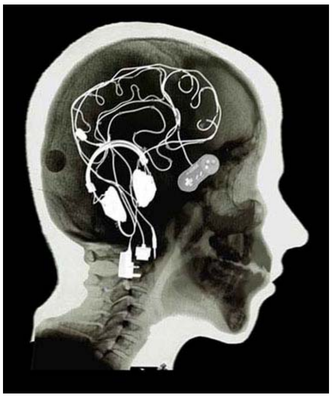


Brain Imaging of auditory function

Maria Chait

Who am I?

- I do (mostly) MEG functional brain imaging of auditory processing.
- Now, I am at the EAR Institute, University College London
  &
  Equipe Audition, LPP, Paris 5, ENS
- PhD from the University of Maryland, USA
  - Cognitive Neuroscience of Language Laboratory
  - Computational Sensory Motor Systems Laboratory

Outline:

- **Introduction to brain imaging techniques.**
- **Spatial processing**
- **Pitch and melody**
- **Attention**
- **Change detection and MMN**
- **Speech**
- **Brain asymmetry**

Some Slides/Images are taken from:

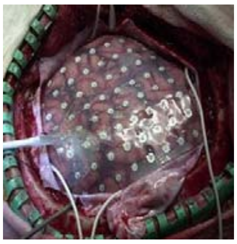
- http://psychology.uwo.ca/fmri4newbies/
- David Poeppel
- Colin Phillips
- Wikipedia
- Istvan Winkler
- Gazzaniga et al. (eds) ‘Cognitive Neuroscience’

Outline:

- **Introduction to brain imaging techniques.**
- Spatial processing
- Pitch and melody
- Attention
- Change detection and MMN
- Speech
- Brain asymmetry

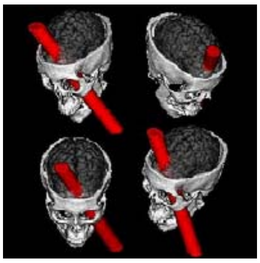
functional brain mapping in humans

- Subdural recording



functional brain mapping in humans

- Subdural recording
- Lesion study

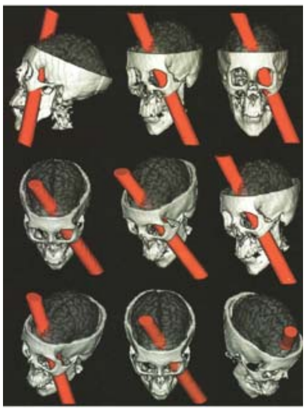


Phineas Gage, 1848

Before: responsible, well-mannered, well-liked, efficient worker, pious

After: capricious, impulsive, irreverent, hypersexual

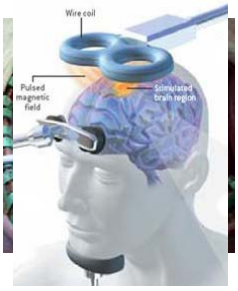
Damage involved VMPFC



functional brain mapping in humans

- Subdural recording
- Lesion study
- Trans-cranial magnetic stimulation (TMS)

Non-invasive method to study brain circuitry and connectivity. Localized neural excitation is caused by weak electric currents induced in the tissue by rapidly changing magnetic fields.

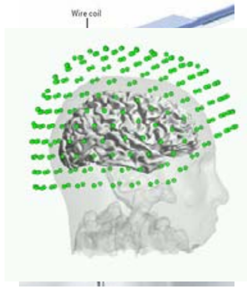


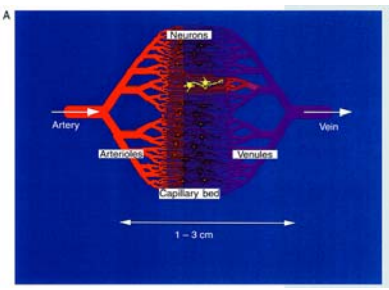
functional brain mapping in humans

- Subdural recording
- Lesion study
- Trans-cranial magnetic stimulation (TMS)

Non-invasive method to study brain circuitry and connectivity. Localized neural excitation is caused by weak electric currents induced in the tissue by rapidly changing magnetic fields.

- Non invasive functional brain imaging methods

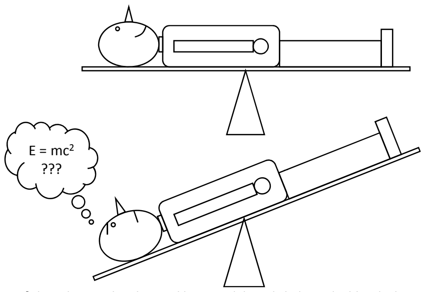




- Active neurons release the neurotransmitter glutamate
- Glutamate opens NMDA receptors on other neurons which allows calcium ions in
- Calcium activates the production of nitric oxide
- Nitric oxide diffuses out and dilates smooth muscle surrounding local arterioles
- This allows more blood into the local capillaries
- More oxygen and glucose reaches the neurons

The First "Brain Imaging Experiment"

Angelo Mosso
Italian physiologist
(1846-1910)

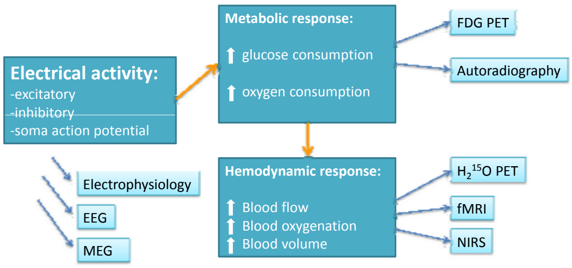


"[In Mosso's experiments] the subject to be observed lay on a delicately balanced table which could tip downward either at the head or at the foot if the weight of either end were increased. The moment emotional or intellectual activity began in the subject, down went the balance at the head-end, in consequence of the redistribution of blood in his system."

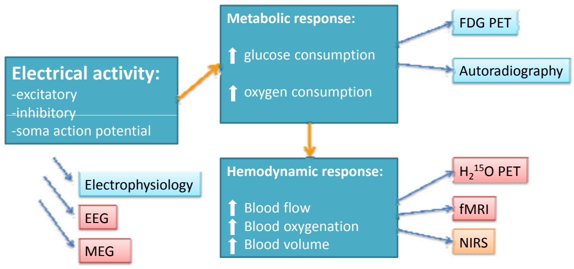
-- William James, *Principles of Psychology* (1890)

From http://psychology.uwo.ca/fmri4newbies/

Physiological correlates of brain electrical activity



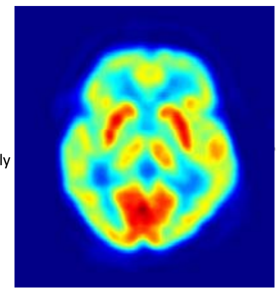
Physiological correlates of brain electrical activity



Positron Emission Tomography (PET)

Positron Emission Tomography (PET)

The system detects coincident pairs of gamma rays emitted by annihilation of a positron-emitting radioisotope, which is introduced into the body on a metabolically active molecule.



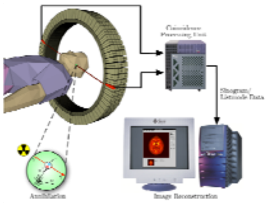
Positron Emission Tomography (PET)

Advantages:

•Good spatial resolution
•Silent

Limitations:

•Moderately Invasive (requires injection of radio nuclides)
•high costs of radio nuclides production.
•Short half life of radio nuclides.
•Poor temporal resolution (requires block design)



Why Temporal Resolution is important: An example from the Lexical Decision task

Required operations:
•Visual registration
•Grapheme-to-phoneme conversion
•Lexical search
•Remembering the task
•Motor response

< 900 ms
distributed processing in neural networks

<u>**PET methodology**</u>

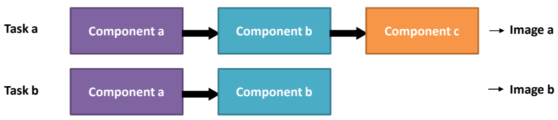
1. Block design

Tasks are run in blocks of 30-60 seconds duration. During each block, the same experimental task must be executed for the entire block duration.

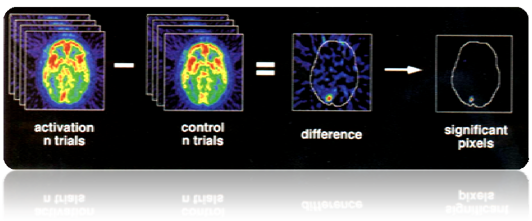
The different experimental blocks are chosen to be in a "hierarchical" or "nested" relationship.

2. Paired-image subtraction

PET images are collected during the execution of blocks and subtracted from one another.



<u>Image a</u> MINUS <u>Image b</u> = difference image (pixel-by-pixel subtraction)
Local activation in difference image is responsible for Component c



From http://psychology.uwo.ca/fmri4newbies/

Why Temporal Resolution is important: An example from the Lexical Decision task

Required operations:
- •Visual registration
- •Grapheme-to-phoneme conversion
- •Lexical search
- •Remembering the task
- •Motor response

< 900 ms

distributed processing in neural networks

PET methodology

1. Block design

Tasks are run in blocks of 30-60 seconds duration. During each block, the same experimental task must be executed for the entire block duration.

The different experimental blocks are chosen to be in a "hierarchical" or "nested" relationship.

2. Paired-image subtraction

PET images are collected during the execution of blocks and subtracted from one another.

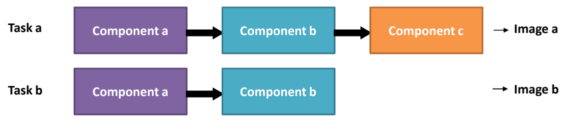


Image a MINUS Image b = difference image (pixel-by-pixel subtraction)
Local activation in difference image is responsible for Component c

---

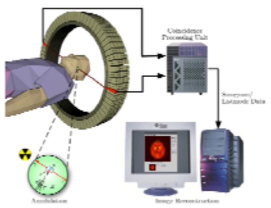
Positron Emission Tomography (PET)

Advantages:

- •Good spatial resolution
- •Silent

Limitations:

- •Moderately Invasive (requires injection of radio nuclides)
- •high costs of radio nuclides production.
- •Short half life of radio nuclides.
- •Poor temporal resolution (requires block design)

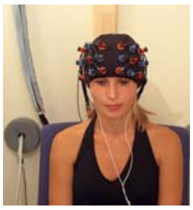


Near infrared spectroscopy (NIRS)

Near infrared spectroscopy (NIRS)

The primary absorbers in tissue at near-infrared wavelengths:
- Water
- **oxygenated haemoglobin (HbO)**
- **deoxygenated haemoglobin (Hb)**

transmission and absorption of NIR light in brain tissues contains information about haemoglobin concentration changes and oxygen saturation.



Near infrared spectroscopy (NIRS)

Advantages:

•Non invasive
•can be used on infants
•much more portable than fMRI machines

Limitations:

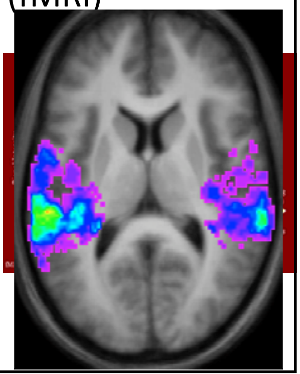
•Works at only centimetre depths (cortical).
•Poor temporal resolution.

Functional magnetic resonance imaging (fMRI)

A method of observing which areas of the brain are active at any given time, based on measuring the degree of magnetization of a haemoglobin in response to an applied magnetic field.

the difference in magnetization between oxygenated haemoglobin and deoxygenated haemoglobin causes magnetic signal variation which is detectable with an MRI scanner.

BOLD=Blood Oxygenation Level Dependent RESPONSE



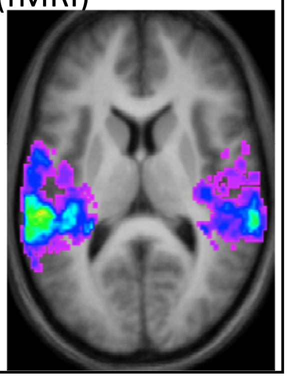
Functional magnetic resonance imaging (fMRI)

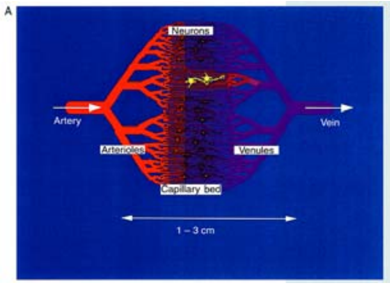
Advantages:

•Non invasive
•Spatial resolution in the region of 3-6 millimetres.

Limitations:

•Very noisy.
•Poor temporal resolution.
•Block design is usually used.





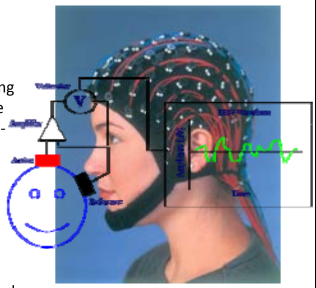
Neural current

Photo by Fritz Goro

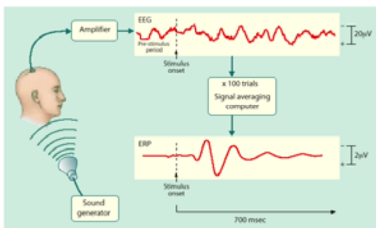
Electroencephalography (EEG)

neurophysiologic measurement of the electrical activity of the brain by recording from electrodes placed on the scalp. The resulting represent a summation of post-synaptic potentials from a large number of neurons.

An evoked potential (or "evoked response") is an electrical potential recorded following presentation of a stimulus (as opposed to spontaneous) and is computed by averaging over stimulus presentations.



Event-related response



Electroencephalography (EEG)

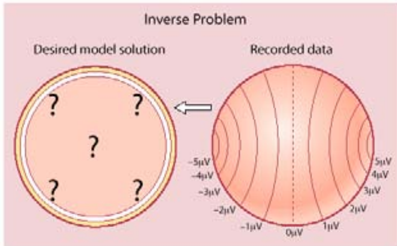
Advantages:

•Non invasive and passive.
•Excellent temporal resolution (direct measure of neural activity)
•Relatively cheap to set-up

Limitations:

•Poor spatial resolution (inverse problem is ambiguous)

Inverse Problem



Electroencephalography (EEG)

Advantages:

•Non invasive and passive.
•Excellent temporal resolution (direct measure of neural activity)
•Relatively cheap to set-up

Limitations:

•Poor spatial resolution (inverse problem is ambiguous)
•'blind' to tangential currents
•Visible activity only for synchronous activation of many (~10^4 ~10^6) neurons

Magnetoencephalography (MEG)

measure the magnetic fields produced by electrical activity in the brain via extremely sensitive devices such as superconducting quantum interference devices (SQUIDs).

signals derive from the net effect of ionic currents flowing in the dendrites of neurons during synaptic transmission.

SQUID detectors measure brain magnetic fields around 100 billion times weaker than earth's steady magnetic field

Magnetoencephalography (MEG)

Advantages:

•Non invasive and passive.
•Excellent temporal resolution (direct measure of neural activity)
•Auditory Cortex is in the 'Fovea' of MEG
•Spatial resolution better than EEG.

Limitations:

•Poor spatial resolution (inverse problem is ambiguous)
•'blind' to perpendicular currents
•Visible activity only for synchronous activation of many (~10^4 ~10^6) neurons

Non-invasive recording from human brain (Functional brain imaging)

Hemodynamic techniques
- Positron emission tomography (PET)
- Functional magnetic resonance imaging (fMRI)

Excellent spatial resolution (~1-2mm)
Poor temporal resolution (~1sec)

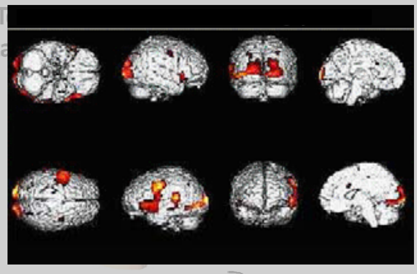
Electro-magnetic techniques
- Electro-encephalography (EEG)
- Magneto-encephalography (MEG)

Poor spatial resolution (~1cm)
Excellent temporal resolution (<1msec)

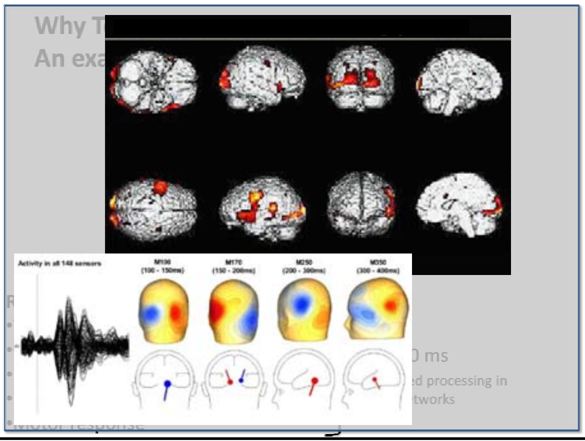
Why Temporal Resolution is important: An example from the Lexical Decision task

Required operations:
•Visual registration
•Grapheme-to-phoneme conversion
•Lexical search
•Remembering the task
•Motor response

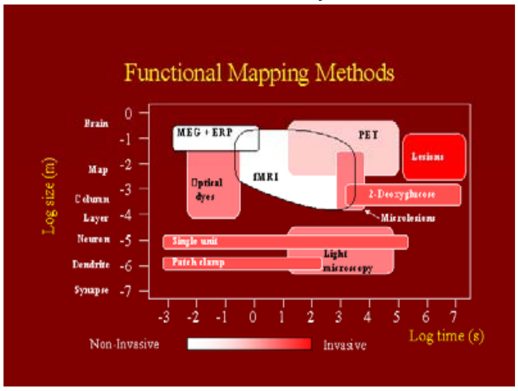
< 900 ms
distributed processing in neural networks



Required operations:
•Visual registration
•Grapheme-to-phoneme conversion
•Lexical search
•Remembering the task
•Motor response
< 900 ms
distributed processing in neural networks



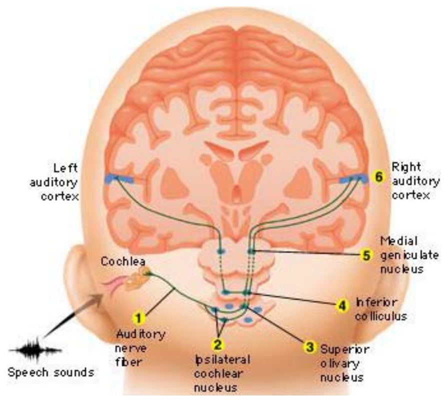
Summary



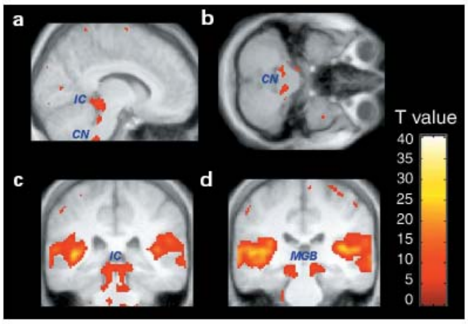
brain imaging techniques - Summary

- **Different functional brain imaging techniques have specific limitations (e.g. what is measured, how results should be interpreted, etc)**
- **require different experimental design**
- **Are designed to answer different questions about processing (e.g. 'where' vs. 'when')**

The auditory pathway

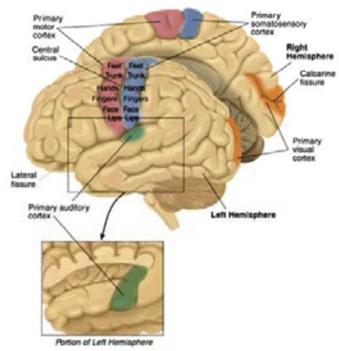


Activation of structures in the ascending auditory pathway with sound stimuli:

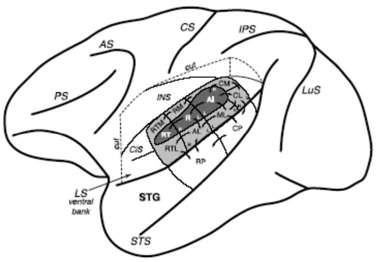


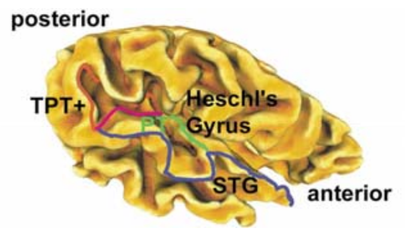
Griffiths et al, 2001

► Lateral View of the Left Side of a Human Brain



From animal models:

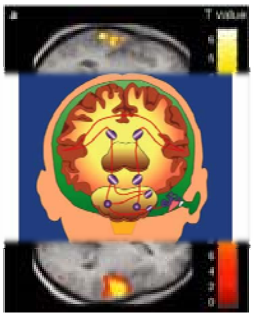




(Figure from Ratnanather et al, NeuroImage 2003, vol 20[1])

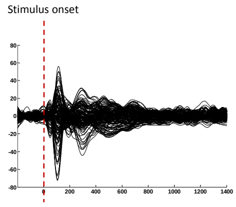
MEG vs. fMRI data interpretation

- If brain area X is the first, in a hypothesized pathway, to be activated by a stimulus feature, then it is hypothesized that this area is involved in extracting that feature.
- If activation in area X is modulated by change in a particular feature, then it is involved in processing that feature.



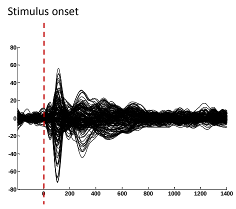
MEG vs. fMRI data interpretation

- The activation pattern, consisting of increases in activation at different latencies, reflects the sequential operation of cortical systems related to analyzing the stimulus
- Cortical processing can be studied by investigating which stimulus features affect the latency or amplitude of these responses.



MEG vs. fMRI data interpretation

- The activation pattern, consisting of increases in activation at different latencies, reflects the sequential operation of cortical systems related to analyzing the stimulus
- Cortical processing can be studied by investigating which stimulus features affect the latency or amplitude of these responses.

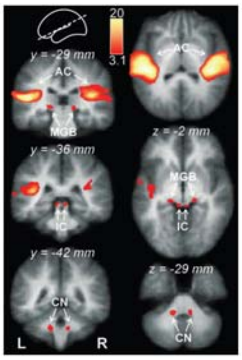


Outline:

- Introduction to brain imaging techniques.
- **Spatial processing**
- Pitch and melody
- Attention
- Change detection and MMN
- Speech
- Brain asymmetry

Spatial processing

Contrast between all sound conditions and silence



fMRI stimuli:
• Silence
•Left ear noise bursts
•Right ear noise bursts
•Center noise bursts
•Moving noise bursts

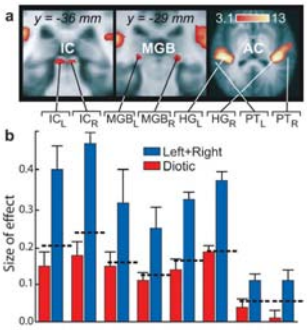
Spatial percept manipulated by ITD

Krumbholz et al, 2005

Spatial processing

Binaural difference contrast:
Center minus (left+right)
(all referred to silence)

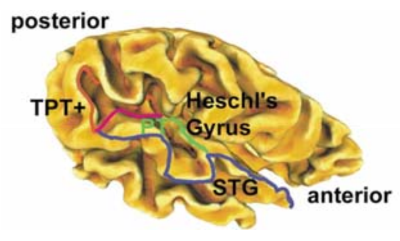
Binaural interaction in IC, MGB and PAC



fMRI stimuli:
• Silence
•Left ear noise bursts
•Right ear noise bursts
•Center noise bursts
•Moving noise bursts

Spatial percept manipulated by ITD

Krumbholz et al, 2005



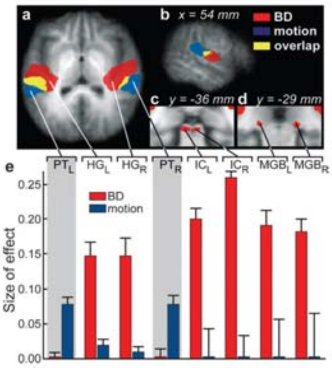
(Figure from Ratnanather et al, NeuroImage 2003, vol 20[1])

Spatial processing

Motion contrast:
Motion - Center

Hierarchical processing of binaural cues

fMRI stimuli:
• Silence
•Left ear noise bursts
•Right ear noise bursts
•Center noise bursts
•Moving noise bursts

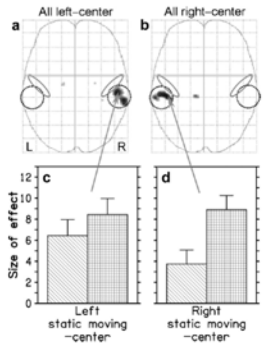


Krumbholz et al, 2005

Spatial processing

Internal representation of lateralized sounds is predominantly contralateral.

fMRI stimuli:
• Silence
•Centre static noise
•Left static noise
•Right static noise
•Leftward moving noise
•Rightward moving noise



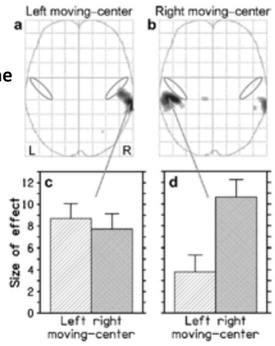
Spatial percept manipulated by ITD

Krumbholz et al, 2004

Spatial processing

Right hemisphere dominance in the processing of sound movement

fMRI stimuli:
• Silence
•Centre static noise
•Left static noise
•Right static noise
•Leftward moving noise
•Rightward moving noise



Spatial percept manipulated by ITD

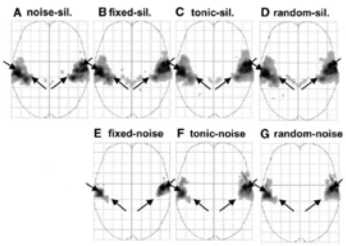
Krumbholz et al, 2004

Outline:

- Introduction to brain imaging techniques.
- Spatial processing
- **Pitch and melody**
- Attention
- Change detection and MMN
- Speech
- Brain asymmetry

Pitch Processing

Contrasts:



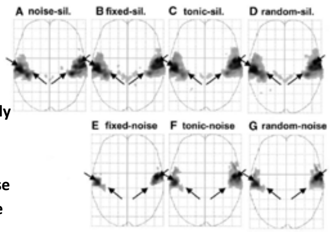
fMRI stimuli:
- **Silence**
- **Noise**
- **Fixed Pitch (IRN)**
- Changing pitch (tonic)
- Changing pitch (random)

Patterson et al, 2002

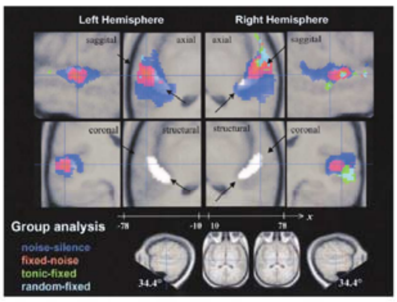
Pitch Processing

There are a number of centers in auditory cortex (HG and PT) that Process all stimuli coming up from subcortical structures in both hemispheres, and one of these regions in lateral HG is differentially active in the presence of pitch.

All of the regions activated by noise were activated to the same degree by sounds with pitch.



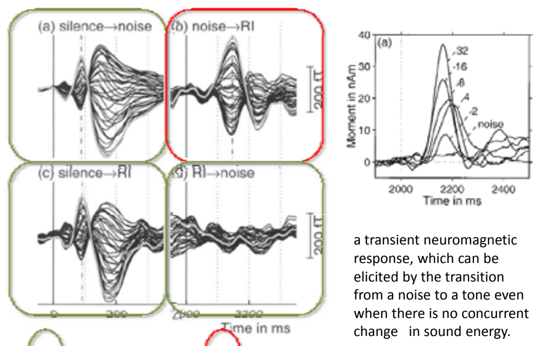
Patterson et al, 2002



fMRI stimuli:
- **Silence**
- **Noise**
- **Fixed Pitch (IRN)**
- Changing pitch (tonic)
- Changing pitch (random)

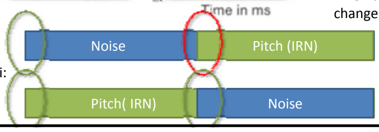
sounds with pitch produced more activation than those without pitch only in the lateral half of Heschl's gyrus (HG).

Patterson et al, 2002



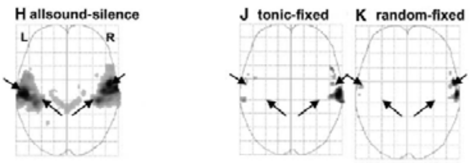
a transient neuromagnetic response, which can be elicited by the transition from a noise to a tone even when there is no concurrent change in sound energy.

MEG stimuli:



Krumbholz et al, 2003

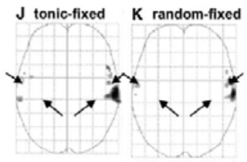
Processing of melody



fMRI stimuli:
- Silence
- Noise
- **Fixed Pitch (IRN)**
- **Changing pitch (tonic)**
- **Changing pitch (random)**

Patterson et al, 2002

Processing of melody

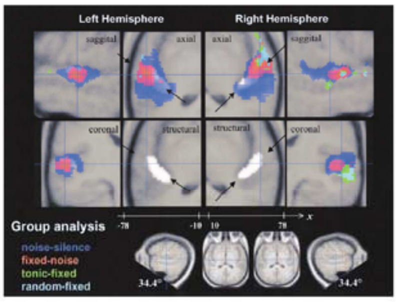


More later

Both contrasts reveal differential activation to melody in STG and PP, but in this case, the activation is asymmetric (more activity in the right hemisphere)

Melody produced the same level of activity as fixed pitch in HG. This suggests that HG is involved in short- term rather than longer-term pitch processing.

Patterson et al, 2002



fMRI stimuli:
- Silence
- Noise
- Fixed Pitch (IRN)
- Changing pitch (tonic)
- Changing pitch (random)

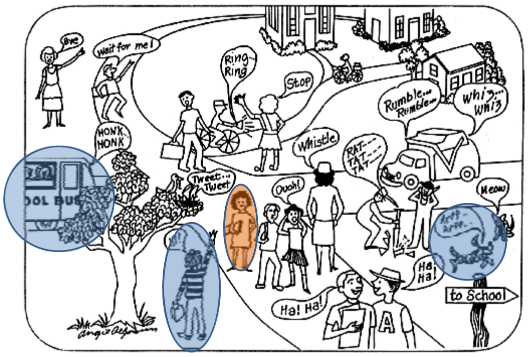
Hierarchy of pitch processing in auditory cortex

Patterson et al, 2002

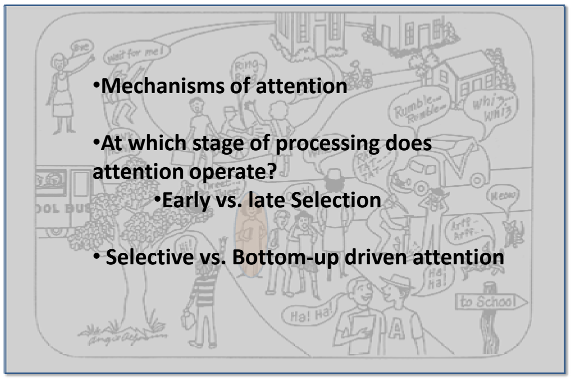
Outline:

- Introduction to brain imaging techniques.
- Spatial processing
- Pitch and melody
- **Attention**
- Change detection and MMN
- Speech
- Brain asymmetry

Attention

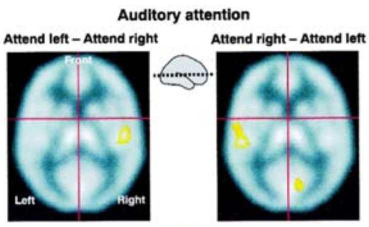


Attention



- Mechanisms of attention
- At which stage of processing does attention operate?
  - Early vs. late Selection
- Selective vs. Bottom-up driven attention

Selective attention

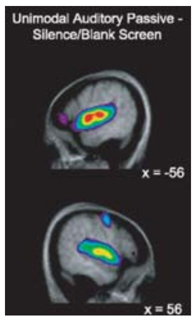


PET stimuli:
- 3 concurrent streams: Left Ear, Right Ear, Visual
- Task:
  - attend left ear (detect deviant tones)
  - attend right ear
  - attend visual

Alho et al, 1999

Selective attention

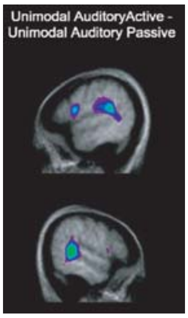
fMRI stimuli:
Melodies and shapes.
- silence + blank screen
- Unimodal Aud passive
- Unimodal Aud active
- Unimodal Vis passive
- Unimodal Vis active
- Bimodal passive
- Bimodal Aud active
- Bimodal Vis active



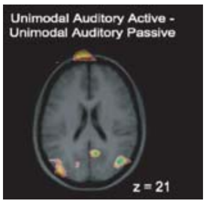
Johnson & Zatorre, 2005

Selective attention

fMRI stimuli:
Melodies and shapes.
• silence + blank screen
•Unimodal Aud passive
•Unimodal Aud active
•Unimodal Vis passive
•Unimodal Aud active
•Bimodal passive
•Bimodal Aud active
•Bimodal Vis active



Increased activity

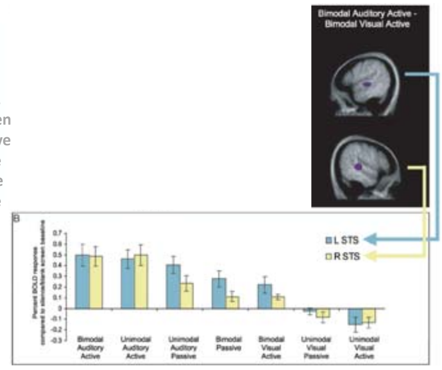


Decreased activity

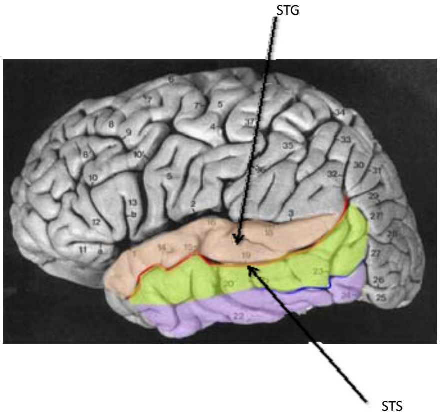
Johnson & Zatorre, 2005

Selective attention

fMRI stimuli:
Melodies and shapes.
• silence + blank screen
•Unimodal Aud passive
•Unimodal Aud active
•Unimodal Vis passive
•Unimodal Aud active
•Bimodal passive
•Bimodal Aud active
•Bimodal Vis active



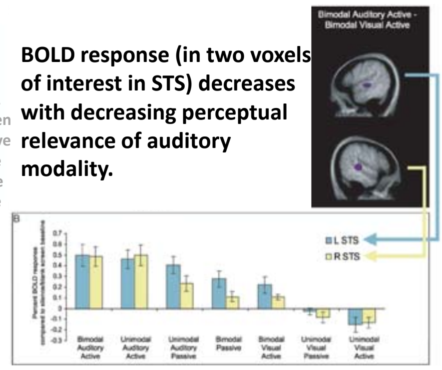
Johnson & Zatorre, 2005



Selective attention

fMRI stimuli:
Melodies and shapes.
• silence + blank screen
•Unimodal Aud passive
•Unimodal Aud active
•Unimodal Vis passive
•Unimodal Aud active
•Bimodal passive
•Bimodal Aud active
•Bimodal Vis active

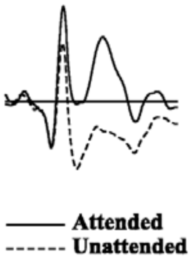
BOLD response (in two voxels of interest in STS) decreases with decreasing perceptual relevance of auditory modality.



Johnson & Zatorre, 2005

Temporal properties of auditory attention

Example from EEG:

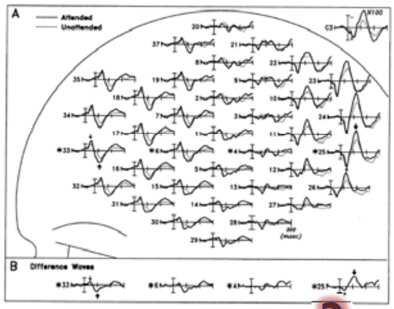


Alain & Izenberg, 2003

Temporal properties of auditory attention

MEG stimuli:
Sequences of tones in left and right ear.
Task:
- **Attend left**
- **Attend right**

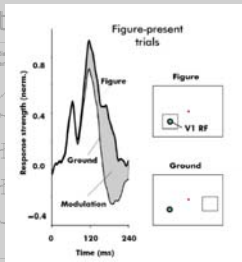
Attention verified by measuring detection-task performance



Early selection mechanism for auditory attention ?

Woldorff et al, 1993

An example from Vision:



Cortico-cortical feedback

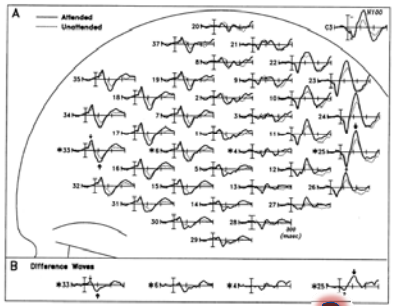
Super et al, 2001

Temporal properties of auditory attention
MEG stimuli:
Sequences of tones in left and right ear.
Task:
•Attend left
•Attend right
Attention verified by measuring detection-task performance
Early selection mechanism for auditory attention ?

Temporal properties of auditory attention

MEG stimuli:
Sequences of tones in left and right ear.
Task:
- **Attend left**
- **Attend right**

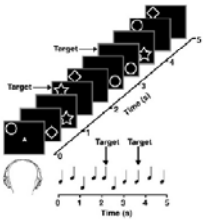
Attention verified by measuring detection-task performance



Early selection mechanism for auditory attention ?

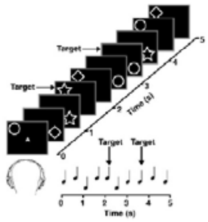
Woldorff et al, 1993

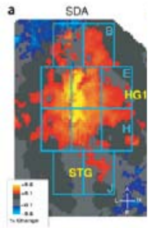
Attentional modulation of human auditory cortex



Petkov et al, 2004

Attentional modulation of human auditory cortex





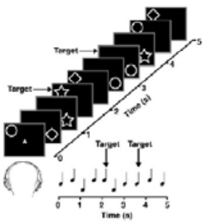
Stimulus-dependent activation

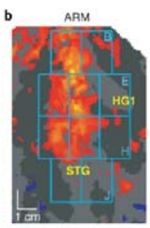
- Maximal in STG
- Enhanced in contralateral hemisphere
- Influenced by sound frequency (tonotopic organization)

Visual attention w-auditory signal minus Visual attention without auditory signals

Petkov et al, 2004

Attentional modulation of human auditory cortex



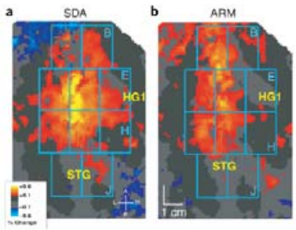


Attention-related activation

Auditory attention minus Visual attention

Petkov et al, 2004

Attentional modulation of human auditory cortex



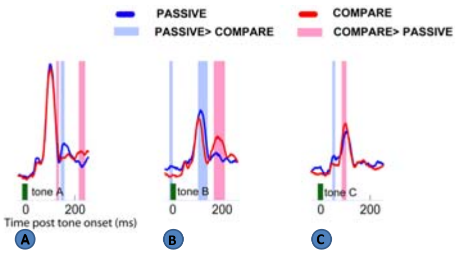
Stimulus-dependent activation

Attention-related activation

Auditory attention does not just amplify neural responses

Petkov et al, 2004

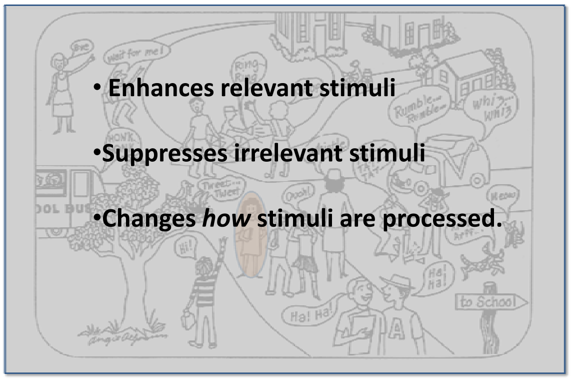
Selectively ignoring a stimulus



MEG stimuli:
Sequences of 3 tones.
Task:
•COMPARE: compare A and C (ignore B)
•PASSIVE: listen passively

Chait et al, in prep

Attention



- **Enhances relevant stimuli**
- **Suppresses irrelevant stimuli**
- **Changes *how* stimuli are processed.**

Krumholz study here

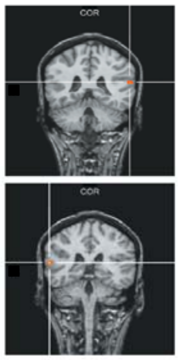
Attention Changes sound representation in auditory cortex

fMRI stimuli:
FM sweeps.

Two tasks:
- **Categorization of pitch direction (rising/falling)**
- **Categorization of duration (short/long)**

Pitch direction

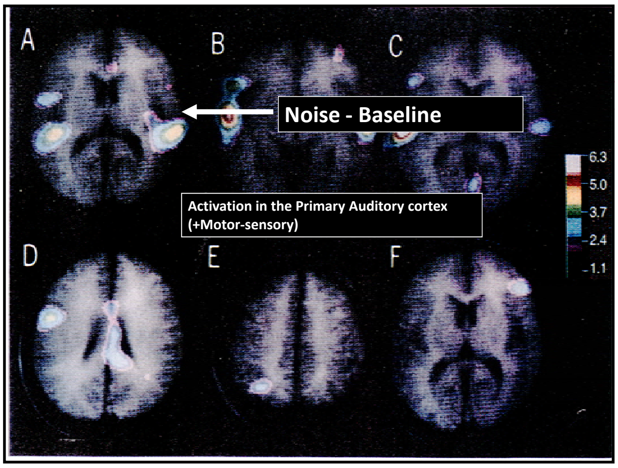
Duration

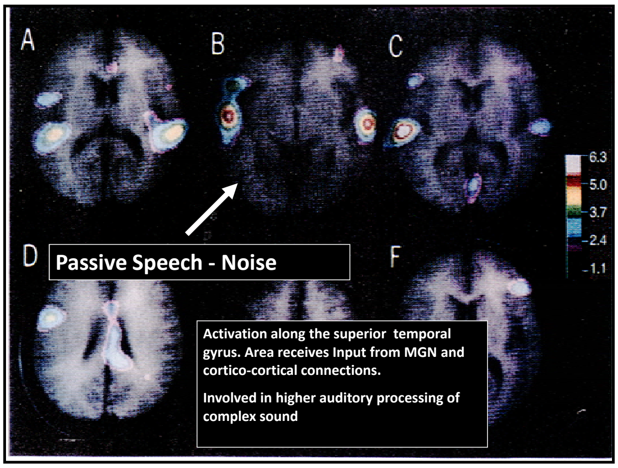


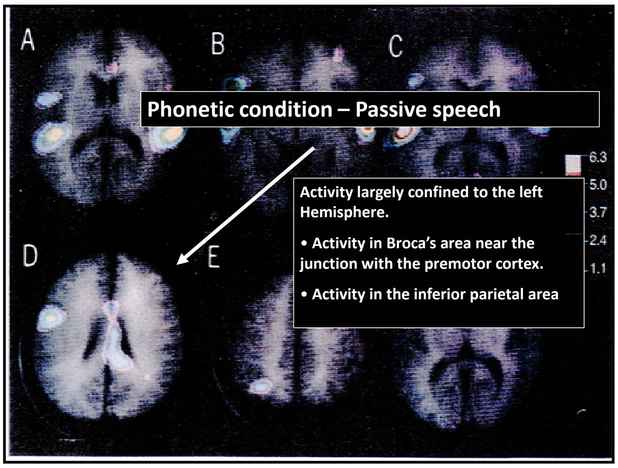
Brechman & Scheich, 2005

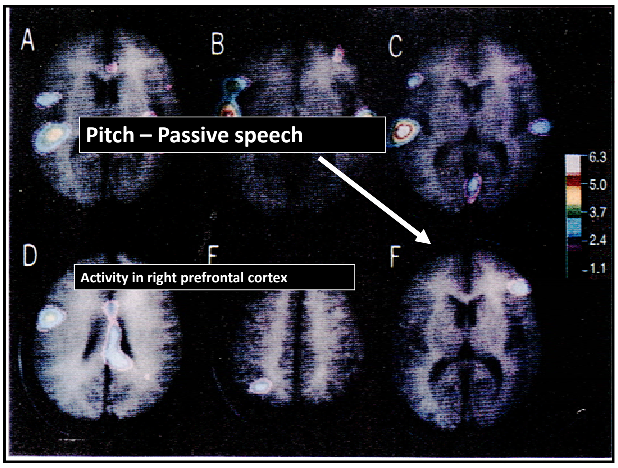
- **Zatorre et al (1992) "Lateralization of Phonetic and Pitch Discrimination in Speech Processing"**

Condition	Stimulus	Required response
Baseline	Silence	
Noise	Noise bursts	Alternating key press
Passive speech	Speech syllables	Alternating key press
Phonetic	Speech syllables	Key press to same final consonant
Pitch	Speech syllables	Key press to rising pitch









Outline:

- Introduction to brain imaging techniques.
- Spatial processing
- Pitch and melody
- Attention
- **Change detection and MMN**
- Speech
- Brain asymmetry

Change detection

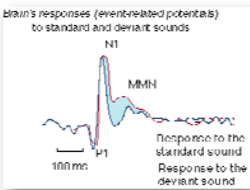
'Y' sound as deviant

X X X X X Y X X X X Y X X X X X X Y X X X Y X X X…

'Y' sound as standard

Y Y Y Y Y X Y Y Y Y X Y Y Y Y Y Y X Y Y Y X Y Y Y…

Mismatch Negativity; MMN; MMF

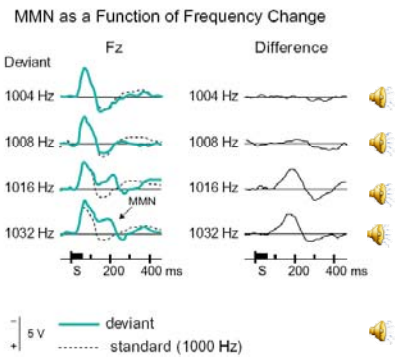


Latency: 150-250 msec.
Localization: Supratemporal auditory cortex

MMN as a tool:

- **Which features of sound is cortex sensitive to?**

©
Risto Näätänen
1978



Sams et al. 1985

MMN as a tool:

- Which features of sound is cortex sensitive to?
- **Relationship to attention**
- Allows to tap internal scene organization

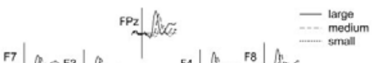
© Risto Näätänen 1978

Brain mechanisms involved in the detection of acoustic changes

EEG + fMRI stimuli: Sequences of click-trains of different lengths

- **100 ms (standard)**
- **74 ms**
- **52 ms**
- **30 ms**

Example trial:



MMN amplitudes increase with deviance magnitude

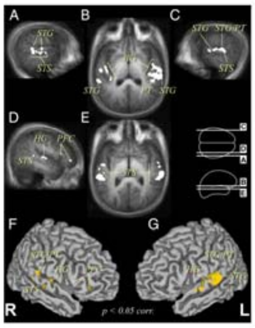
Schonwiesner et al, 2007

Brain mechanisms involved in the detection of acoustic changes

EEG + fMRI stimuli: Sequences of click-trains of different lengths

- 100 ms (standard)
- 74 ms
- 52 ms
- 30 ms

Example trial:

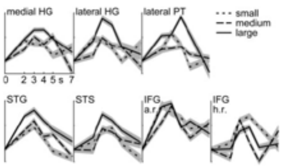


Schonwiesner et al, 2007

Brain mechanisms involved in the detection of acoustic changes

EEG + fMRI stimuli:
Sequences of click-trains of different lengths
- 100 ms (standard)
- 74 ms
- 52 ms
- 30 ms

Example trial:



Hemodynamic response time course in auditory cortex but not Frontal cortex is modulated by deviant size.

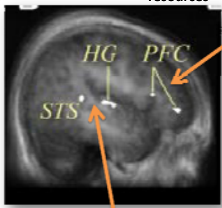
Schonwiesner et al, 2007

Brain mechanisms involved in the detection of acoustic changes

EEG + fMRI stimuli:
Sequences of click-trains of different lengths
- 100 ms (standard)
- 74 ms
- 52 ms
- 30 ms

Example trial:

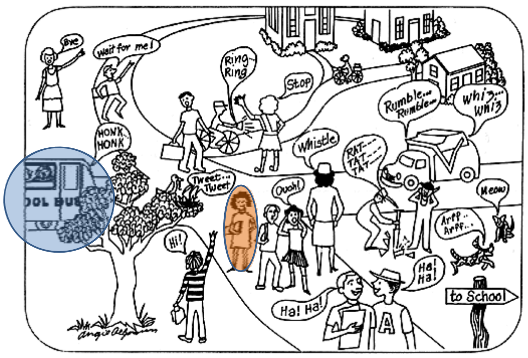
Judgement of sufficient novelty for the allocation of attentional resources



Initial detection of change

Schonwiesner et al, 2007

Attention



MMN as a tool:

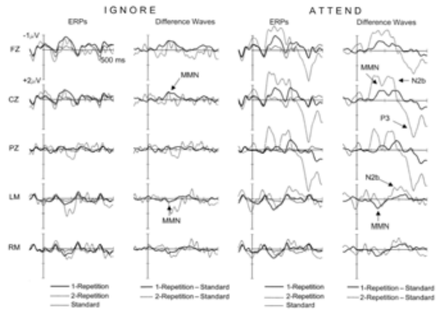
- Which features of sound is cortex sensitive to?
- relationship to attention
- **Allows to tap internal scene organization**

© Risto Näätänen 1978

MMN to trend violation (descending standards)

Tervaniemi et al, 1994

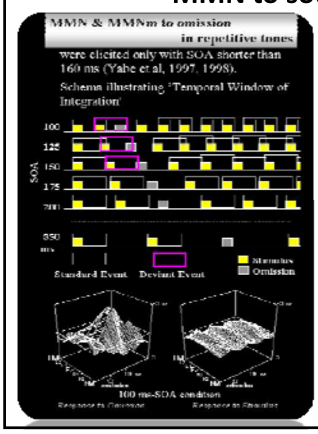
MMN to violation of randomness



frequency variation can be extracted as an invariant feature of the acoustic environment

Wolff et al, 2001

MMN to sound omission



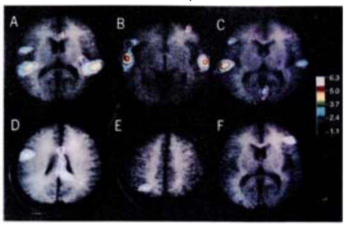
Temporal window of integration revealed by MMN to sound omission

Yabe et al, 1999

Outline:

- Introduction to brain imaging techniques.
- Spatial processing
- Pitch and melody
- Attention
- Change detection and MMN
- **Speech**
- Brain asymmetry

Noise - silence | Passive speech - noise



Phonetic judgement – passive speech | Pitch judgement – passive speech

- **signal undergoes discrete processing stages in separate neural subsystems**
- **A1 = early acoustic analysis of all signals**
  secondary areas = higher order processing
- **When making a phonetic judgment subjects access an articulatory representation involving neural circuits that include Broca's area.**

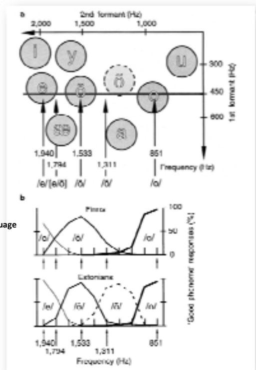
Zatorre et al, 1994

Language specific phoneme representations revealed by MMN

Naatanen et al, 1997

Language specific phoneme representations revealed by MMN

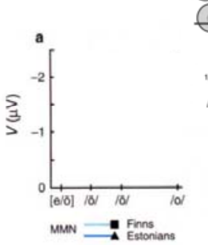
EEG stimuli:
MMN design
- **/e/ (standard)**
- **/ö/**
- **/o/**
- **/æ/** non phoneme in either language
- **/õ/** non phoneme in Finnish only

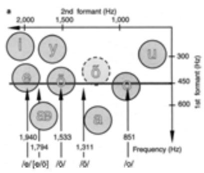


Naatanen et al, 1997

Language specific phoneme representations revealed by MMN

EEG stimuli:
MMN design
- **/e/ (standard)**
- **/ö/**
- **/o/**
- **/æ/** non phoneme in either language
- **/õ/** non phoneme in Finnish only

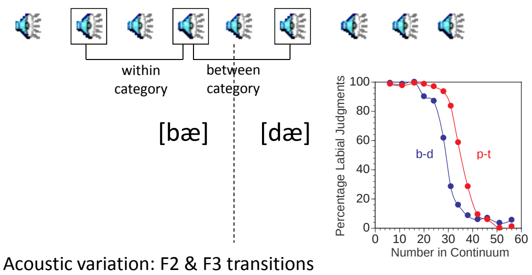




The native language of a listener affects auditory cortical responses to speech sounds

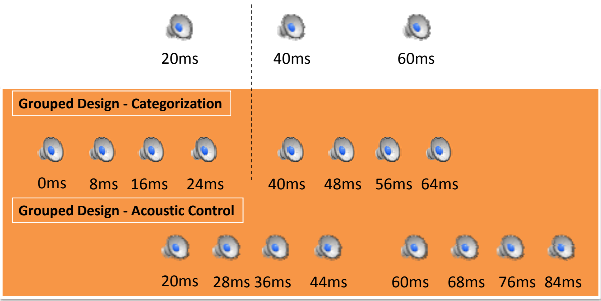
Naatanen et al, 1997

Phonetic categories in auditory cortex

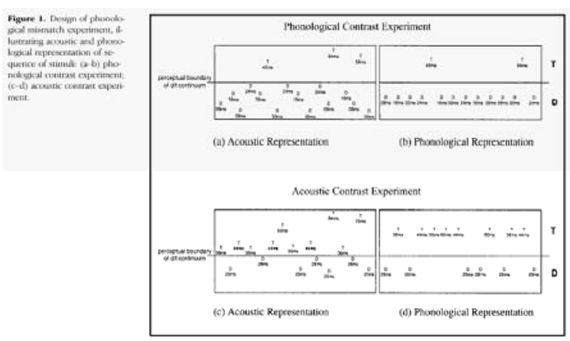


- Acoustic variation: F2 & F3 transitions

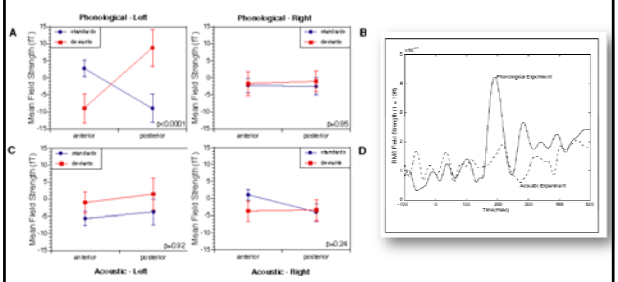
MEG stimuli:



Phillips et al, 2000



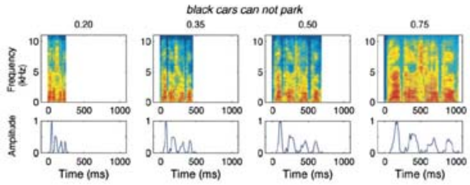
Phillips et al, 2000



a **left-hemisphere only** mismatch response elicited by phonological feature contrast

Phillips et al, 2000

Speech comprehension and response patterns from auditory cortex



MEG stimuli:
Time compressed sentences
•0.75 least compressed
•0.5
•0.35
•0.2 most compressed

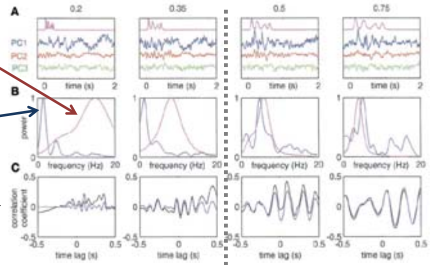
Ahissar et al, 2001

Speech comprehension and response patterns from auditory cortex

Stimulus envelope power spectrum

Power spectrum of PC1

Cross correlation between the two



MEG stimuli:
Time compressed sentences
•0.75 least compressed
•0.5
•0.35
•0.2 most compressed

Bad intelligibility

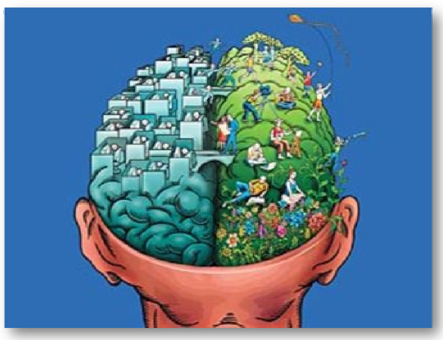
Good intelligibility

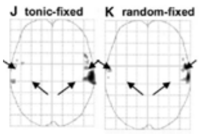
Intelligibility is correlated with the ability of auditory cortex to follow the temporal modulations of the signal

Ahissar et al, 2001

Outline:

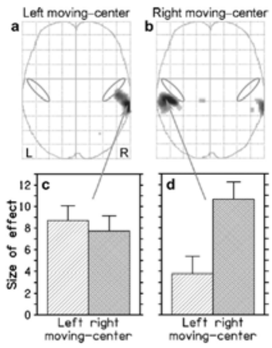
- Introduction to brain imaging techniques.
- Spatial processing
- Pitch and melody
- Attention
- Change detection and MMN
- Speech
- **Brain asymmetry**





Patterson et al, 2002

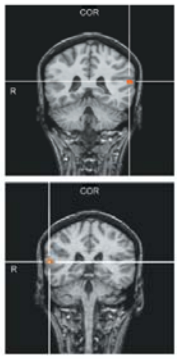
Right hemisphere dominance in Processing melody



Krumbholz et al, 2004

Right hemisphere dominance in Processing sound movement

Pitch direction

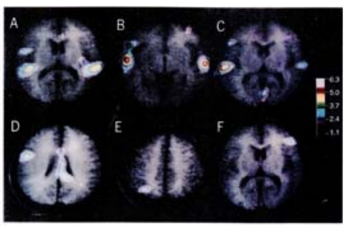


Right hemisphere dominance in Processing pitch direction

Duration

Left hemisphere dominance in processing duration

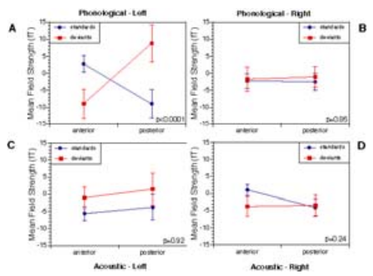
Brechman & Scheich, 2005



Left hemisphere dominance in processing phonemic information

Right hemisphere dominance in processing pitch change information

Zatorre et al, 1994



Left hemisphere dominance in processing phonological contrast information

Phillips et al, 2000

Hemispheric specialization may result from:

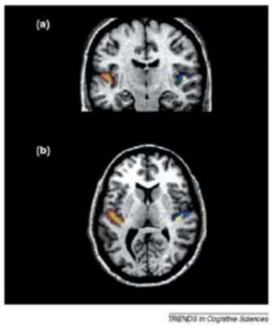
•Domain Specificity: differential specialization for different inputs: 'Speech centre'/'music centre'/ etc…

•Nature of stored representations that signals must interface with : Lexical info for speech/ prosodic info

•Differential specialization for different kinds of computations: Observed difference is due to difference in physical signal properties

Anatomical asymmetries in human auditory cortex

Greater volume of HG in the Left Hemisphere



from Zatorre et al, 2002

Spectral and temporal processing in human auditory cortex

- **Hypothesis #1:**

  Human auditory cortex is functionally segregated such that differences exist in the temporal and spectral resolving power between the two hemispheres

Speech requires good temporal resolution
Music requires good spectral resolution

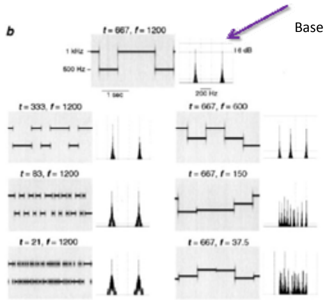
Zatorre & Belin, 2001

Spectral and temporal processing in human auditory cortex

PET stimuli:

Base signal

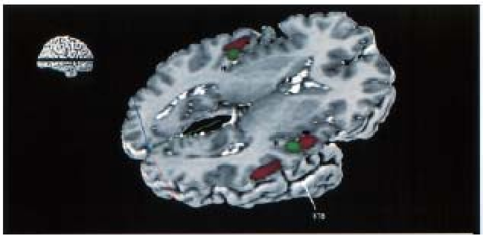
Constant spectral content
Changing temporal content



Constant temporal content
Changing spectral content

Zatorre & Belin, 2001

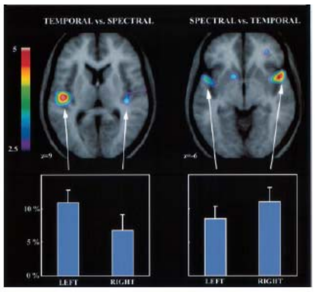
Spectral and temporal processing in human auditory cortex



Covariation of activation with rate of **spectral** change
Covariation of activation with rate of **temporal** change

Zatorre & Belin, 2001

Spectral and temporal processing in human auditory cortex



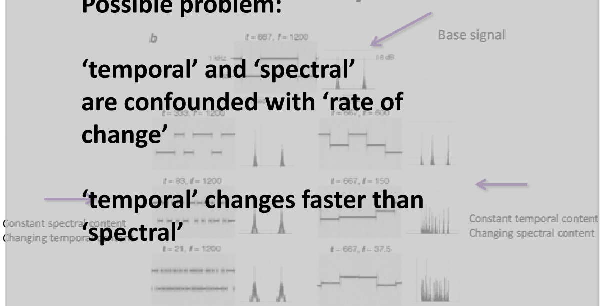
Zatorre & Belin, 2001

Spectral and temporal processing in human auditory cortex

Possible problem:

'temporal' and 'spectral' are confounded with 'rate of change'

'temporal' changes faster than 'spectral'



Zatorre & Belin, 2001

Asymmetric temporal sensitivity in human auditory cortices

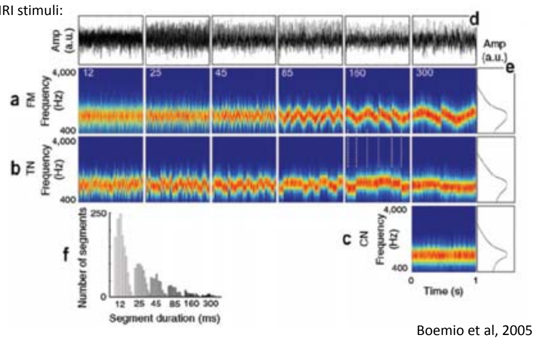
- **Hypothesis #2:**
  Human auditory cortex is functionally segregated such that differences exist in the temporal resolving power between the two hemispheres

Two time scales: 'fast' (25-50 ms)
'slow' (200-300 ms)

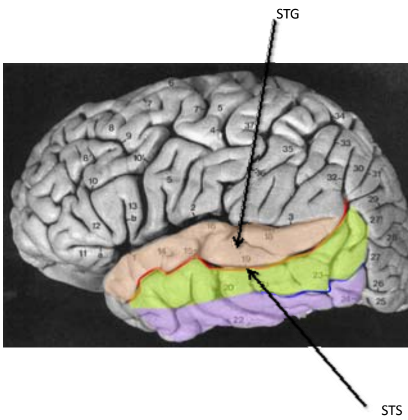
Boemio et al, 2005

Asymmetric temporal sensitivity in human auditory cortices

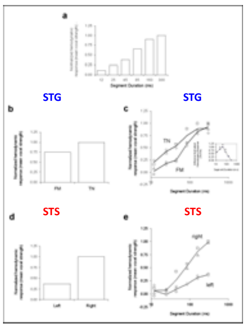
fMRI stimuli:



Boemio et al, 2005



Asymmetric temporal sensitivity in human auditory cortices



a. Effect of temporal structure

b. & c. STG shows sensitivity to signal type at short segment durations

d. & e. STS shows asymmetric sensitivity to segment duration

Boemio et al, 2005

Hemispheric specialization may result from:

- Domain Specificity: differential specialization for different inputs: ‘Speech centre’/’music centre’/ etc…
- Nature of stored representations that signals must interface with : Lexical info for speech/ prosodic info
- Differential specialization for different kinds of computations: Observed difference is due to difference in physical signal properties

Brain Asymmetry summary

+ homage to David Poeppel