

Common Paradigms

- Technology-driven paradigms
 - Neurological imaging
 - Structural imaging
 - Functional imaging
 - Neuro-electrical recording
 - Developmental paradigms
 - HASP
 - Conditioned headturn
 - HPP
 - Preferential looking

Common paradigms, continued

- Non-technological paradigms
 - Speech recognition
 - Speech elicitation
 - Corpus analysis
 - Signal-detection paradigms

Main types of imaging

- Structural brain imaging
- Functional imaging
- Neuro-electrical recording



Image: B. Kolb & I.Q. Whishaw, *Fundamentals of human neuropsychology*, 2nd ed.

Computerized Tomography (CT)

- 3-d X-ray of the brain.
- Looks at physical structures, rather than at function.
 - Useful for trying to localize damage in an individual who suffered some injury.
 - Cannot tell us a lot about what the brain is actually doing.

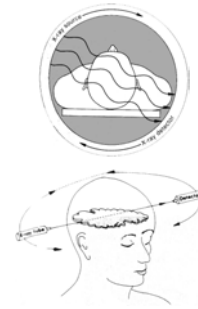


Image: B. Kolb & I.Q. Whishaw, *Fundamentals of human neuropsychology*, 2nd ed.

CT scans



Source: www.tac.tsukuba.ac.jp/aokig/brain.html



Source: Yousef Mohammad, M.D., MSc; The Ohio State University Medical Center

Magnetic Resonance Imaging (MRI)

- Like CT, but more detailed.
 - Better resolution allows examination of small areas,
 - Can distinguish different parts of the brain in a way that CT can't (white vs grey matter)
- Structural, not functional.

MRI & CT, healthy 33-year-old man

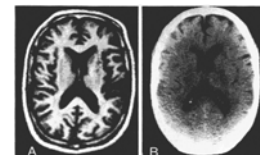
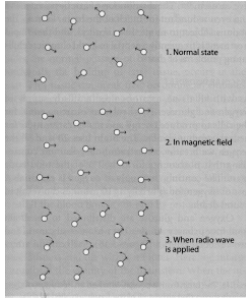


Image by G. Sedvall; Brain imaging. In H. I. Kaplan & B. J. Sadock, *Comprehensive textbook of psychiatry*, 5th ed.

Nuclear Physics of structural MRI



- Hydrogen atoms in tissue have a random orientation normally.
- They have a different density in gray versus white matter.
- When an external magnetic field is applied, the elements become aligned.
- The elements can then be perturbed systematically by the introduction of radio waves; they then emit energy, which the scanner can measure.

Image from H. Haarmann

Positron Emission Tomography (PET)

- Measures changes in blood flow to see what parts of the brain are working the hardest on any specific task.
 - Patient inhales a radioactive gas or is injected with radioactive water or sugar.
 - As the brain does more work, the blood flow increases to that portion of the brain.
 - This brings more oxygen & sugar, and thus more of the radioactive substance is there & can be measured.
- Very expensive; somewhat invasive.
- High spatial resolution (in theory, 2 mm; typically 5-10 mm), decent temporal resolution (30 sec.)

PET scan, cont.

Pet scans, normal adult

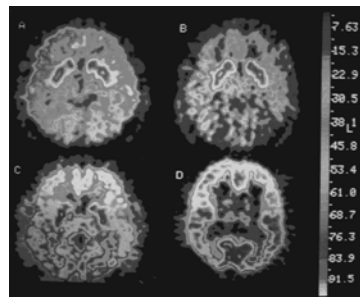


Image from Göran Sedvall, MD

Nuclear physics of PET scanning

- Radio-active tracer O^{15}
 - Half life of about 2 minutes
 - injected into blood flow
 - greatest concentration in active brain areas
 - consume oxygen and glucose in blood flow
 - location and concentration measurable
 - During decay positron emitted spontaneously
 - collision with electron
 - gamma ray released
 - picked up by gamma ray detector

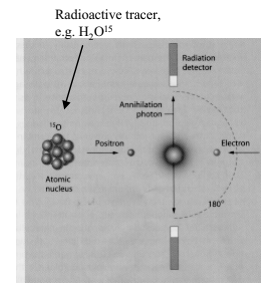
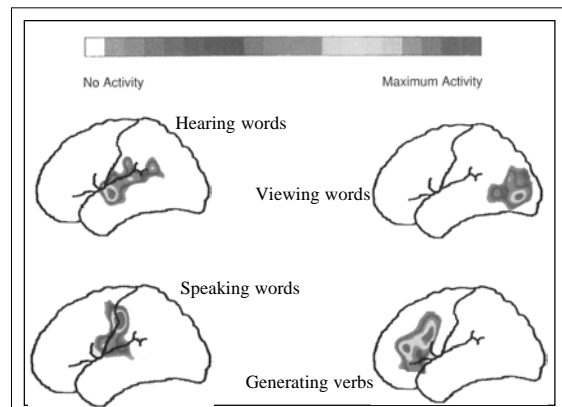


Image from H. Haarmann

Problems with PET

- Only 30 seconds temporal resolution.
 - PET can say that a particular region of the brain is more active than another over a fairly long task.
 - But most cognitive events are very quick, on the order of milliseconds, not seconds.
 - Requires tasks that can be done continuously or repeatedly.
 - Limited testing (due to decay of tracer)
- Requires assumptions about the hierarchy of tasks.
 - Requires subtracting out activation from other tasks.
 - This requires a model of what the task involves.

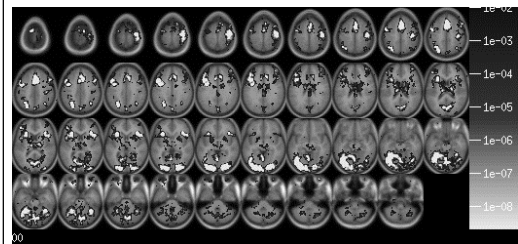


From Posner & Raichle, 1994

Functional Magnetic Resonance Imaging (fMRI)

- Examines function, like PET, but with more detail.
- Same scanner as MRI.
- Measures oxygen/blood use
 - sends electromagnetic currents into the brain
 - extent to which the atoms in the brain resonate will depend on the other atoms in the molecule
 - this allows you to look for specific types of molecules (such as iron, hydrogen or hemoglobin - normally present in blood stream)

fMRI pictures



fMRI, cont.

- Can combine fMRI with MRI to map areas of activation onto structural areas
- Voxel
 - Small brain area showing increased regional blood flow, in an experimental condition relative to a control condition
 - Size depends on spatial resolution
- Degree of brain activation
 - Number of voxels
 - Intensity of activation of a voxel

“The star is above the plus”
* | +

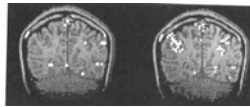


Image from H. Haarmann

Advantages & disadvantages

- Non-invasive (versus PET)
- Best spatial resolution of non-invasive methods
 - 1-3mm
- Shows all participating areas, not just critical ones
- Single-subject studies are possible
- Poor temporal resolution
- No differentiation between neuro-electrical excitation and inhibition
- Difficult to use with subjects and to obtain good measurements
 - Sensitivity to head motion
 - Contra indicators
 - Pregnancy, Obesity, Metal parts (pacemakers, shrapnel, glasses)
- Very expensive to acquire
- Very expensive to use & maintain ones
 - Personnel intensive: Neuro-radiologist, Nurse, Physicist, Statistician, Computer Scientist, Cognitive Psychologists, Research SLP

Event-Related Potential (ERP)

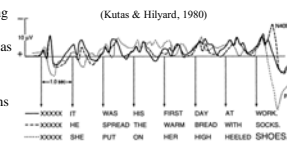
- Measures changes in electricity levels after an event.
 - Place electrodes on scalp, and measure electrical activity.
 - ERPs are EEG measures time-locked to presentation of a stimulus event.
 - Voltage fluctuations as a result of evoked neural activity.
- Examine particular responses (patterns of electrical change) that the brain gives to stimuli.



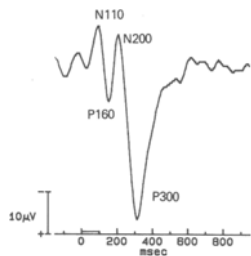
Image from H. Haarmann

Sampling of different ERP potentials

- Mismatch negativity (MMN)
 - preconscious, automatic processing of change or deviation in recurring sounds
 - Measure of auditory discrimination
- Auditory brainstem response
 - Response to sound in the VIIIth cranial nerve and brainstem
 - Used in assessing and screening hearing ability in infants
 - Measure of whether a sound was heard
- N400
 - Response to semantic violations
 - Central processing response



ERP, cont.



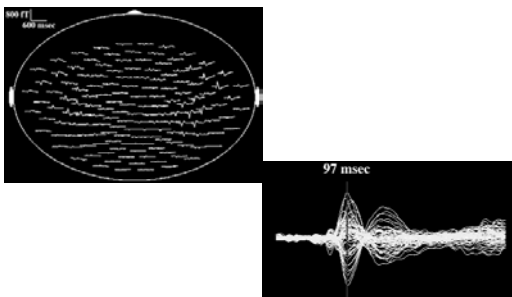
Evoked potential to a tone pip

- Difficult to pinpoint source of electric currents (poor spatial resolution)
- Excellent temporal resolution.
- Requires averaging over many trials
- Eye movements & blinks contaminate recording
- Can only detect large numbers of neurons working in concert
 - there is likely to be a lot of neural activity going on that is too slight to be detected.

Magnetoencephalography (MEG)

- Like ERP, but based on magnetic information
 - When a neuron fires, it produces a magnetic field.
- Skull does not distort magnetic fields, so better spatial localization than ERP.
- Like ERP, requires averaging over many trials
- Like ERP, can only detect large numbers of neurons working in concert

MEG results



From KIT-UMD MEG lab

Main infant testing paradigms

- High-amplitude sucking paradigm (HASP)
- Conditioned head-turn paradigm
- Headturn preference procedure (HPP)
- Preferential looking paradigm

HASP

- Also known as non-nutritive sucking paradigm
- Infants who take pacifiers tend to suck on them more when they are alert and interested in something, and less so when they're bored.
 - Researchers can thus measure sucking rate as an indication of interest level
- This procedure uses a pacifier attached to a computer that can detect changes in air-pressure, and thus can measure infants' sucking.



HASP at birth

Image from: F. Ramus & Laboratoire de Sciences Cognitives et Psycholinguistique

HASP, cont.

- One sound is presented until infants habituate to it.
- Then half the babies get a switch to a new sound, half continue to hear the old one.
- An increase in sucking on pacifier for the group with the switch suggests that infants can hear the difference between the sounds.

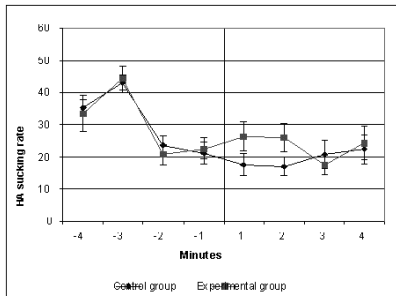


HASP at 2 months

Image from: F. Ramus & Laboratoire de Sciences Cognitives et Psycholinguistique

HASP, cont.

Sample data from a HASP study.



From: F. Ramus & Laboratoire de Sciences Cognitives et Psycholinguistique

Conditioned headturn paradigm

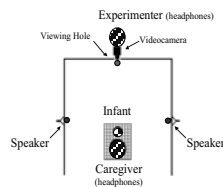


- Whenever there is a change in a stimulus, an electric toy is lit up and activated.
- Infants are thus trained to look at the toy whenever they hear a change.
- Then the target items are played, and an observer (who cannot hear the sounds) judges whether the infant heard a stimulus change by the infant's actions.

Image in *Psycholinguistics* (Gleason/Ratner) from J. Wilson/Woodfin Camp & Assoc.

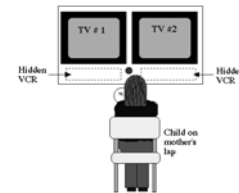
Head-turn preference procedure

- Infants sit on their caregiver's lap in a test booth.
- On each trial, one of the side lights flash, and when the infant orients to the light, sounds come from that speaker.
- The experimenter records how long the infant looks at the "source" of the sound (the flashing light) as a measure of the infant's preference.



Preferential looking

- Infants see two television screens simultaneously, showing different pictures.
- They hear a voice telling them to find a particular picture.



Preferential looking

- Here, infants might hear, "Where is clapping? Find clapping now."
- The infant's looking behavior is videotaped, and later coded. The measures are the amount or percentage of time watching the matching television.



Images from Roberta Golinkoff, University of Delaware & Penn Developmental Lab

Speech recognition

- Measured as
 - Percent correct
 - Signal to noise ratio at which listener achieves 50% correct
- Used to compare/examine:
 - Performance among individuals
 - Individuals with different hearing aids
 - Individuals with cochlear implants
 - Normal-hearing individuals of different ages
 - Changes in performance over time
 - Performance on different types of items
 - Frequent words vs. rare words
 - Highly predictable words vs. unpredictable words
 - Influence of different types of background noise

Speech elicitation

- Classic speech elicitation study by Berko Gleason:

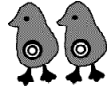
– This is a wug.



– Now there is another one.

– There are two of them.

– There are two _____



Speech elicitation, cont.

- The wug test was first used to examine children's productive knowledge of their language's morphology.
- Since then, speech elicitation and imitation have been used to examine many different types of grammatical knowledge, both in typically-developing and clinical populations.

Corpora analysis

- Examining large databases of speech production (either acoustic databases, or transcripts)
- Has been used to examine
 - Development of children's speech production
 - Comparisons between speech from typically-developing and clinical populations
 - Adults' speech to children
 - Speech production differences between adults from different dialects
 - Gender differences in speech production

Sampling of major corpora

- TIMIT
 - Corpus of read speech of 630 speakers from 8 major American English dialects
 - Designed for use in acoustic-phonetic studies and for testing automatic speech recognition systems
- CELEX
 - Multilanguage lexical database
 - For each word, includes orthography, phonology, morphology, syntactic class, and word frequency information

Sampling of major corpora, cont.

- Linguistic data consortium
 - Provides access to a number of large corpora to its members, including:
 - Switchboard-2
 - Audio from >2700 telephone conversations, with 640 participants (approx. 220 hours speech)
 - RST Discourse Treebank
 - 385 Wall Street Journal articles annotated for discourse structure

Sampling of major corpora, cont.

- CHILDES
 - Large database of thousands of transcripts from hundreds of children and caregivers, from a range of ages and languages
 - Includes both typically-developing and clinical populations, and includes both monolinguals and bilinguals
 - Also provides tools for computerized analysis of transcripts

Theory of signal detection

- TSD provides a researcher with a means of evaluating independently
 - the ability of an organism to distinguish between classes of events (its sensitivity to them)
 - the motivational or other response effects (biases).
- Basic idea: there is no “absolute” threshold
 - our threshold in TSD depends on our ability to distinguish a stimulus from external and internal noise, while accounting for the motivational properties of the subject.

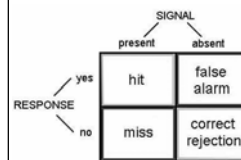
Assumptions of TSD

- There is always noise in the system.
 - Examples: outside noises, bodily noises (stomach growling/gurgling), biological noises (heart beating, air moving in/out lungs), even random firings of neurons in the auditory system
- There is always perceptual variability.
 - Most neurons have random firing in absence of stimulation
 - The presence of a stimulus is signaled by an increase in firing above baseline.
- All stimulation occurs along a single continuum.
 - The neural firings created by noise are no different than those created by the signal; they are qualitatively the same.

Signal detection, cont.

- Thus, the listener must decide whether the activation in the system arises from the signal and the noise, or just from the noise.
 - On average, neural firing will be higher when there is a stimulus.
 - But, on any given trial, if the stimulus is very faint, we can't be absolutely sure whether it was present or not.
 - If the signal is loud enough, the uncertainty becomes vanishingly small; but for faint signals, the listener must make a guess on the basis of the degree of sensory activation present.

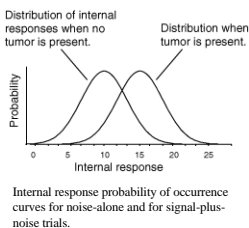
Different possibilities



- Imagine a radiologist is examining a CT scan, looking for evidence of a tumor.
- Either there is a tumor or not.
- Either the doctor sees a tumor or does not.
- Four possible outcomes:

Image from David Heeger, Stanford University, white.stanford.edu/~heeger/sdt/sdt.html

Signal vs. signal + noise



- The signal + noise curve is always at higher point than the noise curve, but they overlap.

Image from David Heeger, Stanford University, white.stanford.edu/~heeger/sdt/sdt.html

Signal detection, cont.

- sensitivity (d')
- Listeners adopt a criterion value and respond that a signal is present whenever internal activation surpasses criterion.
- We can estimate the criterion by looking at responses -- *beta*.

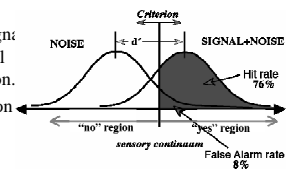
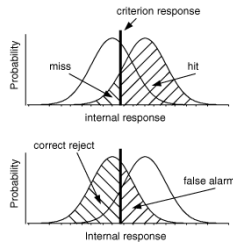


Image from www.cis.rut.edu/people/faculty/montag/vandplite/pages/chap_5/ch5p1.html

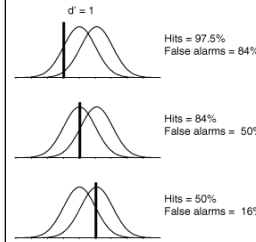
The role of the criterion



- The criterion line divides the graph into four sections that correspond to: hits, misses, false alarms, and correct rejections.
- If the internal response is greater than the criterion, the doctor responds "yes".

Image from David Heeger, Stanford University, white.stanford.edu/~heeger/sdt/sdt.html

Choice of criterion



- With a low criterion (*top*)
 - Responds "yes" to almost everything.
 - Will never miss a tumor when it is present
 - Thus have a very high hit rate (or low auditory threshold).
 - But, large number of false alarms
- With a high criterion (*bottom*)
 - respond "no" to almost everything.
 - rarely make a false alarm, but also miss many real tumors.

Image from David Heeger, Stanford University, white.stanford.edu/~heeger/sdt/sdt.html

Choice of criterion, cont.

- There are **trade-offs**.
- It is inevitable that some mistakes will be made.
- Criterion will be affected by factors such as:
 - differential likelihood of occurrence
 - cost/value relationships
 - Personal tendencies

Summary of SDT

- Enables us to separate changes in performance related to sensory factors from those related to motivations
 - requires measuring proportion of false alarms as well as hits.
- Tells us
 - d' or sensitivity
 - determined strictly by separation between N & SN distributions and by the ability of the auditory system to make use of this
 - beta, a measure of criterion for responding
- Classical measures of determining thresholds can not separate these, because they only look at hits
 - If the subject responded more than 50% of the time to the stimulus when it was present, then the stimulus was above threshold -- this ignores false alarms.

ROC curves

- ROC curves show this info all at once
 - receiver-operating characteristic curves
 - aka relative operating characteristic curves
- Plots proportion of hits vs. false alarms for each criterion.
- Sensitivity

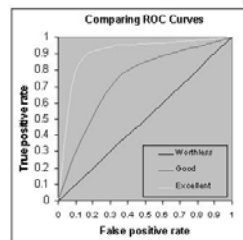


Image from gin.ummc.edu/dxtests/roc3.htm

ROC curves

- Response criteria are shown by the point along the curve
 - a strict criterion results in a point to the right
 - a lax criterion will move towards the left.
- Any point along the curve represents a measure of the net effect of various preferences that influence the response.

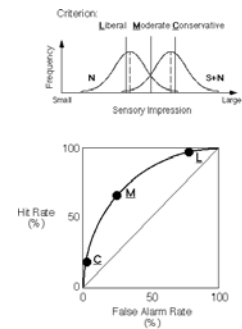


Image from Michael DZmura www.cvr.uci.edu/psych09b/lectures/lec2notes.html

More ROC curves

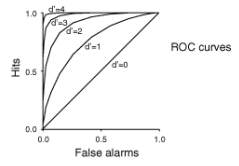
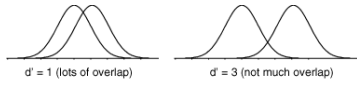


Image from David Heeger, Stanford University, white.stanford.edu/~heeger/sdt/sdt.html