

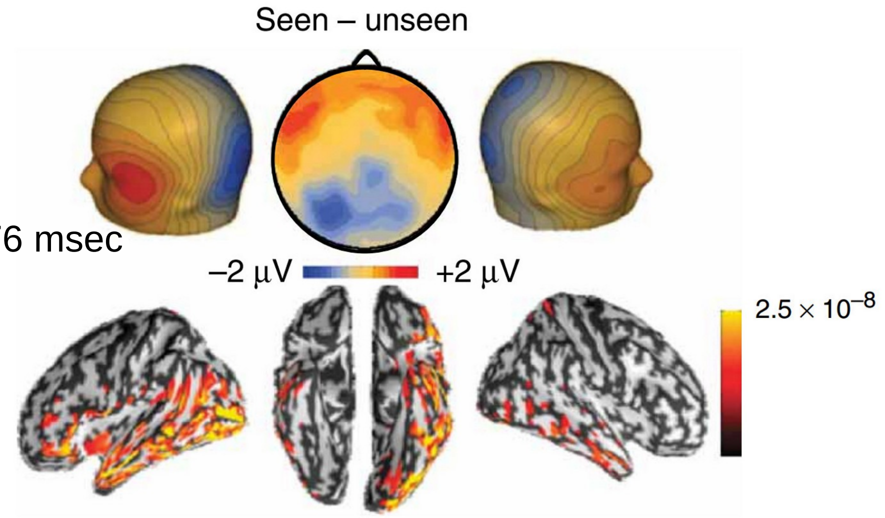
Early and late components (EEG)



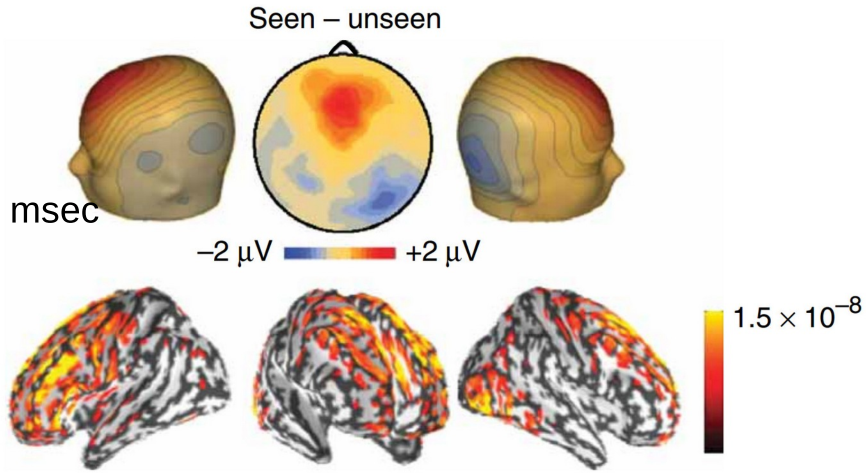
Koivisto & Revonsuo 2010, *Neuroscience & Biobehavioral Reviews*

Early and late components and their source reconstructions (EEG)

276 msec



436 msec



Sergent et al. 2005, *Nature Neuroscience*

Where and when?

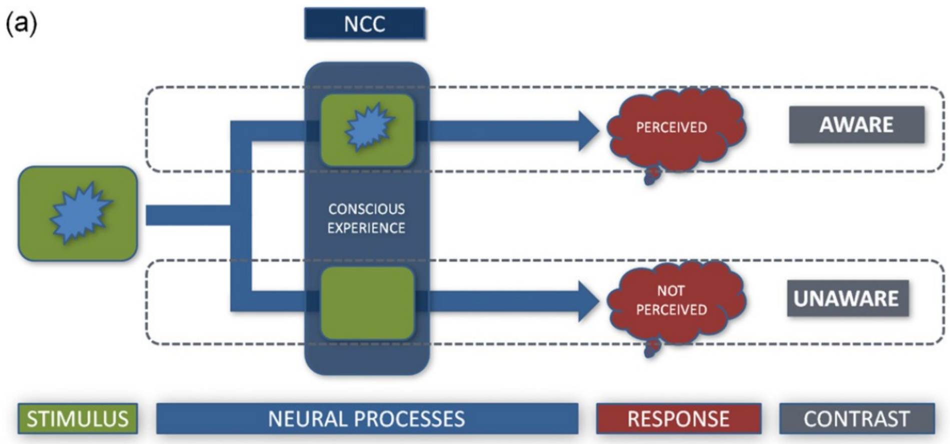
Consciousness of visual content happens *early* (~270 ms) and is *occipito-temporally* realized

Where and when?

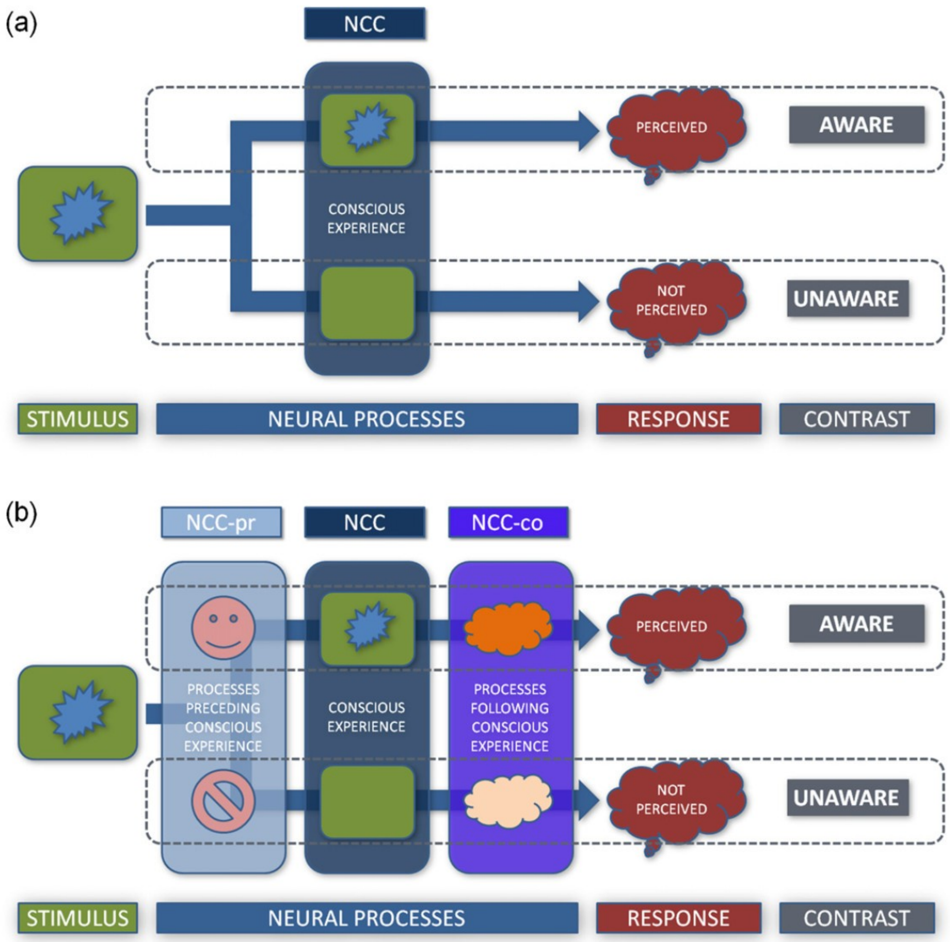
Consciousness of visual content happens *early* (~270 ms) and is *occipito-temporally* realized

Consciousness of visual content happens *late* (~430 ms) and is *fronto-parietally* realized.

Which is the real neural correlate of consciousness (NCC)?



Aru et al. 2012, *Neuroscience & Biobehavioral Reviews*



Aru et al. 2012, *Neuroscience & Biobehavioral Reviews*

Where and when?

Consciousness of visual content happens *early* (~270 ms) and is *occipito-temporally* realized.

Consciousness of visual content happens *late* (~430 ms) and is *fronto-parietally* realized.

Where and when?

Consciousness of visual content happens *early* (~270 ms) and is *occipito-temporally* realized. The late activity is simply a *consequence* of consciousness.

Consciousness of visual content happens *late* (~430 ms) and is *fronto-parietally* realized.

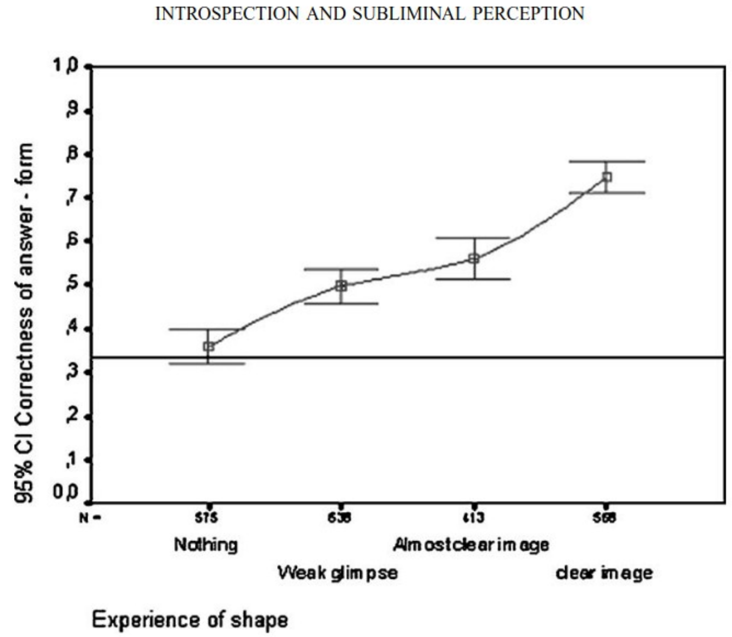
Where and when?

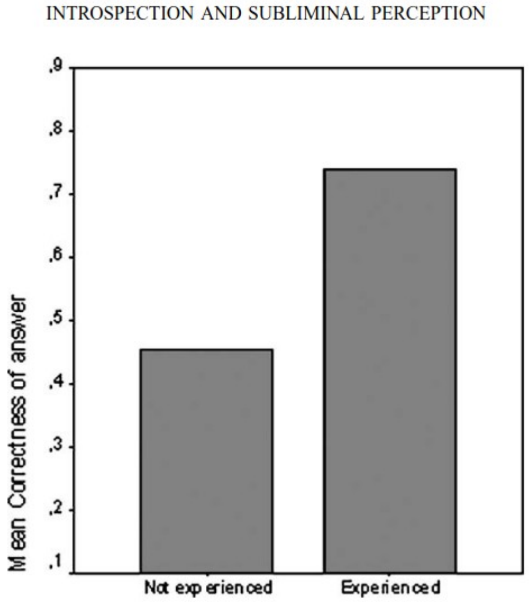
Consciousness of visual content happens *early* (~270 ms) and is *occipito-temporally* realized. The late activity is simply a *consequence* of consciousness.

Consciousness of visual content happens *late* (~430 ms) and is *fronto-parietally* realized. The early activity is simply a *prerequisite* for consciousness.

Is subjective experience dichotmous or graded?

(Ramsøy and Overgaard 2004)





(Ramsøy and Overgaard 2004)

Exhaustiveness and sensitivity

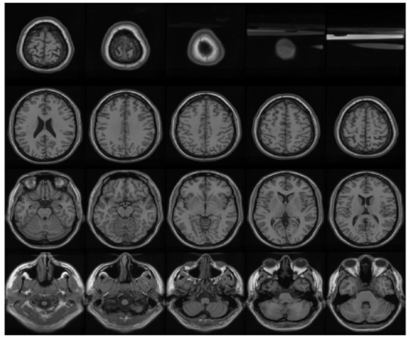
- Exhaustiveness
  - No more scale points are needed to capture the range of subjective experiences
- Sensitivity
  - The scale points given all reflect a real difference in behaviour

Interim summary

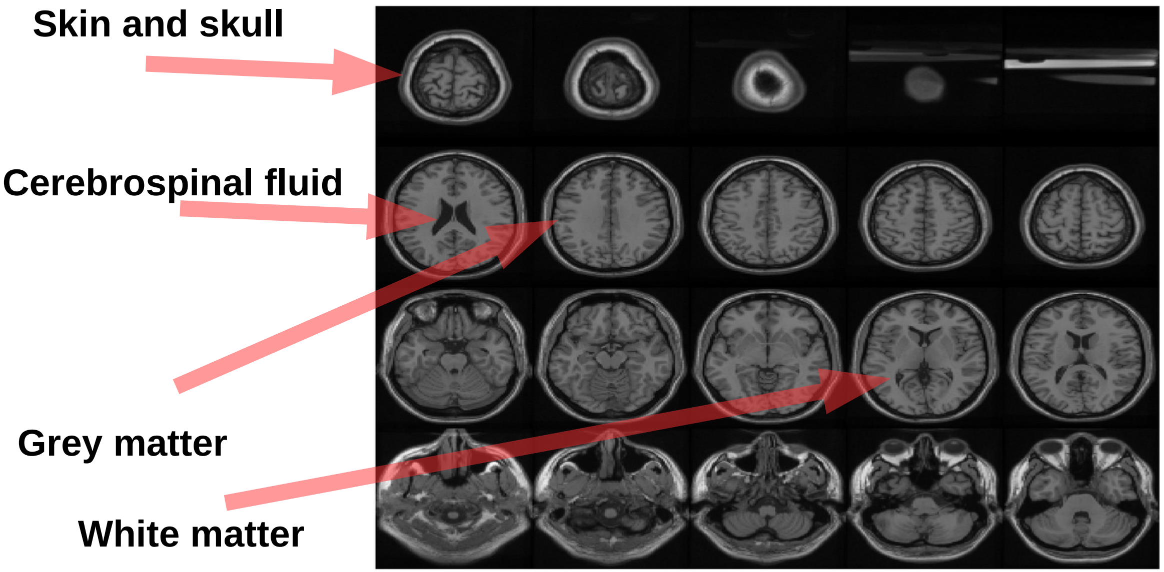
- Goal: find evidence for *where* and *when* subjective experience can be predicted the best
- Goal: find evidence, behavioural and electrophysiological, for the sensitivity and the exhaustiveness of the Perceptual Awareness Scale

What about MR?

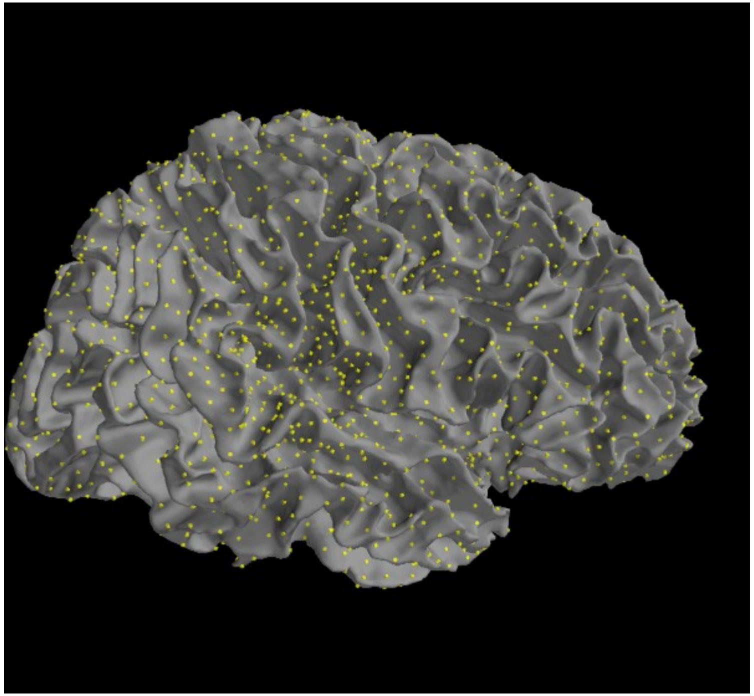
We need images of the brain to get estimates of brain activity



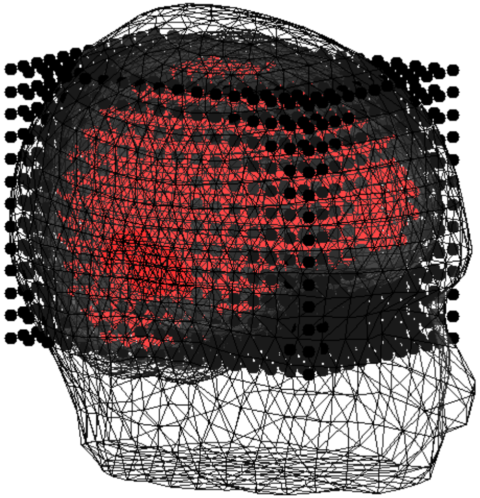
What do we see?



Source model examples



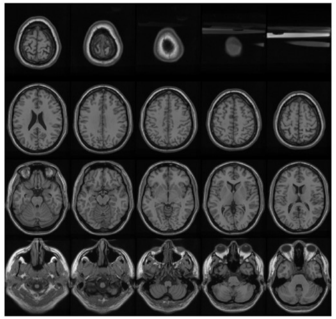
Restricted to the cortical surface



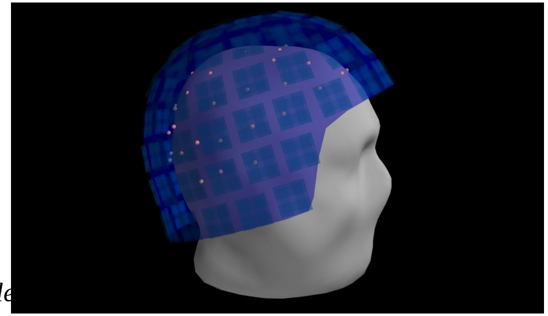
Volumetric grid

Sensor positions

- The MR-images and the helmet/electrode data will be represented in different coordinate systems
  - Thus, they have to be co-registered



≠

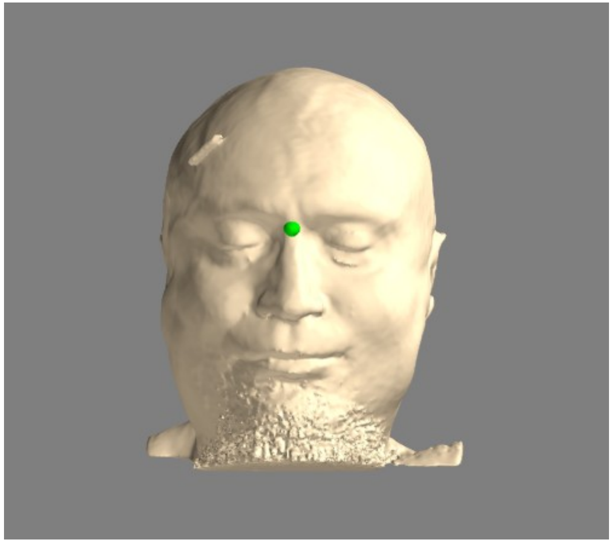


Co-registration

Construct a head model based on the MRI

Co-registration

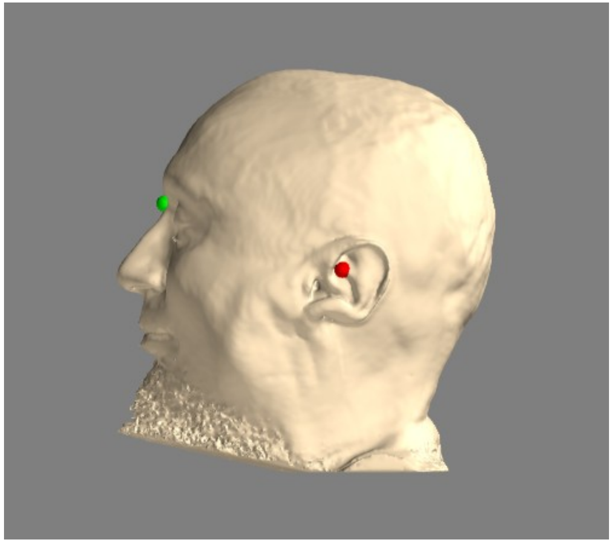
1. Nasion



Plot in fiducial points (these are acquired before recording)

Co-registration

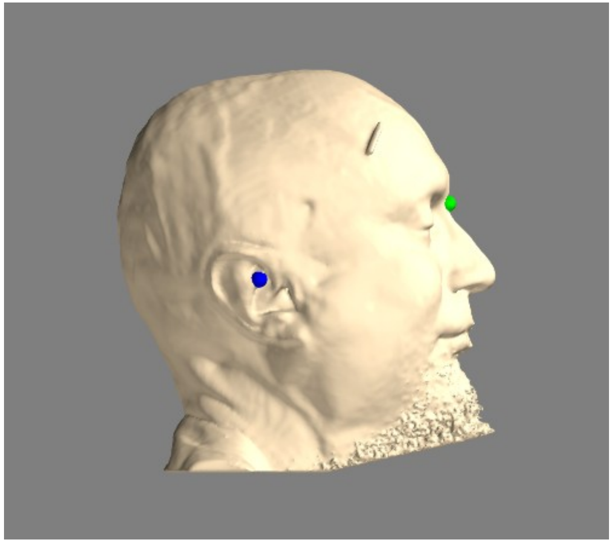
1. Nasion
2. Left pre-auricular point



Plot in fiducial points (these are acquired before recording)

Co-registration

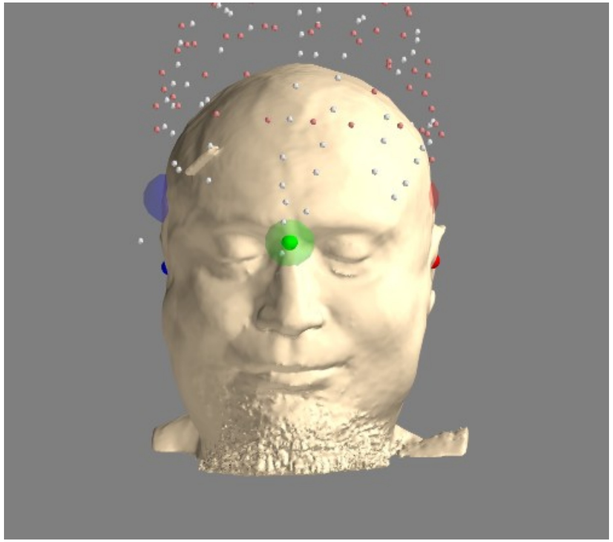
1. Nasion
2. Left pre-auricular point
3. Right pre-auricular point



Plot in fiducial points (these are acquired before recording)

Co-registration

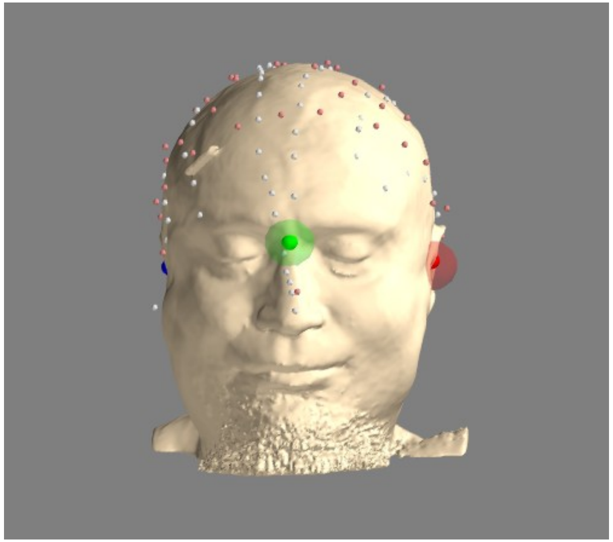
1. Nasion
2. Left pre-auricular point
3. Right pre-auricular point



Plot extra head points (as seen on lab tour)

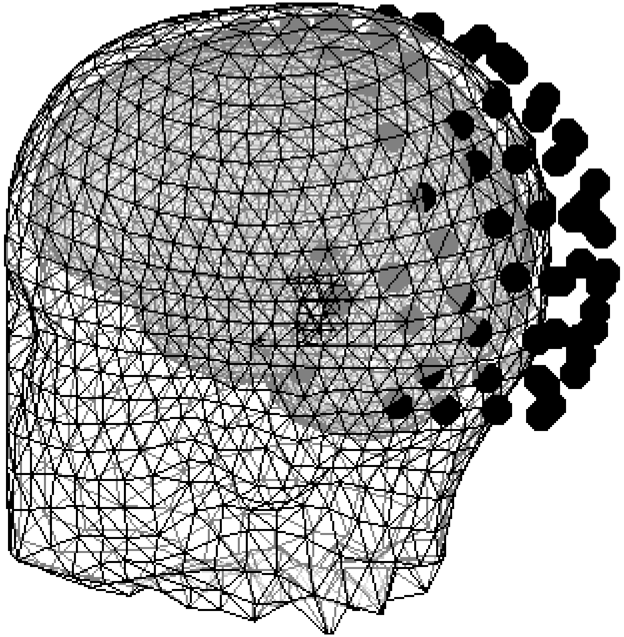
Co-registration

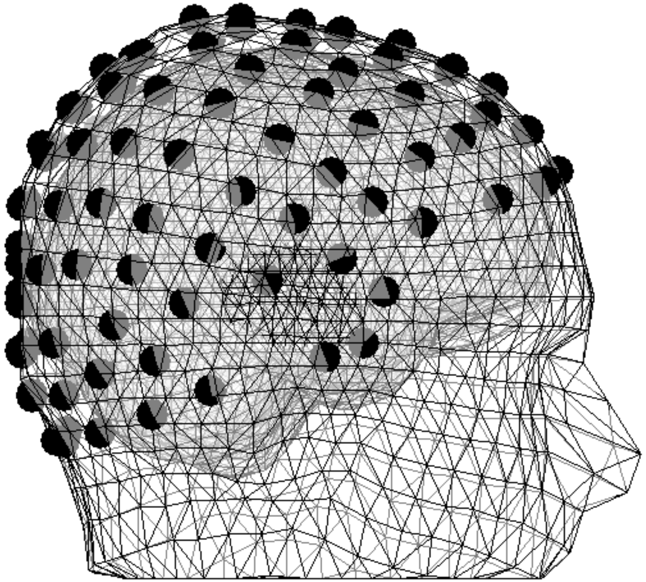
1. Nasion
2. Left pre-auricular point
3. Right pre-auricular point



Use an algorithm to minimize the distance between points and head shape. The MR and the MEG are now co-registered

Without co-registration With co-registration





Now we can create the forward model (leadfield)

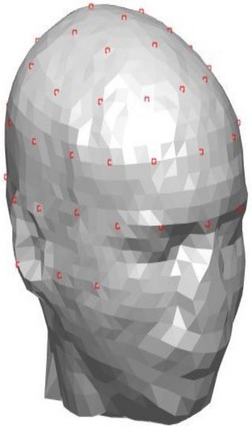
The forward model models how each source in the source space *would* be seen by the sensors in the helmet, *given* that that source is active

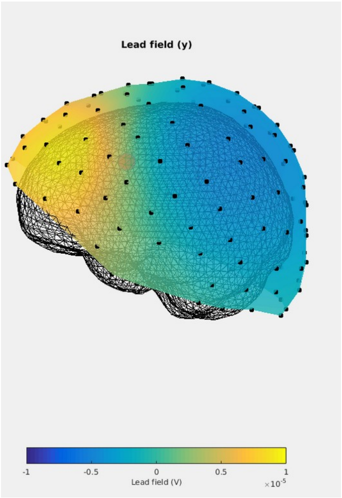
forward model

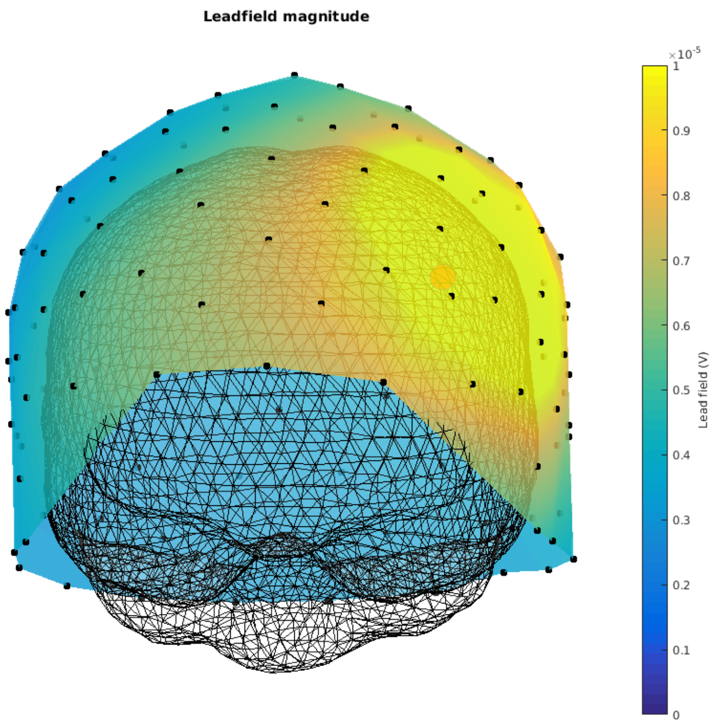
physiological source
(source model)

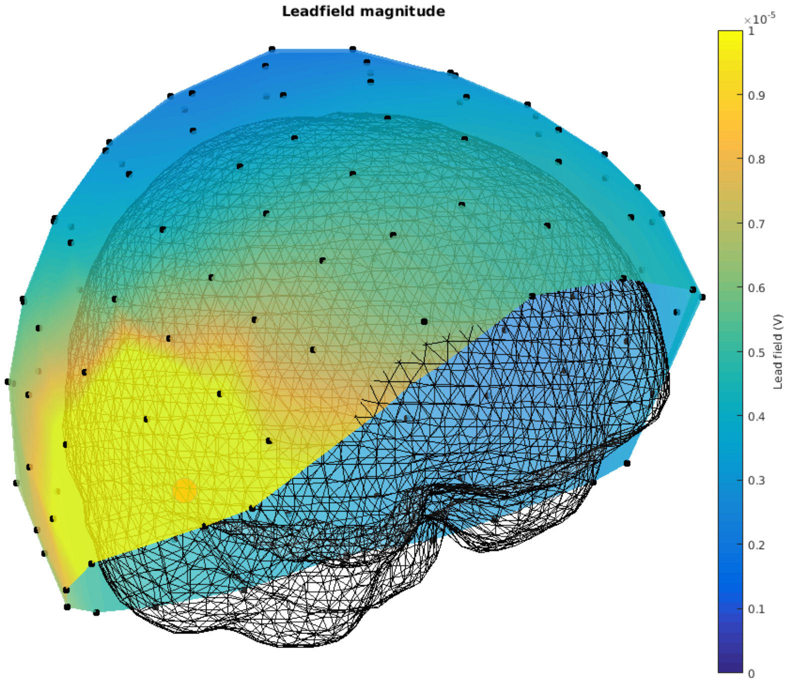
volume conductor
(head model)

expected
potential or field
(lead field)









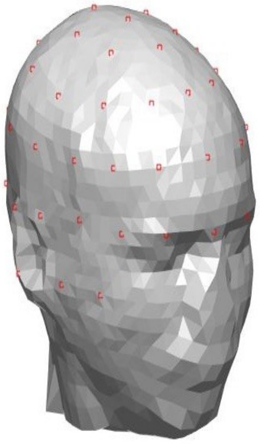
and so on for each source in the source model ...

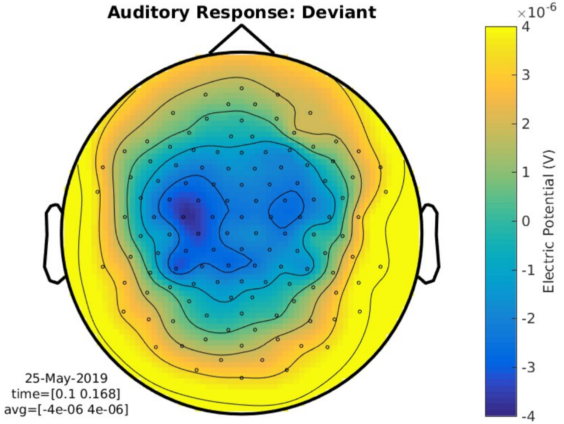
inverse model

physiological source
(source model)

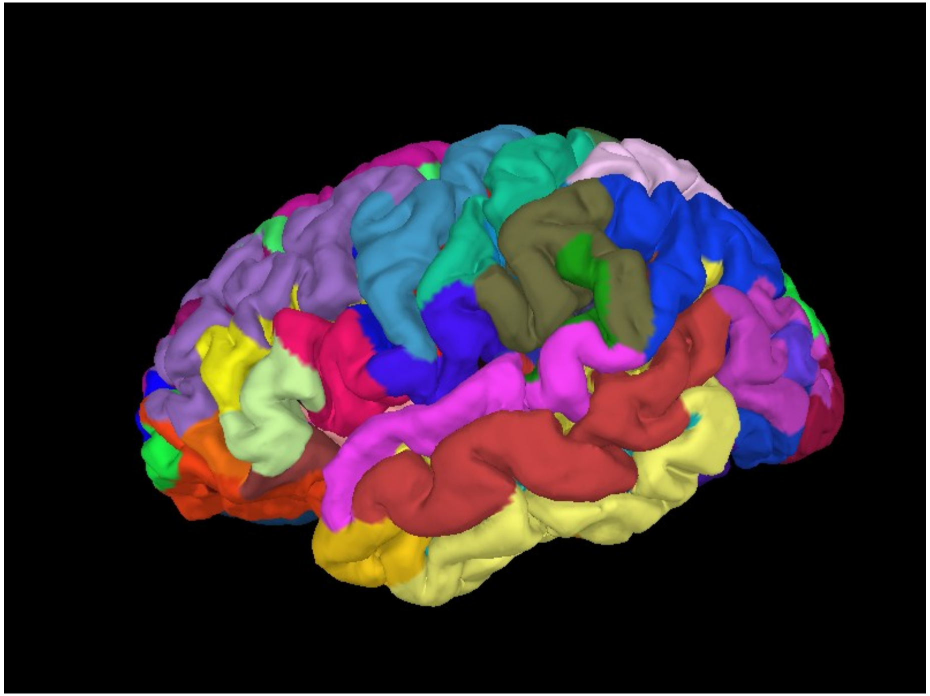
volume conductor
(head model)

observed
potential or field
(actual data)





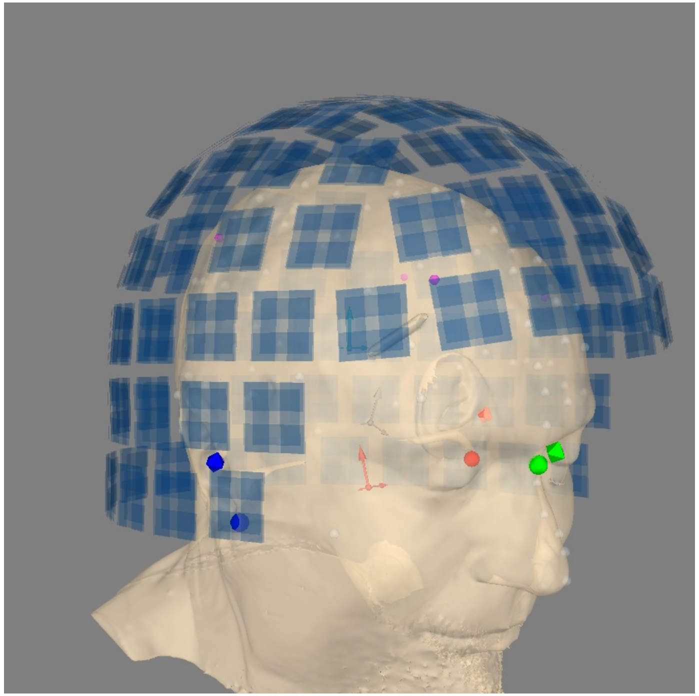
Segmented cerebral cortex



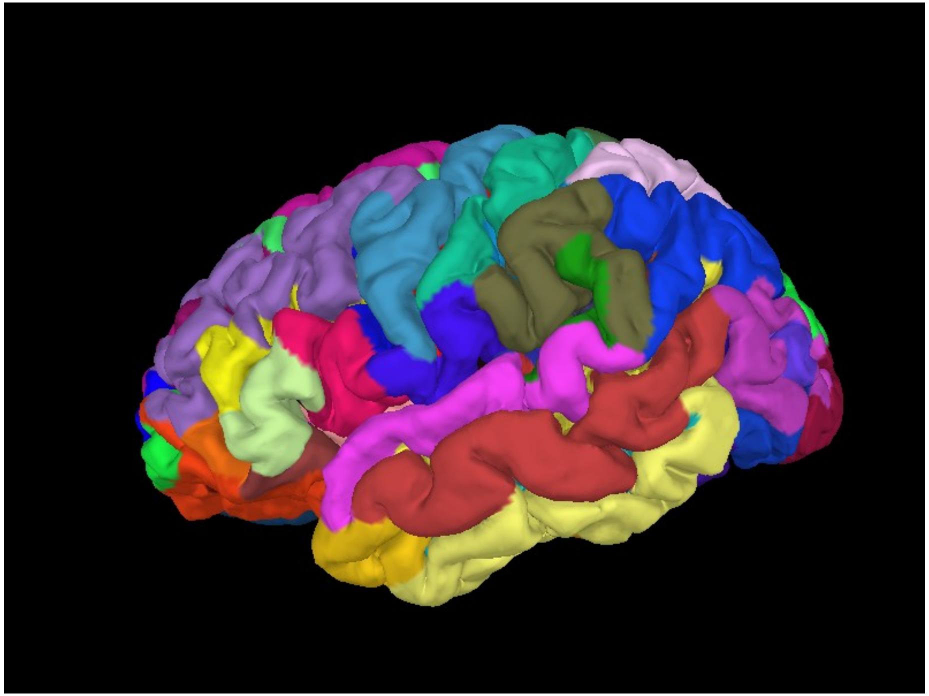
https://mne.tools/stable/auto_tutorials/forward/10_background_freesurfer.html#sphx-glr-auto-tutorials-forward-10-background-freesurfer-py

Multivariate analyses

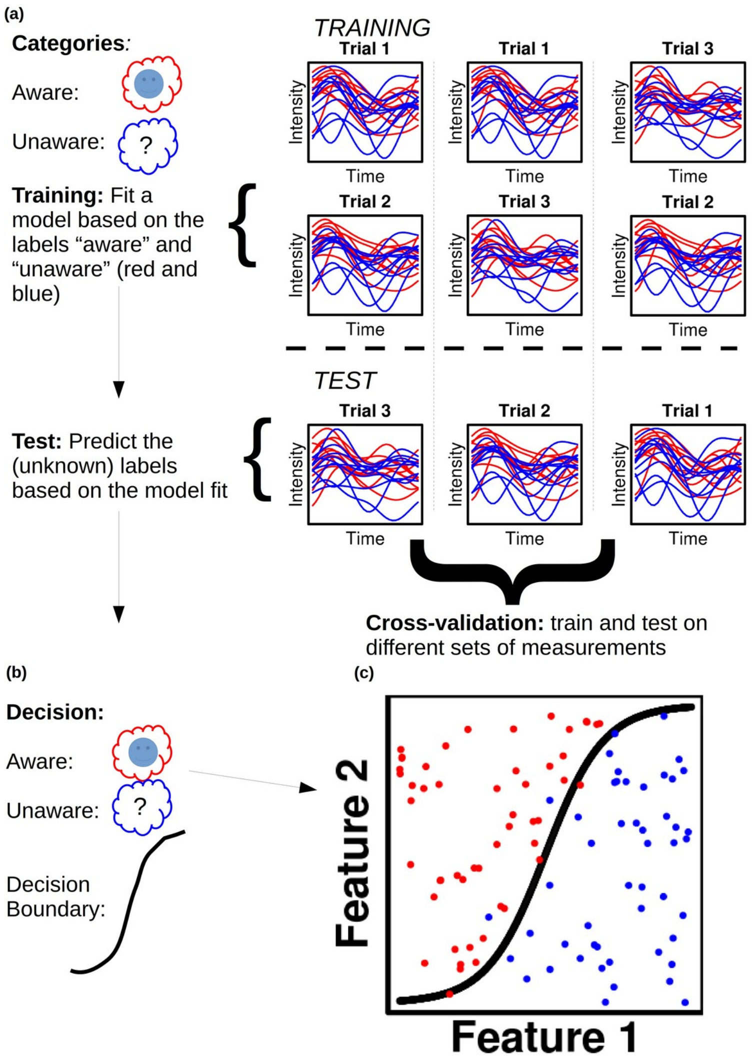
https://mne.tools/stable/auto_tutorials/forward/20_source_alignment.html#sphx-glr-auto-tutorials-forward-20-source-alignment-py



Sensor space



Source space


(a)
Categories:
Aware:
Unaware:
?
Training: Fit a model based on the labels "aware" and "unaware" (red and blue)
TRAINING
Trial 1
Trial 1
Trial 3
Intensity
Time
Trial 2
Trial 3
Trial 2
TEST
Trial 3
Trial 2
Trial 1
Test: Predict the (unknown) labels based on the model fit
Cross-validation: train and test on different sets of measurements
(b)
Decision:
Aware:
Unaware:
?
Decision Boundary:
(c)
Feature 2
Feature 1

Pros and cons

- Sensor space
  - Likely to get better predictions
  - Lower specificity – where is the activity coming from?
- Source space
  - Likely to get worse predictions
  - Better specificity – we model where the activity is coming from

Summary

- Goal: find evidence for *where* and *when* subjective experience can be predicted the best
  - which can be informed by source space and brain segmentation
- Goal: find evidence, behavioural and electrophysiological, for the sensitivity and the exhaustiveness of the Perceptual Awareness Scale
  - You can use *glmer* to fit the proportion correct

The course plan

Week 36:
Lesson 0: What is it all about?
Class 0: Setting up UCloud and installing MNE-Python

Week 37:
No Teaching

Week 38:
Lesson 1: Workshop paradigm: Measuring visual subjective experience + MR Recordings
Class 1: Running an MEG analysis of visual responses

Week 39:
MEG workshop: Measuring and predicting visual subjective experience

Week 40:
Lesson 2: Basic physiology and Evoked responses
Class 2: Evoked responses to different levels of subjective experience

Week 41:
Lesson 3: Multivariate statistics
Class 3: Predicting subjective experience in sensor space
Deadline for feedback: Video Explainer

Week 42:
Autumn Break

Week 43:
Lesson 4: Forward modelling and dipole estimation
Class 4: Creating a forward model

Week 44:
Lesson 5: Inverse modelling: Minimum-norm estimate
Class 5: Predicting subjective experience in source space

Week 45:
Lesson 6: Inverse modelling: Beamforming
Class 6: Predicting subjective experience in source space, continued

Week 46:
Lesson 7: What about that other cortex? - the cerebellar one
Class 7: Oral presentations (part 1)
Deadline for feedback: Lab report

Week 47:
Lesson 8: Guest lecture: Laura Bock Paulsen: Respiratory analyses
Class 8: Oral presentations (part 2)

Week 48:
Lesson 9: Sensors of the future
Class 9: Oral presentations (part 3)

Week 49:
Lesson 0 again: What was it all about?
Class 10: Oral presentations (part 4)

Next lecture – workshop

Reading questions

- Chapters 5-7, Puce A, Hari R (2023)
  - Chapter 5
    - What are the differences between magnetometers and planar gradiometers?
  - Chapter 6
    - What is visual angle (see chapter 14?)
  - Chapter 7
    - What are fiducial points – and why are they important?
    - Why would you record other physiological signals, e.g. the heart and the eyes

Next class – Running an MEG analysis of visual responses