Studying the musical brain

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Overview

- Objective
  - By the end of this session, you should be able to understand the most common methods used to study music in the brain

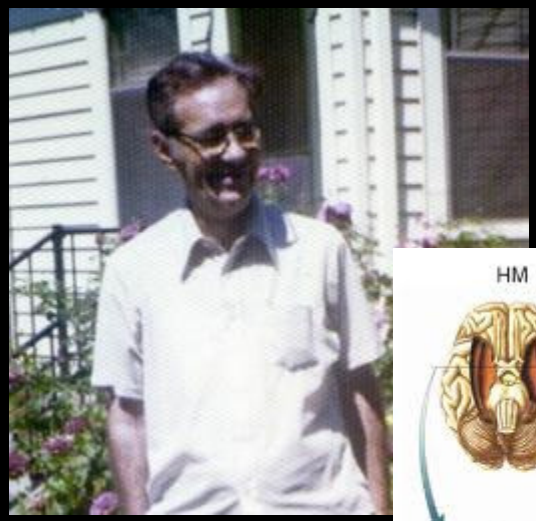
- To achieve that, during this session we will
  - go over the basic principles of each method
  - discuss its pros and cons
  - work through an example study with each method
  - emphasise the importance of triangulation

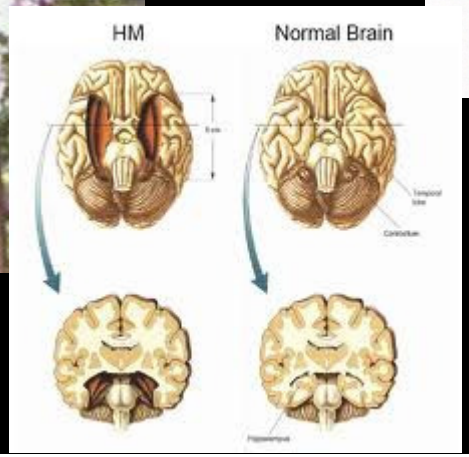
Before we start…

- Any exciting discoveries?

Thank goodness for imaging?

- Before non-invasive techniques, relied on post-mortem examinations and lesions
  - Phineas Gage, HM, Tan…
  - Can now look while person is alive and performing a specific task





Thank goodness for imaging?

- Before non-invasive techniques, spent more time on strong theories than on observations
  - Can now scan as many people as we want, look through the data until we find something… New phrenology?

Thank goodness for imaging?

- Only if it is used sensibly
  - to test theories
  - to build up evidence as part of a wider set
  - to challenge current assumptions
  - to contribute new theoretical developments

  - with a carefully controlled experimental design
  - with a good set of stimuli

  - acknowledging potential confounds

How else do we study "the brain"?

- Traditional approaches
  - Self-report
  - Behaviour
  - Reaction times
  - Individual differences
- Psychophysiological approaches
  - Heart rate
  - Galvanic skin response
  - Respiration
  - Hormones

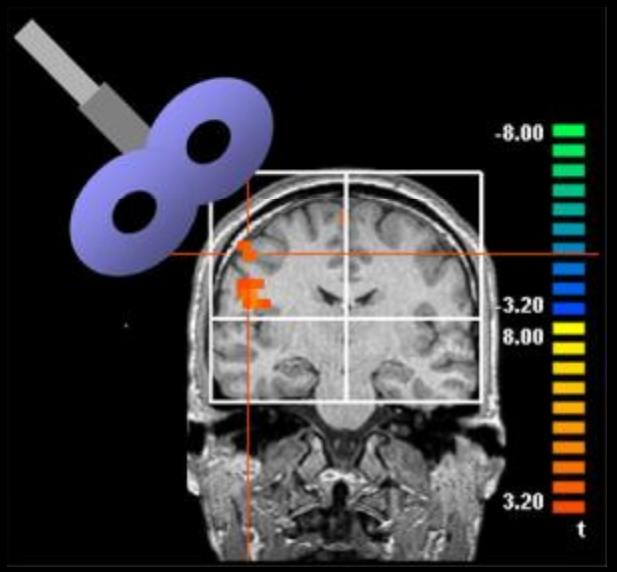
How else do we study the brain?

- Penfield (1950s) used electrical stimulation of the brain during surgery to map somatosensory cortex
- No pain receptors in the brain
- Area A → palm of hand tingles, B → thumb tingles
- Homunculus
- http://www.youtube.com/watch?v=PjX6ErmKY14

Common methods

- TMS
  - electricity manipulation
- EEG / ERP / MEG
  - electricity observation
- PET
  - blood use observation (glucose* / oxygen*)
- fMRI
  - blood use observation (oxygen)

TMS



TMS

- Inducing “virtual lesions”
  - Temporary!
  - Stimulation at low frequency suppresses neuronal excitability
  - Can last several minutes

→ Look at what function is disrupted

TMS

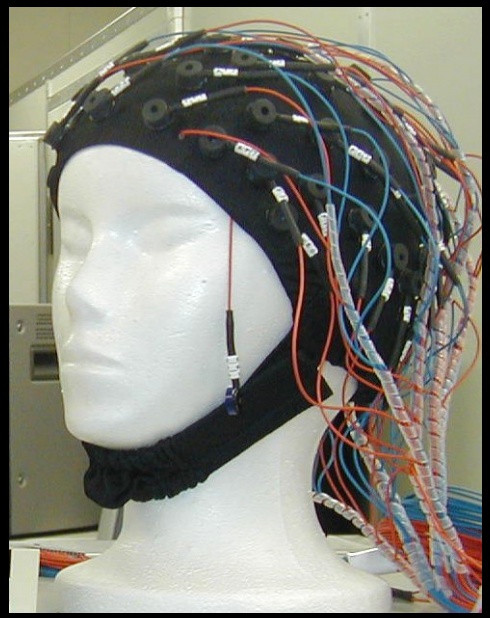
- Pros
  - Can reproduce neurological symptoms (e.g. hemineglect)
  - Double dissociations, function localisation
  - Good for looking at cortical functions

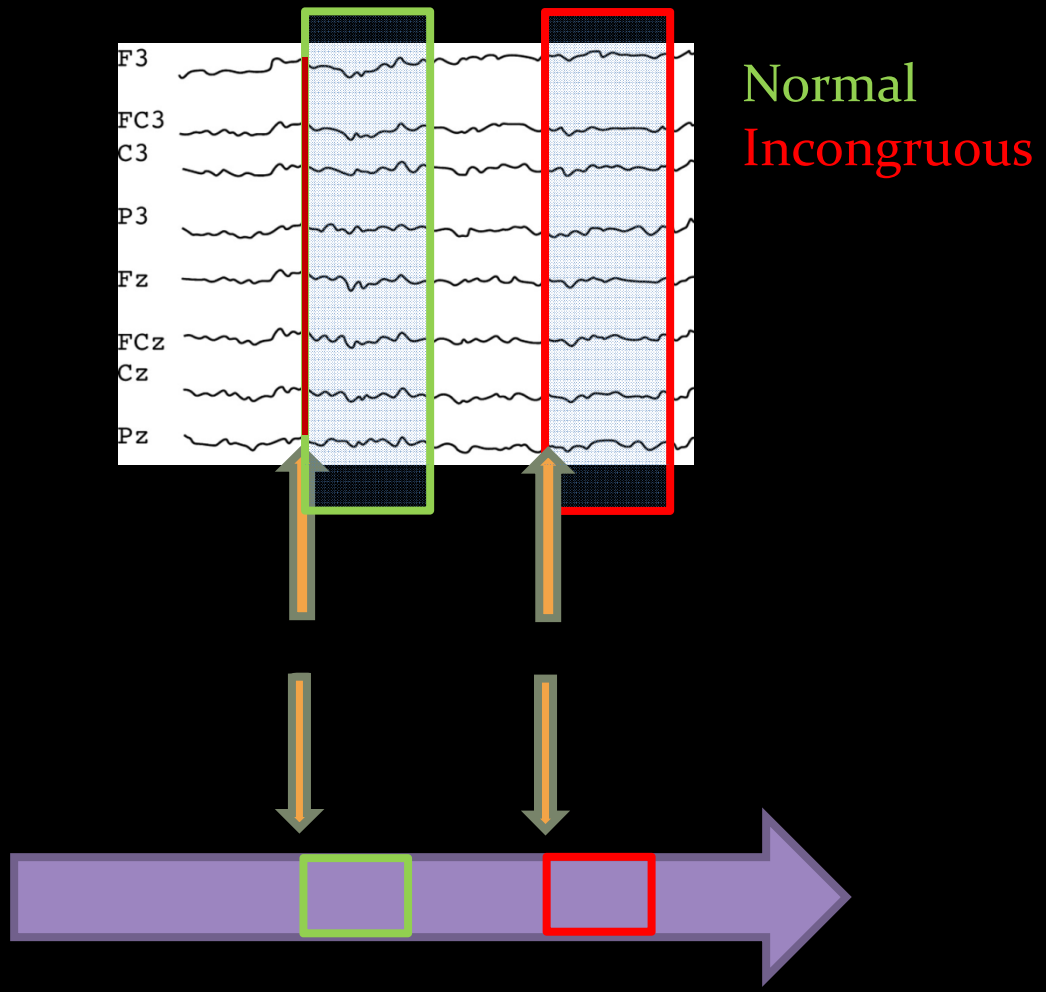
- Cons
  - Not good beyond cortex
  - Still relatively new
  - At the moment, more for clinical applications (tinnitus) but research growing

TMS in music

- Sparing et al. (2007) European Journal of Neurology
  - Used TMS to study lateralisation of music and language (right or left in the brain?)
  - Looked for "Task-dependent changes of the size of the TMS-elicited motor evoked potentials"
  - During speech, left hemisphere more excitable
  - During music, right hemisphere more excitable
  - Concluded music mostly Right, language mostly Left
  - Link between dominant hand and speech?

EEG / ERP





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EEG / ERP

- Electroencephalography / Event-Related Potential
  - Neurons, structured in columns, polarized at rest (inactive potential)
  - Action potential (firing) depolarizes the neuron
  - Changes are recorded on the scalp via electrodes
  - Time-locked and averaged → pattern associated with task

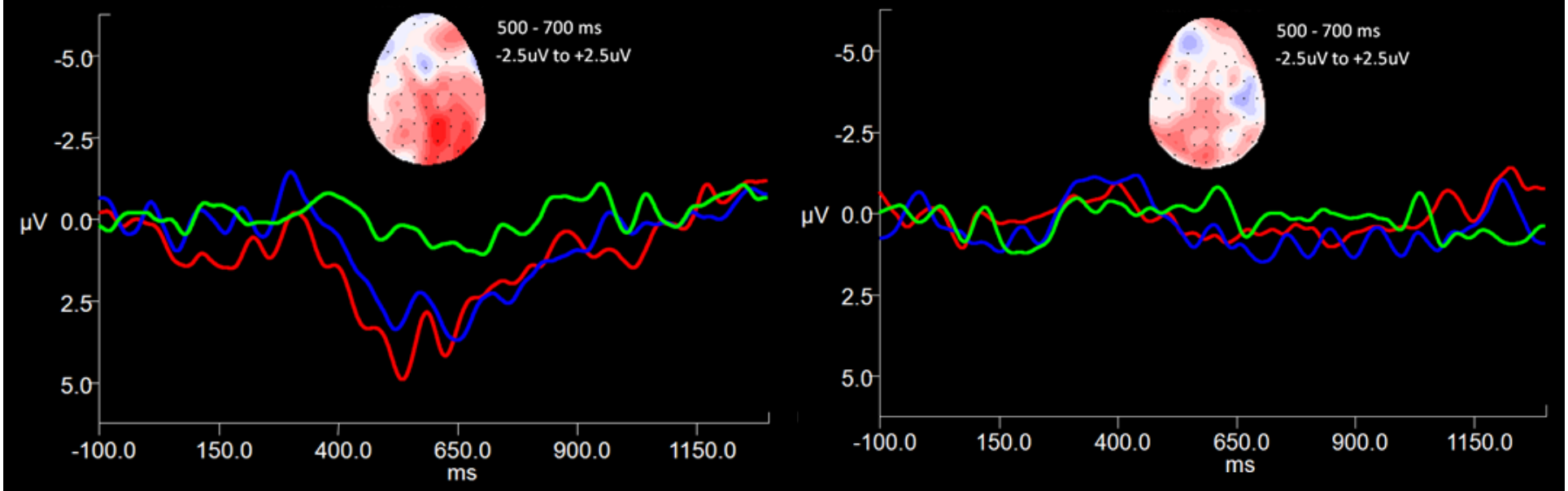
- Assumption
  - "If the average ERPs from two experimental conditions differ reliably at any given point in time, it can then be inferred that the associated brain and mental activity also differ at least by that point" (Kutas, 1998, p. 955)

EEG / ERP

- Pros
  - Very precise in its timing
  - Non-invasive
  - *Relatively* inexpensive
  - Flexibility in stimulus design
- Cons
  - Poor localisation
  - Data can be messy, so need lots of trials per condition

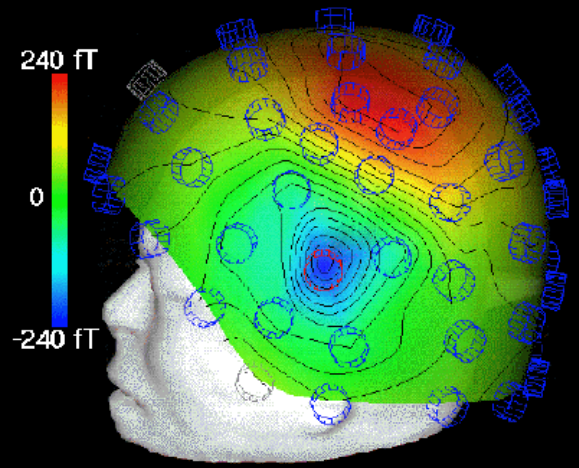
EEG / ERP in music

- Featherstone et al. (2010)
  - Compared processing of normal chords to processing of incongruous chords
    www.carafeatherstone.co.uk/stimuli
  - Compare musicians to non-musicians



MEG

- Magnetoencephalography
  - EEG + Localisation
  - Active neurons generate tiny magnetic fields
  - Locate area of maximum magnetic field activity
  - Source localisation



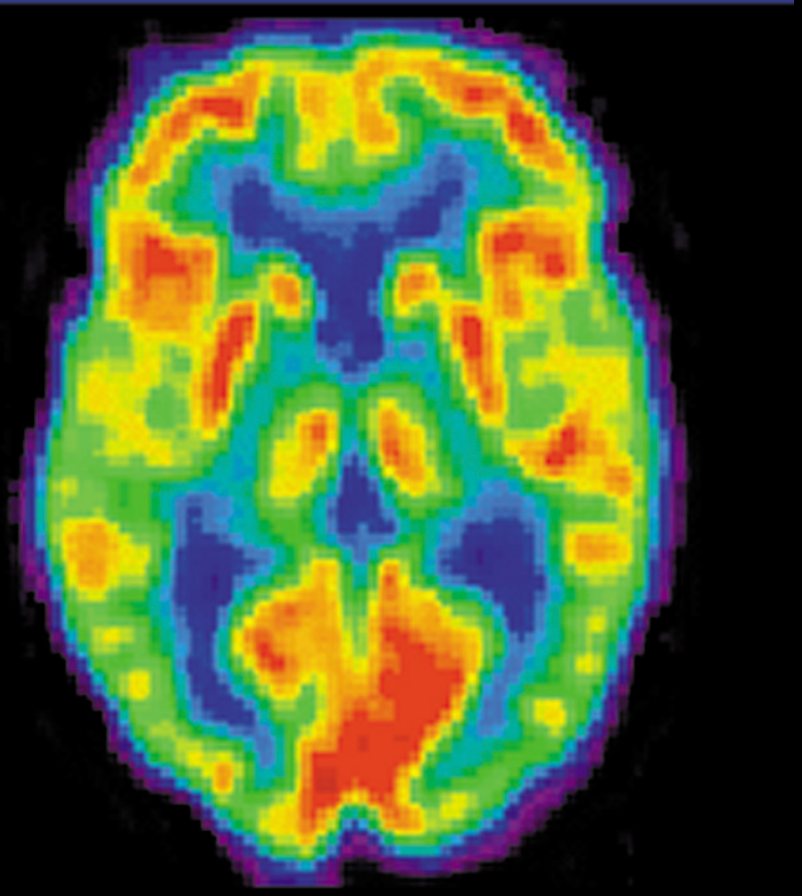
MEG

- Pros
  - Excellent timing
  - Good localisation
  - Non-invasive
- Cons
  - Only suitable for surface structures of the brain
  - More expensive than EEG
  - Complex calculations for localisation

MEG in music

- Maess et al. (2001)
  - Chord sequences containing a Neapolitan 6^{th} on 3^{rd} or 5^{th} chord of the 5-chord sequence
  - Compared to normal chords
  - Found "Early Right Anterior Negativity", identical to in ERP studies using this methodology (Koelsch et al. 2001)
  - Source of the ERAN: Broca's area
  - Effect stronger on 5^{th} chord than on 3^{rd} chord → importance of the musical context

PET



PET

- Positron emission tomography
  - Water with radioactive isotope of oxygen or glucose injected into participant
  - Using an area of the brain increases blood-flow to it
  - Watch where the gamma rays are produced

  - Looks at relative activation of brain areas
  - Need to subtract one condition from another one

PET

- Pros
  - Can look at deep structures
  - Isotopes could be used in future to look at specific neurotransmitter functions
  - Silent scanner
  - Spatial resolution to 5mm
- Cons
  - Very time consuming and expensive
  - Potentially toxic substances (ethics?)
  - Takes time to build up signal (2 minutes), so no quick stimuli

PET in music

- Mirz et a. (1999)
  - Does the area processing music depend on how complex the stimulus is?
  - PET scan, passive listening
  - Silence, continuous white noise, continuous pure tone, pure tone pulse train of 100ms duration, pure tone pulse train of 2 different alternating frequencies, single words, standardised speech, classical music

  - More complex stimulus, more laterally localised activations. From primary auditory cortex to structure processing structures (bilateral activation for music).

fMRI

fMRI

- Functional Magnetic Resonance Imaging
  - Oxygenated and deoxygenated hemoglobin have different magnetic properties
  - Where oxygen is consumed more, magnetic signals change more
  - BOLD (Blood Oxygenation Level Dependent) contrasts between conditions

fMRI

- Pros
  - Can look at structural AND functional differences
  - Spatial resolution to 1-3mm, but still “indirect”
  - Non-invasive (apart from noise)
  - Can look at deep structures
- Cons
  - Very noisy!
  - Temporal resolution (time accuracy) better than PET, but still 4-8 seconds

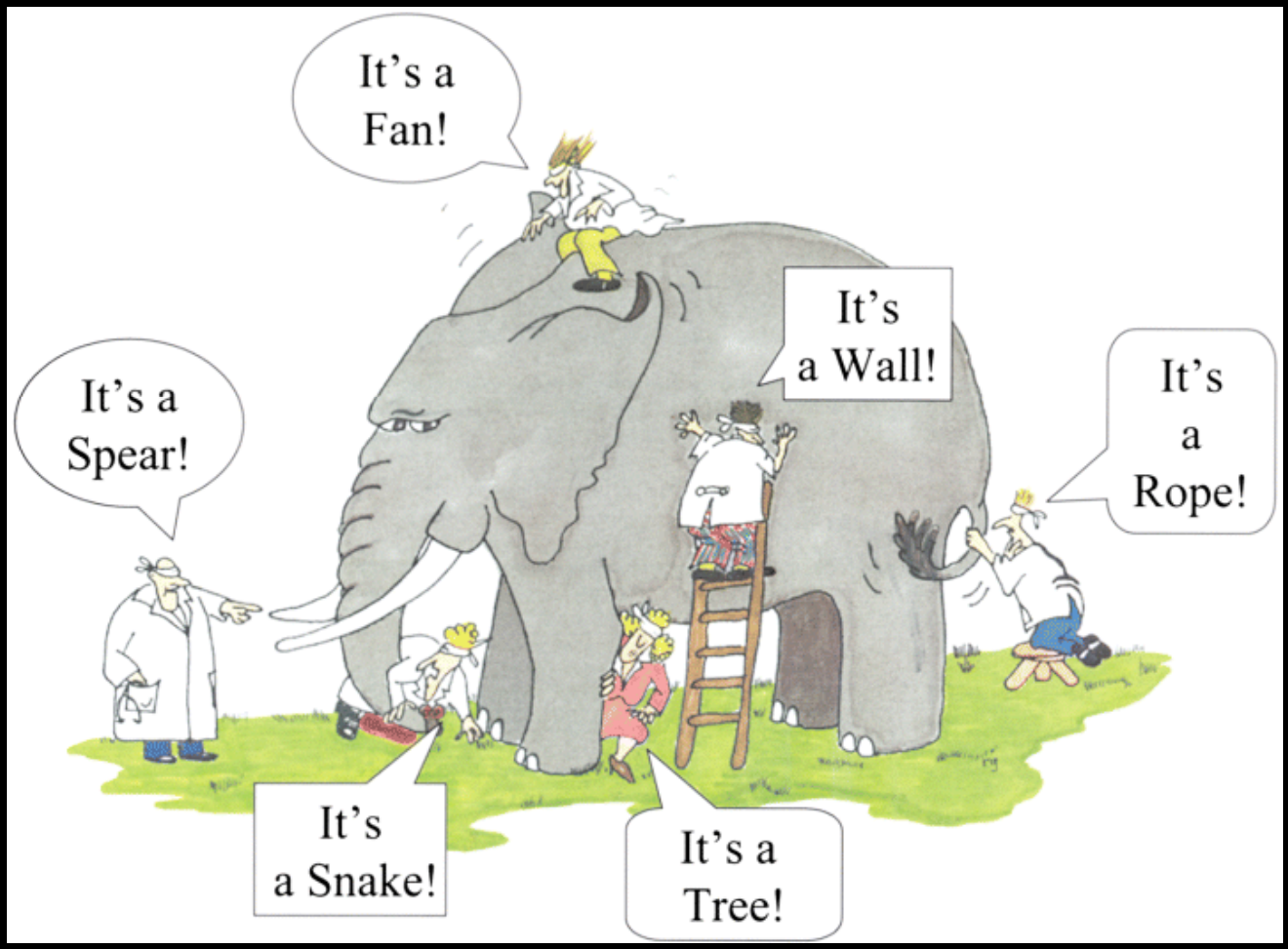
fMRI in music

- Levitin and Menon (2005)
  - Looked at areas involved in processing structure in music
  - Classical music and scrambled classical music

  - No differences in primary auditory cortex
  - When there was a structure to track, BA47 activated, which is implicated in processing language syntax

  - Structure in music and language tracked by the same area? The same processes? What does the area do?

Triangulation



Triangulation

- "Converging operations"
  - Mixed methods approach always gives richer data, and allows a validation / challenge of what you think the brain imaging data are showing
- Combine imaging techniques with traditional approaches
- Construct experiments carefully
  - Screwdriver vs. chair → Thoughts? Motor signals?...

Triangulation

- "A key element of imaging studies in neuropsychology is the vital importance of good experimental design aimed at testing specific hypotheses" (Stirling, p.21)

- For each theory: psychological, computational and biological plausibility?

- Ask yourself…
  - What else could these data be showing?
  - If I want to test this, what controls should I put in place?

Your turn

- Design an experiment in groups to look at…
  - Music-induced emotions
  - Sight-reading
  - Recognising a melody
  - Hearing music and language
  - Learning musical motor skills
  - A different topic of your choice…

- Feedback and discuss

These last three weeks

- Finding and assessing the literature
- A crash course on the brain
- Methods used to study the musical brain

- Lots to take in!

Next week…

- Class presentations
  - Any questions on this, email Katie

- Next lecture with me (week 10): Music and Language