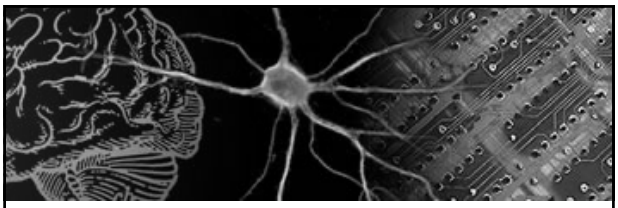


PSYC305

Applied Cognition & Neuroscience

Mātai hinengaro whaipainga

Lecture 11: Methods used in Neuroscience

Topics:

© Assoc Prof. John Perrone
Psychology Dept.
The University of Waikato

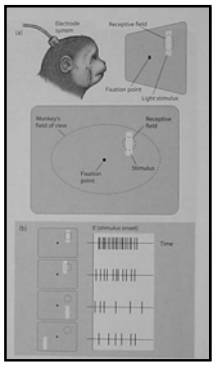
1. Methods of Cognitive Neuroscience
2. Modern Psychophysical Methods

Figures from:
Cognitive Neuroscience: The biology of the mind
by Michael S. Gazzaniga, Richard B. Ivry & George R. Mangun.
(2nd Ed. 2002, WW. Norton & Co. NY).

1. Experimental Techniques Used with Animals.

(a). Single-cell recording:
A thin electrode is inserted into an animal's brain. If the electrode is in the vicinity of a neuronal membrane, electrical changes can be measured.

Most recording is done _____ (electrode) is outside of the neuron. It is very hard to record intracellularly.



Single cell recording enabled researchers to describe response characteristics of individual elements.

They no longer had to describe the nervous system just in terms of functional regions.

It is one of the most important technological advances in neurophysiology.

However there are many issues surrounding the ethics and practice of animal research (see p 108, Gazzaniga et al.)

1. Experimental Techniques Used with Animals (continued).

(b). Lesions
A long-standing method of the neurophysiologist has been to study how behaviour is altered by selectively removing one or more subcortical nuclei or distinct cortical areas.

However one cannot be confident that the effect of a lesion eliminates only the contribution of a single structure.

Newer methods allow for more control over the extent of the lesion. E.g., Kainic acid, reversible lesions (cooling).

1. Experimental Techniques Used with Animals (continued).

(c).Genetic manipulations
Many aspects of cognitive functioning are heritable.

- The genome sequence for many species have been mapped out (including humans).

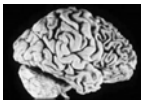
- The reproductive propensities of the fruit fly and the mouse allow many generations to be spawned over a relatively short period of time.

- Using 'knock-out' procedures (manipulating specific genes so they are no longer present or expressed), researchers have been able to create mouse strains that lack single types of postsynaptic receptors in specific brain regions (like lesion method but at a microscopic level).

2. Neurology

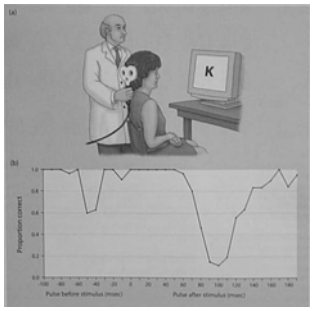
Human pathology has long provided key insights into the relation between brain and behaviour.
Observers of neurological dysfunction have contributed much to our understanding of cognition – long before the advent of cognitive neuroscience.

Discoveries concerning the contralateral wiring of sensory and motor systems were made by physicians in ancient societies attending to warriors with open head injuries.



A human brain showing frontotemporal lobar degeneration causing frontotemporal dementia.

Virtual lesions

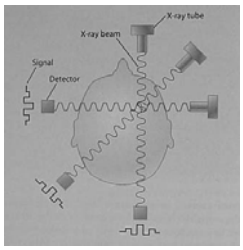


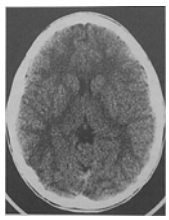
Transcranial magnetic stimulation (TMS)

Structural imaging of Neurological damage.

Tools that help neurologists visual brain structure (and are now used by neuroscientists doing research into sensory areas such as vision).

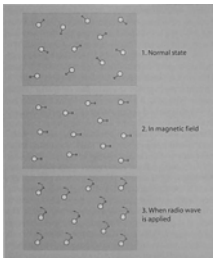
(a) Computed tomography (CT or CAT scanning)

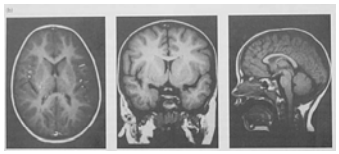




CT based on the same principles as x-rays. An x-ray is projected through the head and a 3-D image based on tissue density is obtained.

(b) Magnetic resonance imaging (MRI)



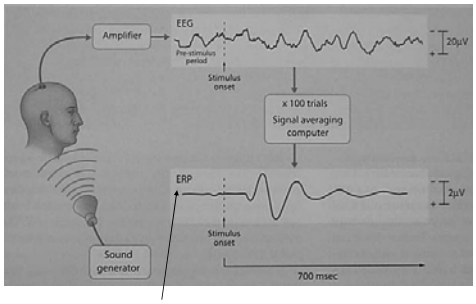


Many organic elements such as hydrogen are magnetic. When an external magnetic field is applied, the elements become aligned and since the density of hydrogen atoms is different in white and gray matter we can see these areas in the brain.

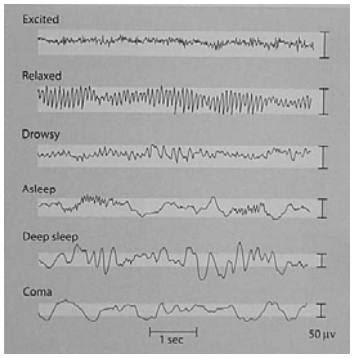
(c) Electroencephalography (EEG).

Neural activity is an electrochemical process.
Although the electrical potential produced by a single neuron is minute, when large populations of neurons are active together, they produce electrical potentials large enough to be measured by electrodes placed on the scalp.

The record of the signals is referred to as the electroencephalogram.



Event Related Potential

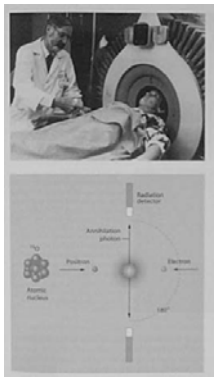


EEG profiles obtained during various states of consciousness.

(d) Metabolic signals

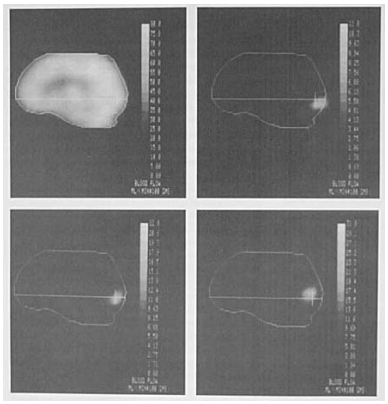
It is possible to record metabolic changes correlated with neural activity (rather than measuring the electrical activity directly).

Two relatively new and important methodological advances for cognitive neuroscience are based on this idea.



<u>Positron emission tomography (_____) scanning.</u>

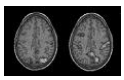
Water labeled with radioactive oxygen is injected into the subject. Regions that are most active in the brain will increase their demand for _____ and can be detected (see next slide).

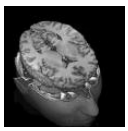


Measurement of cerebral blood flow using PET.
A retinotopic map can be identified with central vision identified separately from peripheral vision.

Functional MRI (fMRI)



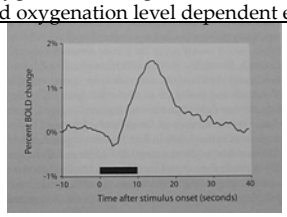




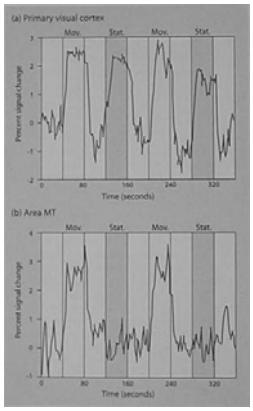
Functional MRI (fMRI)

Exploits the fact that that local blood flow increases in active parts of the brain. Also uses radio waves and magnetic field (like MRI) but looks at the magnetic properties of hemoglobin (which carries oxygen in the bloodstream).

fMRI detectors measure the ratio of oxygenated to deoxygenated hemoglobin. This ratio is called the blood oxygenation level dependent effect (BOLD).

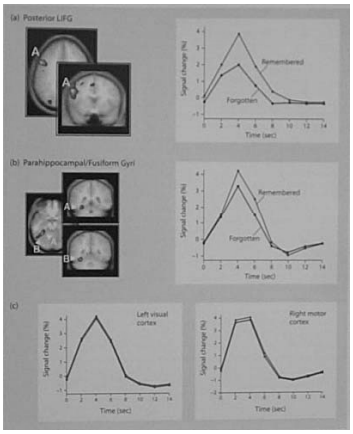


BOLD signal from visual cortex of cat measured with a 4.7 tesla scanner.



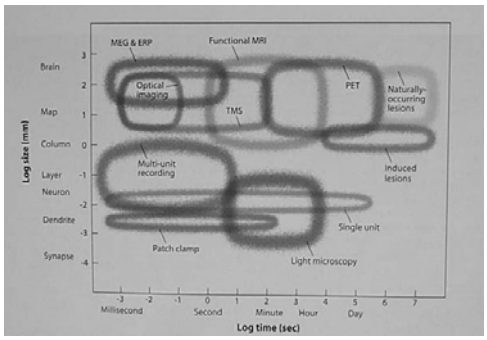
fMRI has good spatial resolution.

Figure shows differences between V1 and MT motion processing.



fMRI is becoming very popular and common in wide range of research areas.

Using fMRI to identify areas associated with failures during memory encoding.

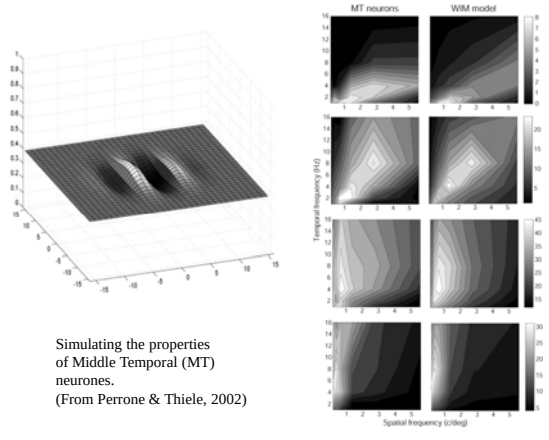


Spatial and temporal resolution of the prominent methods used in cognitive neuroscience.

3. Computer Modelling.

Cognitive scientists use computers to simulate cognitive and sensory processes.

Simulation: To imitate, to reproduce behaviour in an alternative medium.



Simulating the properties of Middle Temporal (MT) neurones.
(From Perrone & Thiele, 2002)

Computer Modeling (continued).

- Models are explicit. In creating a simulation the researcher has to be completely explicit; the way the computer represents and processes information must be totally specified.
- Models lead to testable predictions. Models can generate novel predictions that can be tested with real brains.
- Limitations with computer models. Usually include radical simplifications in how the nervous system is modeled.

Lecture 11 Topics:

1. Methods of Cognitive Neuroscience
2. Modern Psychophysical Methods

- Psychophysics (Classical Methods review)
- Extensions of the classical methods
  - -Two Alternative Forced Choice procedure
  - -Staircase Methods.

In trying to understand behaviour and the way the brain works we could ask questions such as:

- How bright does a light have to be before we can see it?
- What sounds can we hear?
- What colours can a horse see?
- Can dogs hear some sounds better than we can?
- etc., etc.

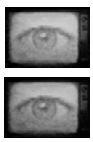
Methods used to answer these questions = Psychophysical methods.

Psychophysical methods are used to study perceptual abilities in humans, infants and a wide range of animals.




Psychophysics is also used in a large number of applied situations:

e.g.,



Assessing the quality of TV/computer displays

Discrimination of different smells (e.g., perfumes)

Assessing the visibility properties of important signs and displays.

Psychophysics

- *Psychophysics* is the study of the relationship between the physical stimulus and the observer's perceptual response to that stimulus.

- History:

Fechner (1860), a German physicist and philosopher, published book: 'Elements of Psychophysics'.

He tried to work out in a scientific manner the relations between mind and body, or between the psychical and physical worlds.

To solve this problem he had to develop suitable methods of experimentation.

Measuring Thresholds

- *Absolute threshold* is the smallest amount of energy needed to detect a stimulus
- *Difference threshold*. The minimum difference between two stimuli that can be detected.

Classical psychophysical methods:

1. **Method of limits**
2. **Method of constant stimuli**
3. **Method of adjustment**

Covered in PSYC103, PSYC226
We will do a quick review, but will concentrate on problems that arise with these methodologies.

Note: Many of these classical psychophysical methods have been replaced by modern versions (see later part of lecture).

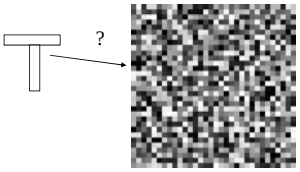
However the basic principles remain the same and your understanding of the new versions will benefit from knowledge of the techniques they have evolved from.

Psychophysical Methods

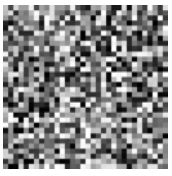
(1) Method of Limits

The experimenter presents stimuli in either ascending or descending order. The observer responds 'yes' if they can see the stimulus or 'no' if they cannot.

Can you see the letter 'T' in this picture?

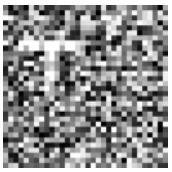


Intensity = 1

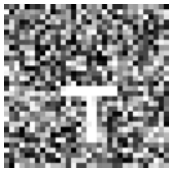


Intensity = 2

Intensity = 3



Intensity = 4



Intensity = 5

(1) Method of Limits

The experimenter presents stimuli in either ascending or descending order. The observer responds 'yes' if they can see the stimulus or 'no' if they cannot.

A series of stimuli are presented to the observer until they reach a limit or point of change in their judgments.

Need to control for various effects:

• Error of habituation. Observer becomes accustomed to making the same response and goes beyond the point where a reversal of sensation occurs.

Error of habituation

Trial Number	Response
1	No
2	No
3	No
4	No
5	No
6	No
7	No
8	?

Not sure so I will say 'No' again.

letter present or not?

(1) Method of Limits

The experimenter presents stimuli in either ascending or descending order. The observer responds 'yes' if they can see the stimulus or 'no' if they cannot.

A series of stimuli are presented to the observer until they reach a limit or point of change in their judgments.

Need to control for various effects:

• Error of habituation. Observer becomes accustomed to making the same response and goes beyond the point where a reversal of sensation occurs.

•Error of anticipation. Observer is aware that sooner or later the direction of sensation must change and they anticipate the change.

Series 1

Intensity	Response
1	No
2	No
3	No
4	Yes

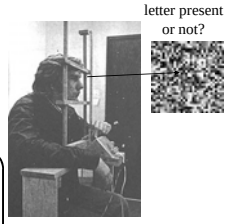
Series 2

Intensity	Response
1	No
2	No
3	No
4	Yes

Series 3

Intensity	Response
1	No
2	No
3	No
4	?

Error of anticipation



letter present or not?

Hmm, 3 trials have gone by. Must be time to say 'Yes'

(1) Method of Limits

The experimenter presents stimuli in either ascending or descending order. The observer responds 'yes' if they can see the stimulus or 'no' if they cannot.

A series of stimuli are presented to the observer until they reach a limit or point of change in their judgments.

Need to control for various effects:

- Error of habituation. Observer becomes accustomed to making the same response and goes beyond the point where a reversal of sensation occurs.
- Error of anticipation. Observer is aware that sooner or later the direction of sensation must change and they anticipate the change.

The Methods of Limits uses ascending and descending series to cancel out these effects.

'T' Detection Experiment
Method Of Limits

	1 ↑	2 ↓	3 ↑	4 ↓	Series
Intensity					
5		Y		Y	
4		Y		Y	
3	Y	N		N	
2	N		Y		
1	N		N		
0	N		N		
Crossover Values	2.5	3.5	1.5	3.5	

Threshold = Mean of crossover values = 2.75

Y = Yes response
N = No response
↑ = ascending series
↓ = descending series

An additional technique that can be used to prevent errors of anticipation is to randomize the starting point of each series.

'T' Detection Experiment
Method Of Limits (randomized starting points)

	1 ↑	2 ↓	3 ↑	4 ↓	Series
Intensity					
5		Y			
4		Y		Y	
3	Y	N		N	
2	N		Y		
1	N		N		
0	N				

First ascending series starts at intensity 0

2nd ascending series starts at intensity 1

Y = Yes response
N = No response
↑ = ascending series
↓ = descending series

Big problem with the Method of Limits is that the observer knows that succeeding stimuli will be getting weaker or stronger.

I can't see it yet, but eventually it will show up

or

I can see it now but soon it is going to disappear

letter present or not?

We can overcome this problem with …

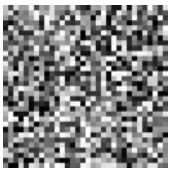
Psychophysical Methods

(2) Method of Constant Stimuli

Presents a set of stimuli (ranging from clearly perceptible to clearly imperceptible) in a prearranged irregular order.
i.e., fixed (constant) set of stimuli used.

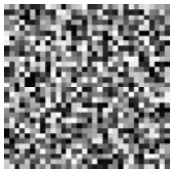
Main difference from Method of Limits is that the stimuli are presented, not in serial order, but in a random fashion.

Trial 1



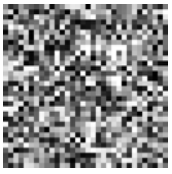
Intensity = 2
Presentation 1

Trial 2



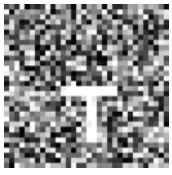
Intensity = 1
Presentation 1

Trail 3



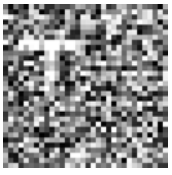
Intensity = 3
Presentation 1

Trial 4



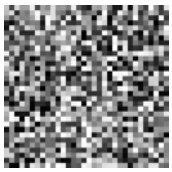
Intensity = 5
Presentation 1

Trial 5



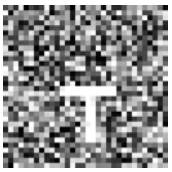
Intensity = 4
Presentation 1

Trial 6



Intensity = 2
Presentation 2

Trial 7



Intensity = 5
Presentation 2

This random sequence is continued until each intensity level is presented a fixed number of times (e.g., 10 presentations).

Psychophysical Methods

(2) Method of Constant Stimuli

Presents a set of stimuli (ranging from clearly perceptible to clearly imperceptible) in a prearranged irregular order. i.e., fixed (constant) set of stimuli used.

Main difference from Method of Limits is that the stimuli are presented, not in serial order, but in a random fashion.

Usually 5 to 9 stimuli are used, which bracket the likely value of the threshold being determined. Each stimuli is presented a relatively large number of times to the observer.

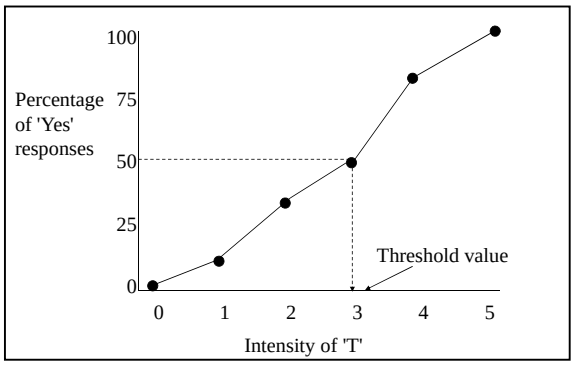
The absolute threshold is the stimulus value that elicits the appropriate sensation on 50% of its presentations to the observer.

Made up data for Method of Constant Stimuli ('T' detection).

Stimulus level (intensity of T)	Number of times observer said 'yes' (out of 10 trials)	Percentage of the number of presentations (10)
0	0	0
1	1	10
2	3	30
→ 3	5	50
4	8	80
5	10	100

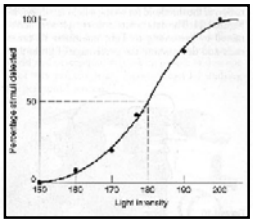
Threshold = 3.0
However data are usually plotted on a graph (e.g. see next slide) and the threshold found from where the 50% point intersects the curve.

Method of Constant Stimuli data for 'T' detection experiment



These plots have a special name …….

Psychometric functions



Comparing the Method of Limits and the Method of Constant Stimuli.

- Method of Limits does not yield as much information about the threshold process as the Method of Constant Stimuli.
  (e.g., the slope of the psychometric function tells us how precise the observers were in their judgments).
- Method of Constant Stimuli has one important disadvantage. Every stimulus must be presented a large number of times. Can get tedious for the observer, especially for stimuli way above or below threshold.

For fast (but often less accurate) estimations of the threshold you can sometimes use…

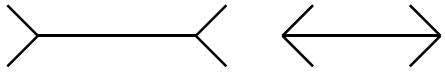
Psychophysical Methods

(3) Method of Adjustment

The observer is presented with a standard stimulus and a variable stimulus. The variable stimulus is adjusted by the observer until the standard and variable stimulus are judged to be equal.

Most commonly used in perceptual experiments involving illusions (e.g., Müller-Lyer illusion used in 0518.103 expts).

variable stimulus standard stimulus

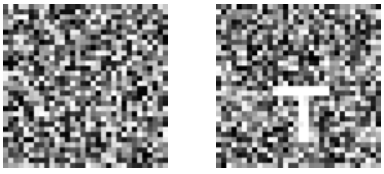


Extensions of the classical methods

(1) Two-alternative-Forced Choice (2AFC) procedure

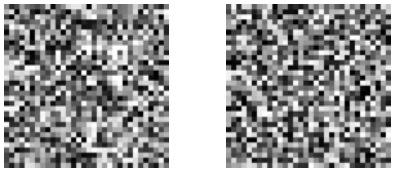
•The observer is presented with two alternatives and must pick one, even if the stimulus was not detected.

e.g., Which side (left or right) contains the letter 'T'?

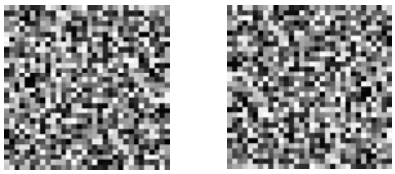


The stimulus appears on the left or right on a random basis (determined by the experimenter with the help of a computer). On 50% of the trials it appears on the right and 50% on the left.

e.g., Which side (left or right) contains the letter 'T'?



e.g., Which side (left or right) contains the letter 'T'?



You must answer even if you are not sure!

Extensions of the classical methods

(1) Two-Alternative-Forced Choice (2AFC) procedure

•The observer is presented with two alternatives and must pick one, even if the stimulus was not detected.

•It is less subjective than the 'Yes-No' response method, i.e., it is an objective method.

Extensions of the classical methods

(1) Two-alternative-Forced Choice (2AFC) procedure

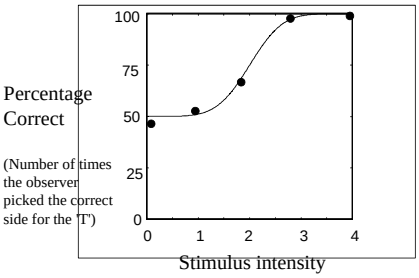
•The observer is presented with two alternatives and must pick one, even if the stimulus was not detected.

•It is less subjective than the 'Yes-No' response method, i.e., it is an objective method.

• It removes the 'criterion' problem present in Yes-No methods, i.e., Observer may refuse to say 'Yes' unless stimulus is very obvious or say 'Yes' at the slightest hint of the stimulus (or even change their criterion during the experiment!).

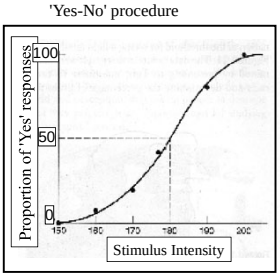
NOTE: Signal Detection Theory specifically looks at observer biases and criterion effects.

• The psychometric curve from a 2AFC experiment goes from 50% to 100%.

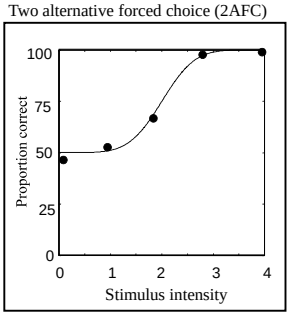


Why does the curve go from 0% to 100% for a 'Yes-No' experiment but from 50% to 100% for a 2AFC experiment?

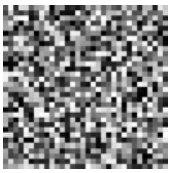
'Yes-No' procedure



Two alternative forced choice (2AFC)

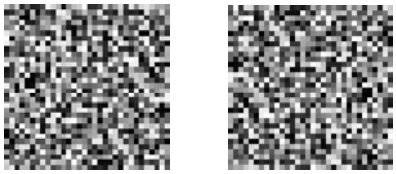


'Yes-No' Procedure



If you cannot see the 'T', how many times out of 10 trials would you respond 'Yes'?

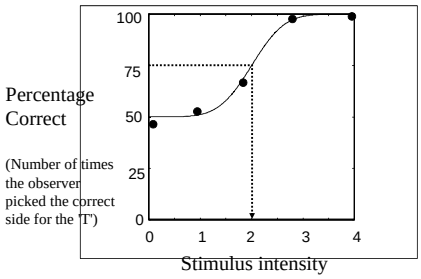
2AFC experiment



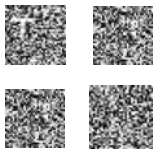
If you cannot see the 'T', how many times out of 10 trials do you expect to pick the correct side?

• The psychometric curve from a 2AFC experiment goes from 50% to 100%.

The threshold is given by the 75% point.



Note: It is also possible to have three alternative forced choice methods or four alternative forced choice methods etc.



4AFC

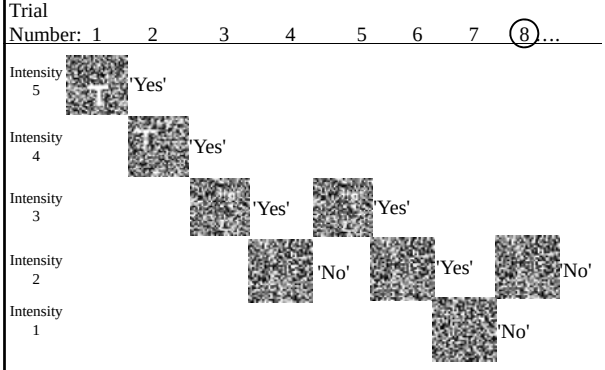
Which quadrant contains the 'T'?

Extensions of the classical methods

(2) The staircase-method

•Derived from the Method of Limits (see earlier slides)

•Basic procedure: If during a descending series, the observer says 'Yes' (I see it/hear it etc.), the stimulus level is made less intense on the next trial. If the observer says 'No', the stimulus is made more intense.



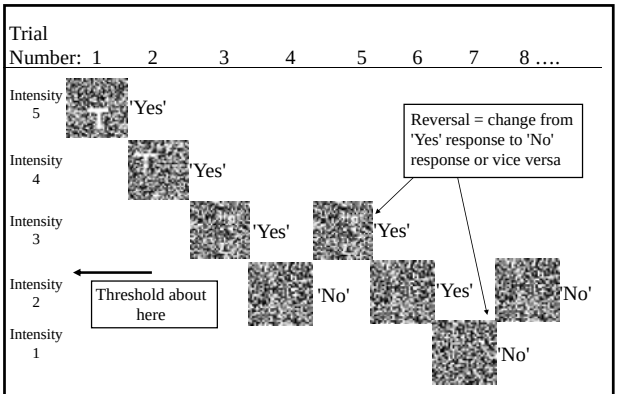
Extensions of the classical methods

(2) The staircase-method

•Derived from the Method of Limits (see earlier slides)

•Basic procedure: If during a descending series, the observer says 'Yes' (I see it/hear it etc.), the stimulus level is made less intense on the next trial. If the observer says 'No', the stimulus is made more intense.
•The stimulus level goes up and down (like a staircase).

•After a number of trials the stimulus level tends to reach a limit and hovers around the threshold point.



There are a number of methods for finding the threshold from staircase procedure data (e.g, Find the mean of the 'reversals').

Extensions of the classical methods

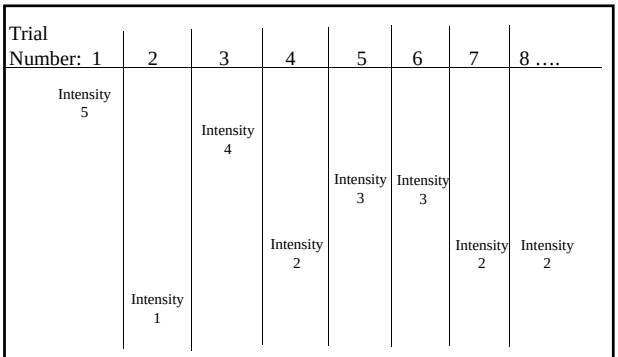
(2) The staircase-method (continued)

Advantages over other methods:
The staircase-method is extremely efficient. It requires much fewer presentations of stimuli (most are near the threshold level).

Disadvantage of basic staircase-method:

The observers can become aware of the stimuli order.

However this can be overcome by using Double-staircase methods



Double-staircase method
Descending and ascending series running in sequence.

Extensions of the classical methods

(2) The staircase-method (continued)

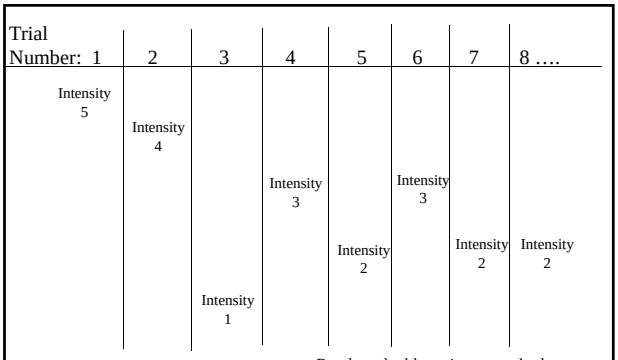
Advantages over other methods:
The staircase-method is extremely efficient. It requires much fewer presentations of stimuli (most are near the threshold level).

Disadvantage of basic staircase-method:

The observers can become aware of the stimuli order.

However this can be overcome by using Double-staircase methods

or even better: Random-double-staircase methods.



The computer selects on a random basis, which staircase to present on which trial.

Random-double-staircase method
Descending and ascending series running in a random sequence.

The Random-double-staircase method is an efficient and a very objective method for establishing thresholds (hard to cheat!)

Even the experimenter can act as an observer if a computer is making the random trial assignments.