

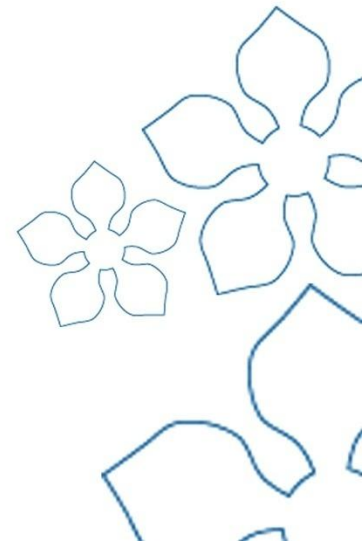
The Brain, Biology and Cognition (BBC)

The Research Methods of Biopsychology and
Cognitive Neuroscience

Dr Kate Williams



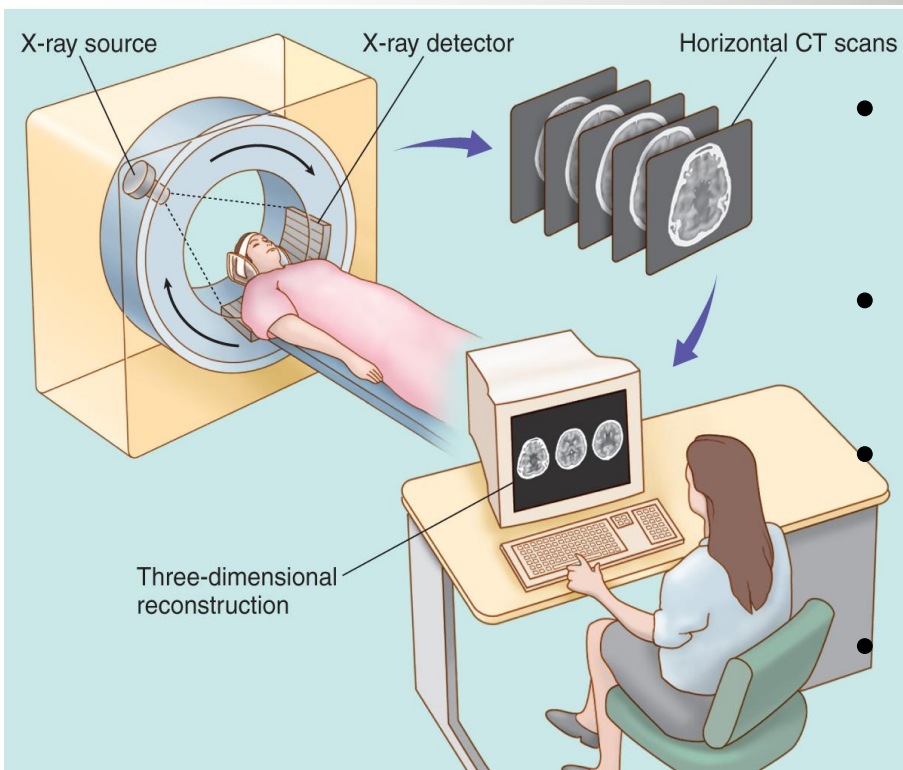
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Methods of Visualising the Living Human Brain



- **X-Ray computed tomography (CT)**
- Head in cylinder: projects x-ray beam to detector.
- Tube and detector rotate to take pictures.



- Pics combine on PC to create scan of horizontal section of brain.
- Head moved to next level
- Process repeated until 8/9 horizontal brain sections obtained
- All combine to create 3D image.

Methods of Visualising the Living Human Brain



Magnetic resonance imaging (MRI)

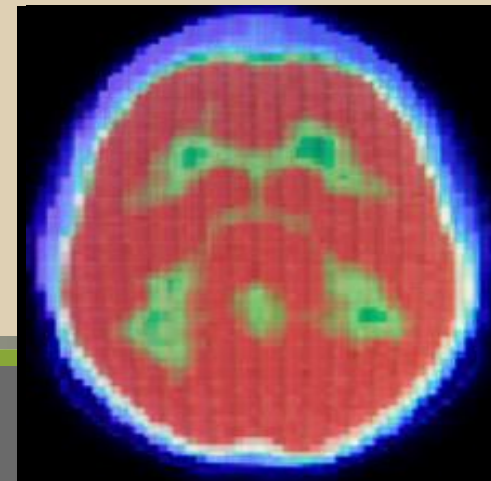
- Radio waves excite atoms in brain.
- Produces magnetic changes picked up by large round magnet
- High resolution digital image from waves that atoms emit when activated by radio-frequency waves in a magnetic field.
- Clearer than CT & high spatial resolution
- Conducted from many angles
- Shows structure of brain but not function.
- Enable production of structural brain images
- Technological development means we can now produce functional brain images - showing brain activity.....

Methods of Visualising the Living Human Brain



Positron emission tomography (PET)

- Inject radioactive glucose (taken up by active cells)
- Radioactive particles emit positrons detected by scanner.
- Area of brain high in activity produce more gamma rays (take up more glucose).
- Transformed to colour coded 3D image - regions of increased blood flow.
- Good spatial resolution but not good temporal resolution.
- Indirect measure of neural activity.
- Not brain image: only coloured map of radioactivity in tiny cubic voxel (pixelated area) from scan, superimposed on image of brain.



Methods of Visualising and Stimulating the Living Human Brain



Functional MRI (fMRI)

- Brain structure *and* activity.
- Strong magnetic field
- Two properties of oxygenated blood allow it to work.
 1. Active areas take up more oxygenated blood than needed.
 2. Oxygenated blood has magnetic properties through iron.
- Structure imaged using waves emitted by hydrogen ions
- Function imaged using signal created from interaction between oxygen and iron in blood
 - Blood Oxygenated Level Dependent (BOLD) signal
- Good spatial and temporal resolution
- 3D images of activity over whole brain.
- But indirect measure of neural activity through BOLD.
- Also, 2-3 seconds to create image too slow to capture neural responses e.g., action potentials in milliseconds

Methods of investigating the Living Human Brain



Magnetoencephalography (MEG)

- Neural activity via changes in magnetic fields on surface of scalp produced by underlying patterns of neural activity
- Fast temporal resolution

Transcranial magnetic stimulation (TMS)

- NOT a measure of neural activity
- Figure of 8 coil runs pulse of current.
- Produces brief, strong magnetic field that alters neural activity
 - Activate or “deactivate” brain structures
 - Observe changes in behavior

Recording Human Psychophysiological Activity



- **Scalp electroencephalography (EEG)**
 - Measure gross electrical activity of the brain
 - Including action potentials & postsynaptic potentials.
 - Uses electrodes attached to scalp (individually or in cap)
- **Many techniques of EEG**
 - Wave form assessment (e.g., alpha waves)
 - Event-related potentials (ERPs)
 - Combination of EEG with MRI

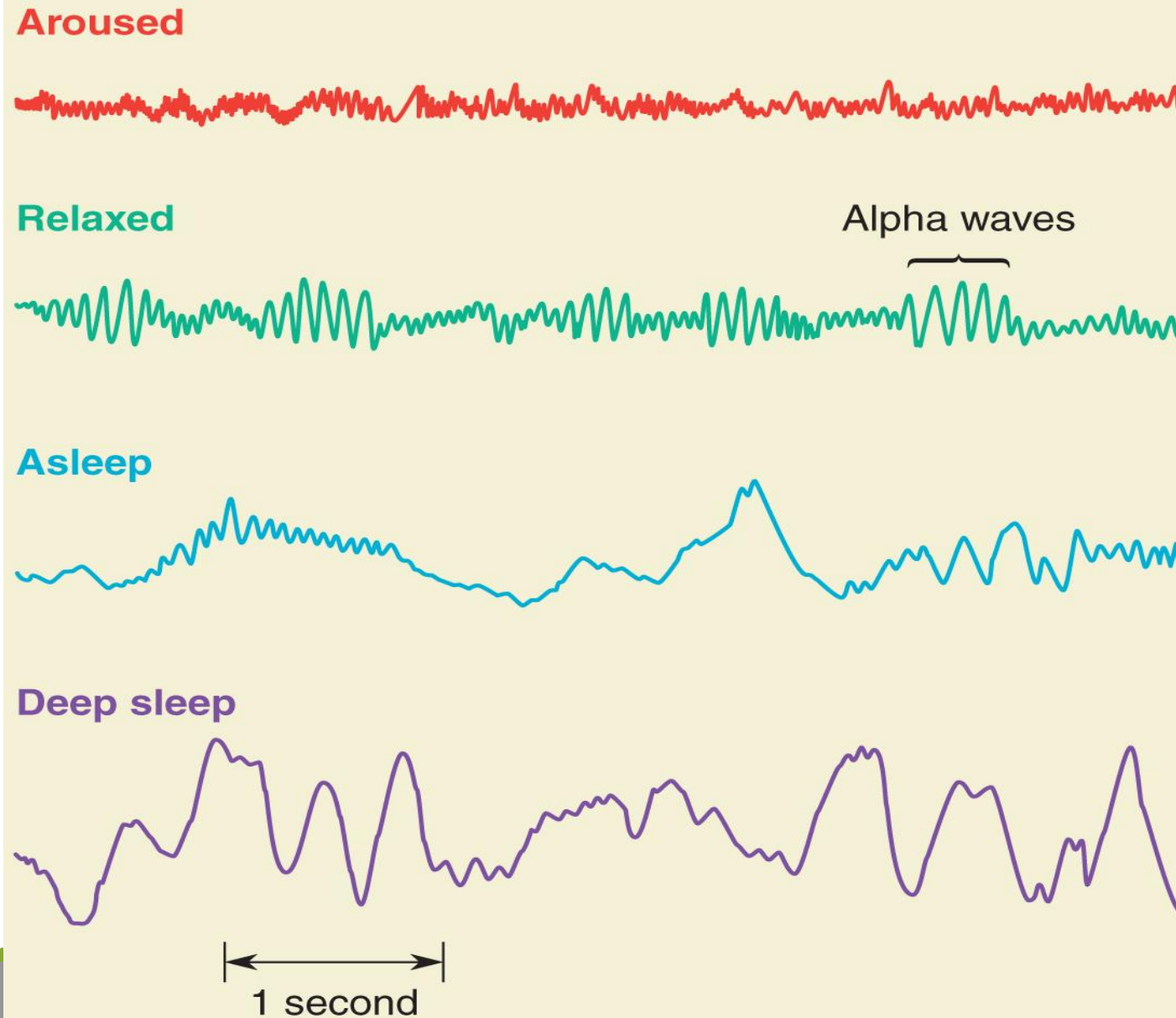


Recording Human Psychophysiological Activity



EEG waves associated with states of consciousness

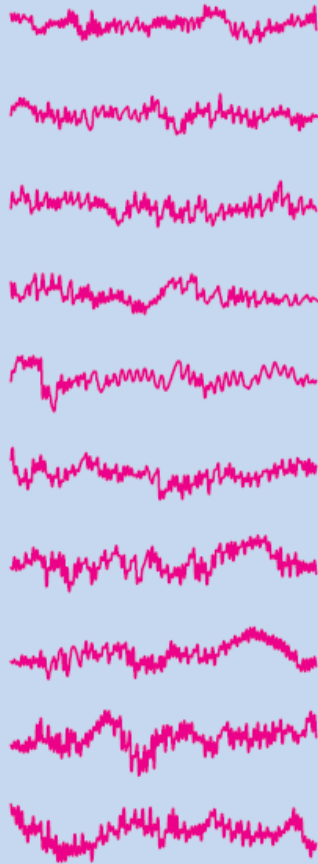
Some typical EEGs and their psychological correlates.



Recording Human Psychophysiological Activity



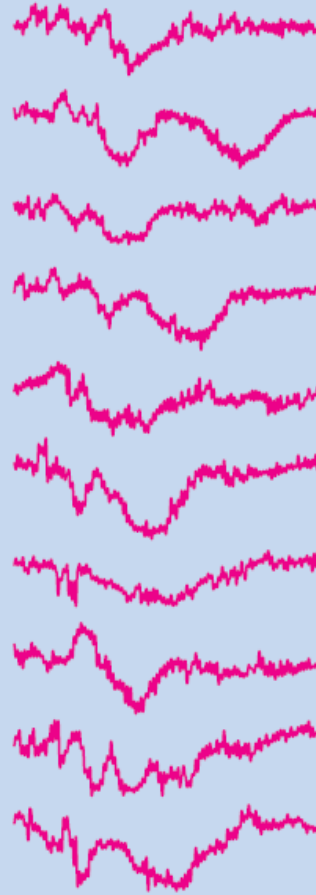
1-second segments
of background EEG



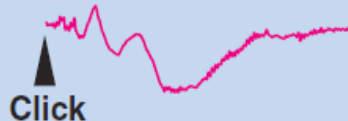
Average
background
EEG



1-second segments
of EEG with evoked
potential



Average
evoked
potential

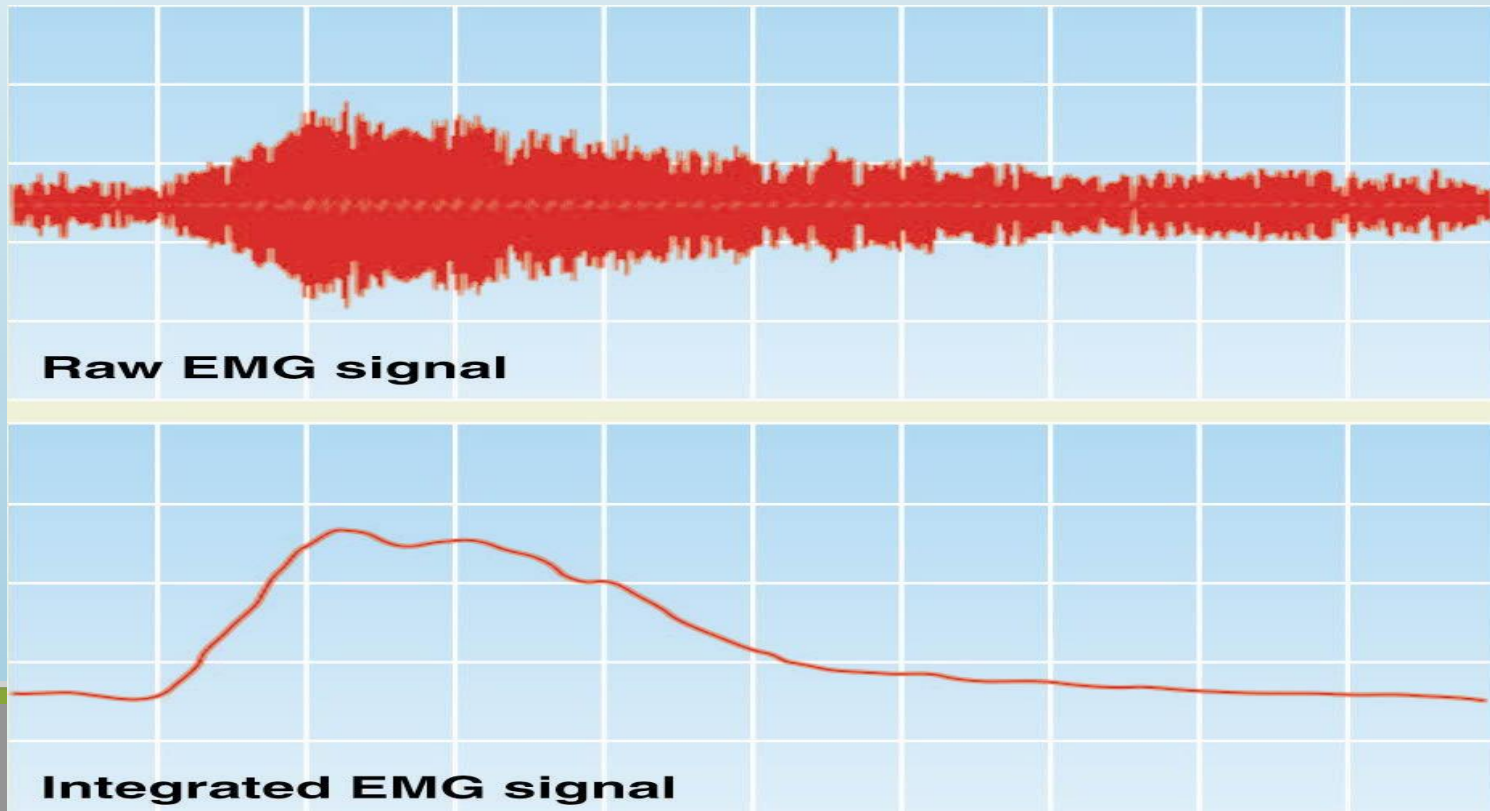


- Event-related potentials (ERPs).
- Same stimulus presented repeatedly & pattern of electrical brain activity recorded by several electrodes & averaged to produce single wave form.
- Can work out timings of various cognitive processes.

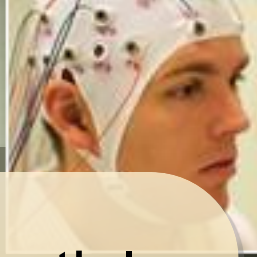


Muscle tension

- Electromyography measures electrical activity of muscles
- Electromyogram (EMG) indicates tension of muscles under skin
- Number of muscle fibers contracting at any one time.
- Raw signals converted and calculated as total of MEG spiking

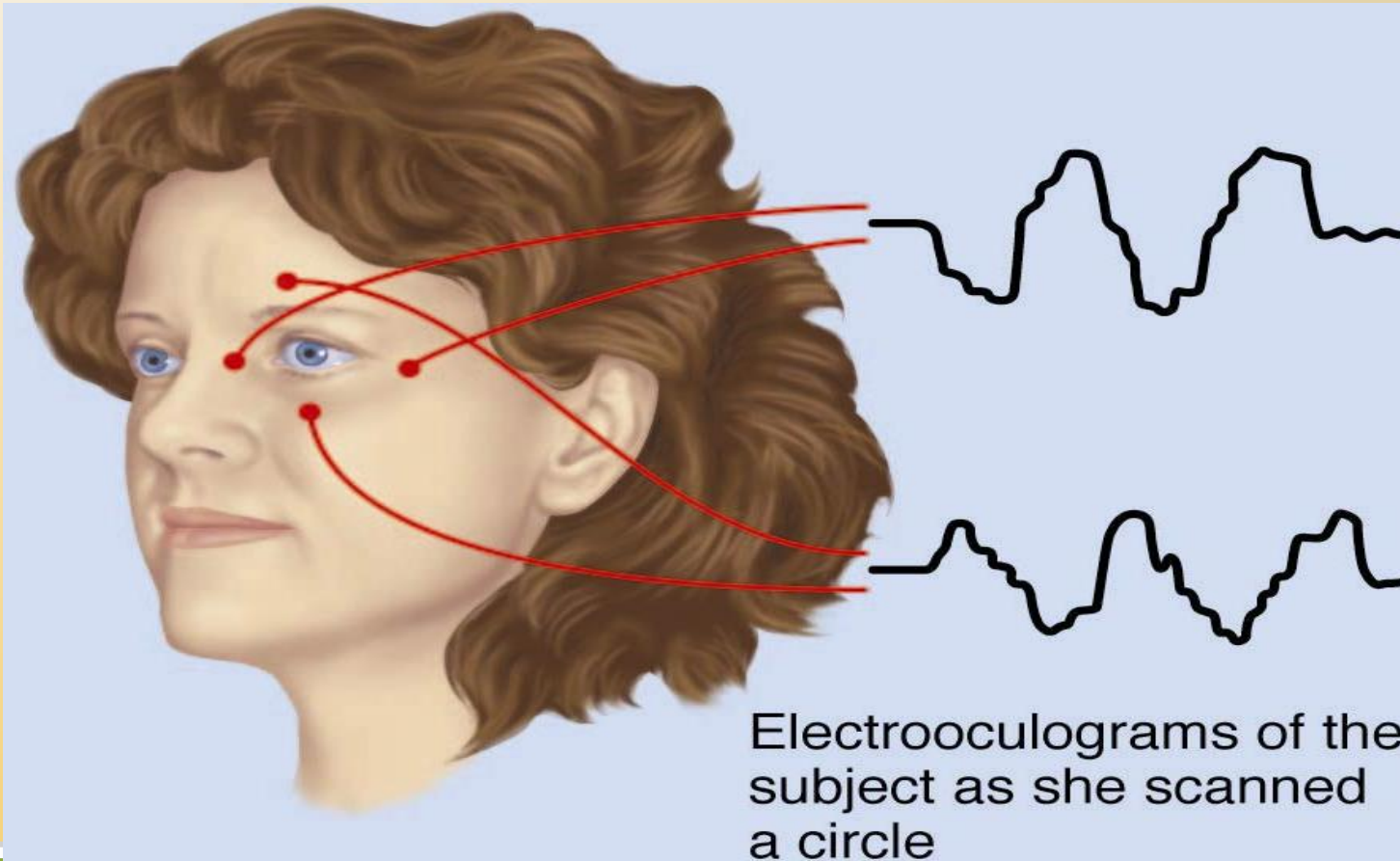


Recording Human Psychophysiological Activity



Eye movement

- Electrooculogram (EOG) - changes in electrical potential between front and back of eyeball



Typical placement of electrodes around eye for electrooculography. Two electrooculogram traces recorded as subject scanned a circle.

Recording Human Psychophysiological Activity



Autonomic nervous system activity

Skin Conductance

- Measures electro-dermal activity of experience.
- Include measurement of:
 - Skin conductance level (SCL): background level of conductance associated with specific situation
 - Skin conductance response (SCR): transient skin changes associated with discrete experiences.

Cardiovascular Activity

- Used to link physiological changes with emotional state
- Include heart rate (ECG), blood pressure, and blood volume (amount of blood going to area of body).

Why Examine Physiology in Psychology?

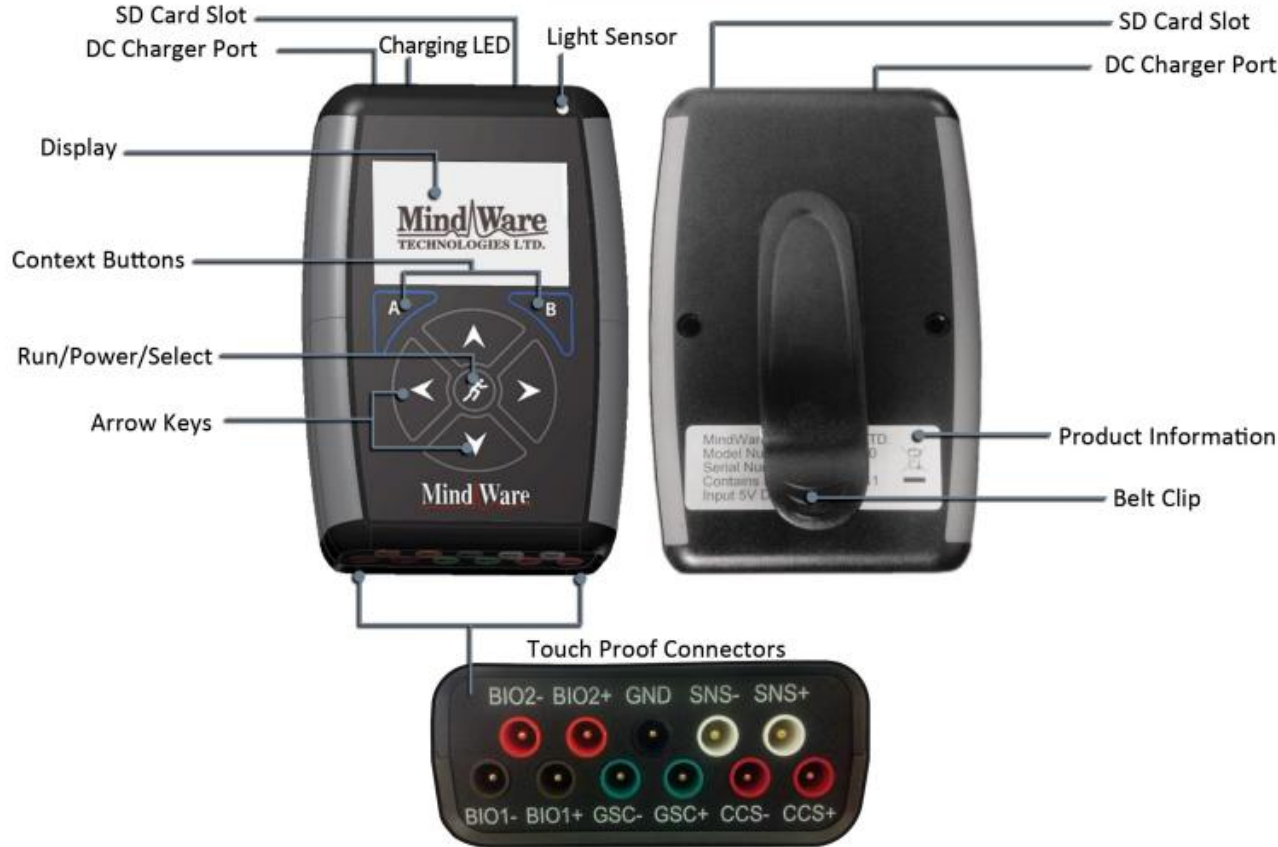


- Someone may appear/claim to be calm but may be concealing stress/anxiety
 - Objective physiological measure can reveal this
- Galvanic Skin Response:
 - Skin resistance varies with state of sweat glands
 - Sweat controlled by sympathetic nervous system
 - Skin conductance = psychological arousal.
 - If sympathetic branch of ANS is aroused, sweat gland activity increases.
 - Increase in skin conductance = measure of emotional and sympathetic responses

Technology for capturing physiological response



Device Overview



Data Acquisition device



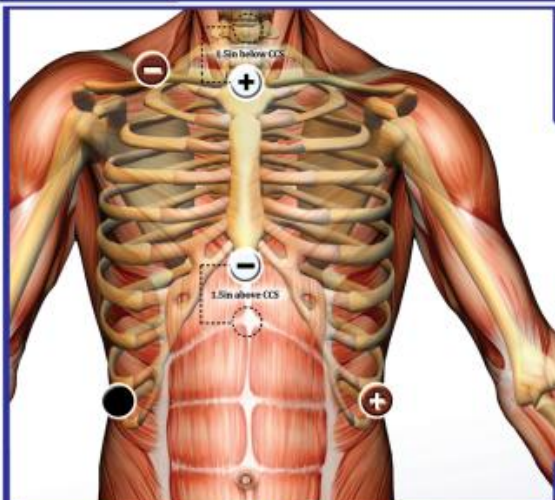
Electrodes

Electrode placement

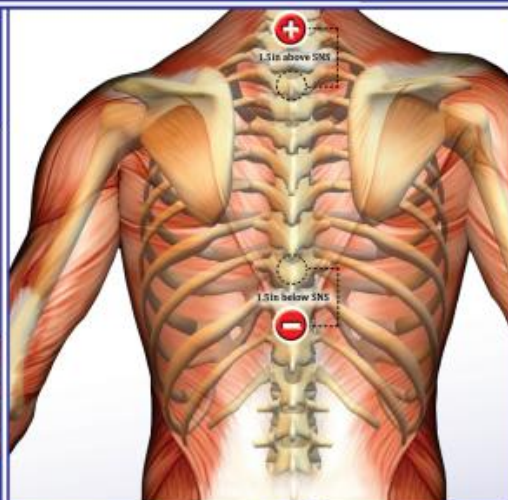


Electrode Placement

ECG, Impedance Cardiography, GSR



Front



Back



To order more electrodes call: (888) 765-9735 or email: sales@mindwaretech.com

ECG	—	+	-
Ground	—	●	
CCS	—	+	-
SNS	—	+	-
GSR	—	●	●

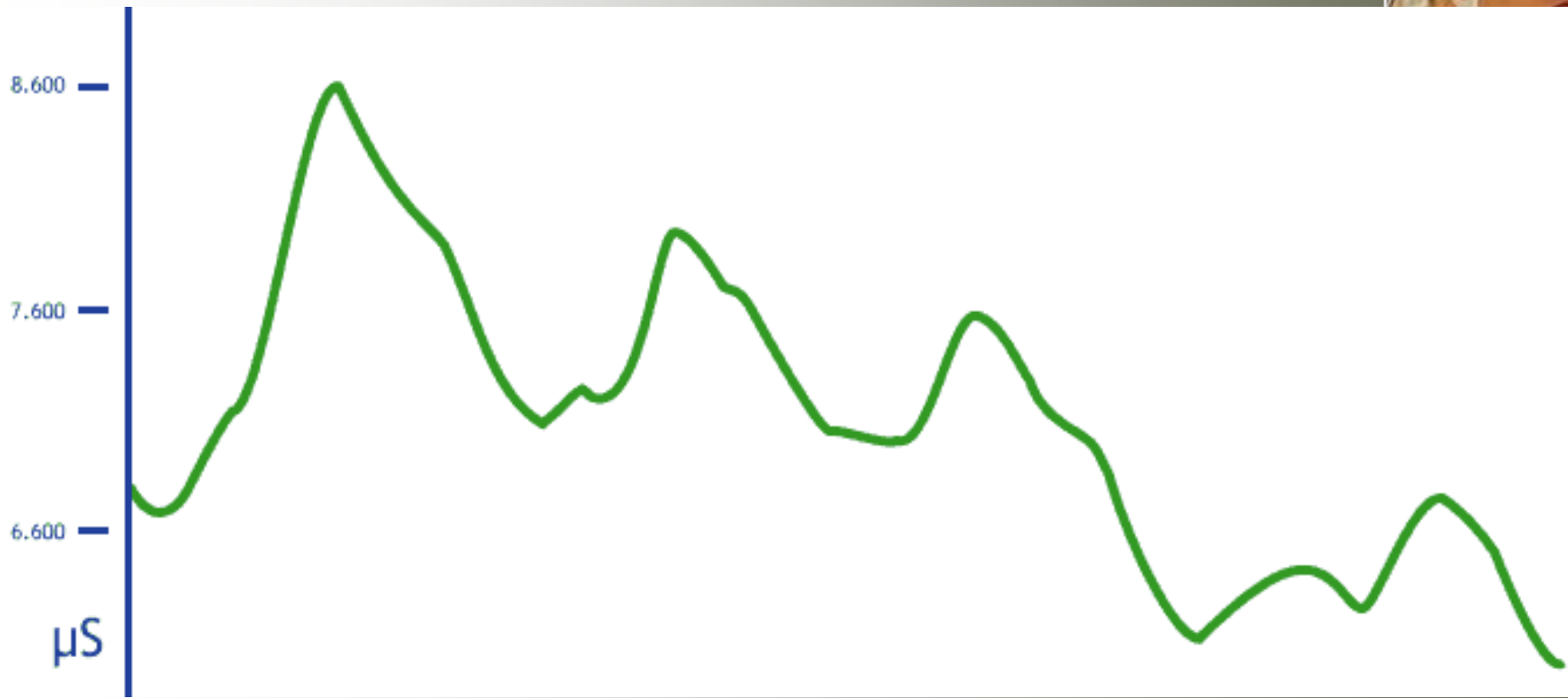
Secure lead wire using medical tape to prevent noise caused by movement. Significant slack should be left between electrode and tape

Recommended Practices

Before placing electrodes, clean areas (except GSR) with rubbing alcohol. Use water in place of alcohol for GSR site cleaning. For comfort, attach snap leads to electrode before placing on the subject.

- Place on the bottom left rib near the side
- Place on the right collar bone (clavicle)
- Place on the bottom right rib on the subjects side (Is not required when used with Impedance Cardiography)
- Place on the spine, 1.5 inches (3.81cm) above the SNS electrode
- Place on the spine, 1.5 inches (3.81cm) below the SNS electrode
- Similar to the Qu configuration, place on the jugular notch just above where the collar bones meet. If the subject is speaking during a study, offset the electrode to the left or right to prevent artifact
- Similar to the Qu configuration, place just below the sternum (on xiphoid process). Make sure any straps or bands do not interfere with the electrodes
- Place high on the subject's palms (thenar and hypothenar eminence) or on middle and pointer digits (distal & medial phalanges). Polarity is not a factor. Do not prep area with alcohol

GSR Data



- Measured in microsiemens (μS) - unit of conductance
- Typical skin conductance signal amplitude between 0.5-45 μS
- EDA signals characterized by slow rolling changes in amplitude, with sharper changes associated with specific responses.

Ethical considerations



- Along with usual BPS research ethics, additional ethics must be considered:
- Possible allergic reaction to electrode gel
- Electrode placement on ribs and collarbone
 - Have two researchers present (male/female) and ensure participant is wearing suitable clothing
- Secure and anonymous storing and transfer of data
- Checking condition of equipment and following electrode use health and safety protocols.



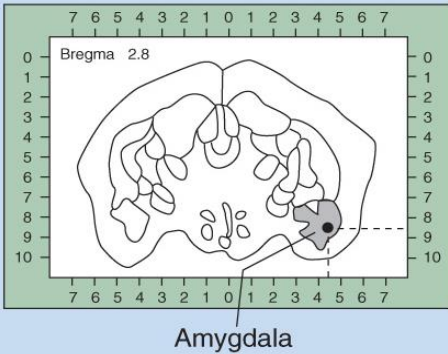
GSR in Action Demonstration

Invasive Physiological Research Methods

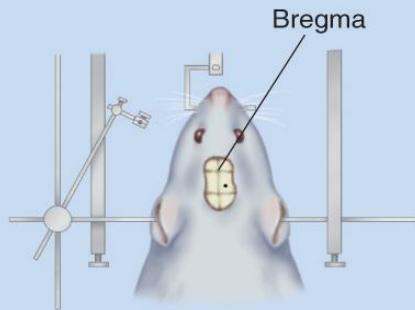


- **Biopsychological research on animals = 3 categories**
 - 1. Lesioning: remove, damage, or inactivate a structure**
 - 2. Electrical stimulation: “activate” a structure**
 - Stimulation may have opposite effect to that seen with lesioning.
 - 3. Electrophysiological recording**

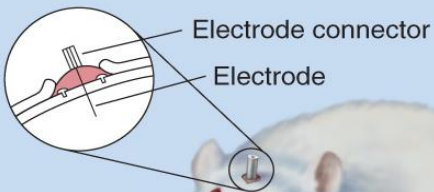
Invasive Physiological Research Methods



1 The atlas indicates that the amygdala target site is 2.8 mm posterior to bregma, 4.5 mm lateral, and 8.5 mm ventral.



2 A hole is drilled 2.8 mm posterior to bregma and 4.5 mm lateral to it. Then, the electrode holder is positioned over the hole, and the electrode is lowered 8.5 mm through the hole.



3 The electrode is anchored to the skull with several stainless steel screws and dental acrylic that is allowed to harden around the electrode connector.



Stereotaxic surgery

- Device positioned precisely deep in animal brain.
- Stereotaxic atlas to locate brain structures in 3D.
- Brain represented in stereotaxic atlas by series of individual maps, one per page, each representing structure of single 2D frontal brain slice
- Distance in millimeters from reference point – called bregma (top of skull) in rat atlas.

Stereotaxic surgery: implanting electrode in the rat amygdala

Invasive Physiological Research Methods



Lesion methods: Can be Bilateral and unilateral

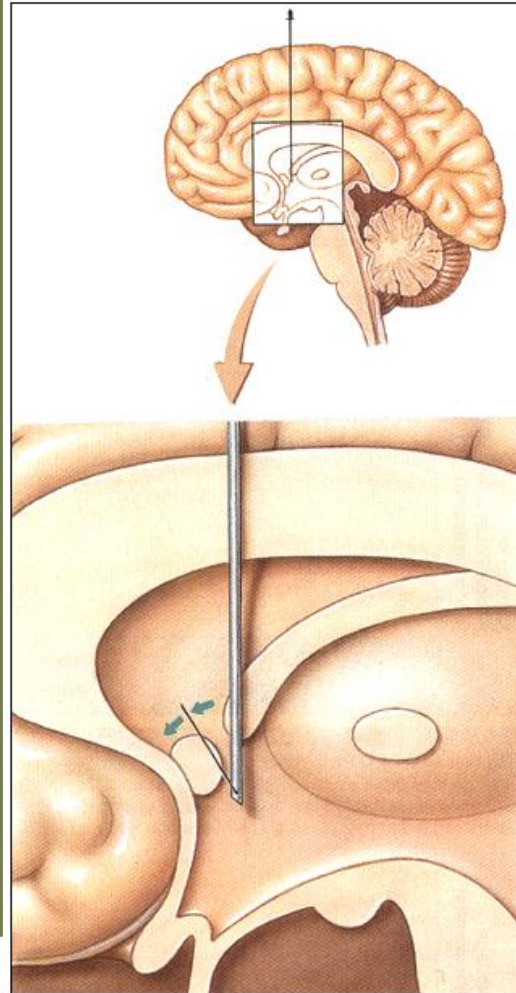
1. **Aspiration:** lesion to area accessible via eyes and instruments of surgeon, cortical tissue drawn off by suction through glass pipette.
2. **Radio-frequency:** place current through tissue from electrode. Heat from current destroys tissue - size & shape of lesion determined by duration & intensity

Invasive Physiological Research Methods

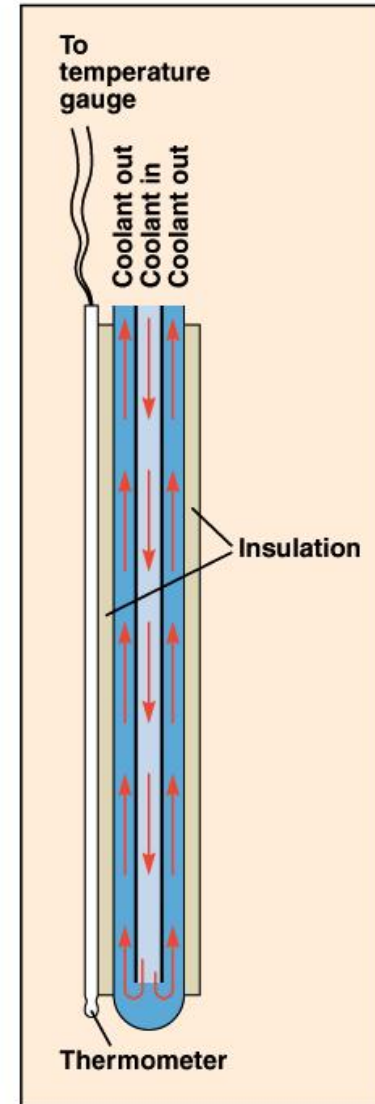


3. **Knife cuts:** cut nerves or tracts. Blade enters & swivels out to make cut.
4. **Cryogenic blockade:** implant cryoprobe in brain then pump coolant through. Neurons cooled to stop firing, but temperature maintained above freezing to avoid structural damage. When tissue warms up, usual neural activity resumes.

► Subcortical Knife Cuts



► A Cryoprobe



Invasive Physiological Research Methods



Invasive electrophysiological recording methods:

- **Intracellular unit recording**
 - Membrane potential of a neuron
- **Extracellular unit recording**
 - Firing of a neuron
- **Multiple-unit recording: large electrode tip**
 - Firing of many neurons
- **Invasive EEG recording:**
 - signals recorded through large implanted electrodes in brain rather than scalp. Cortical EEG signals recorded through stainless steel skull screws, while subcortical EEGs recorded through implanted wire electrodes.

Pharmacological Research Methods



- **Administer drugs to either increase or decrease effects of a neurotransmitter, then observe subsequent behaviour.**
- **Selective chemical lesions: inject neurotoxins (neural poison) that destroy only certain neurons**

Measuring Chemical Activity of the Brain



- **2-deoxyglucose (2-DG)**
 - Inject animal with 2-DG and leave to engage in behaviour
 - 2-DG is like glucose (brain's main source of energy), so activated neurons during test will absorb 2-DG.
 - Brain is sliced for autoradiography to see where radioactivity accumulates in brain
- **Cerebral dialysis:** measures extracellular concentration of specific chemicals in live animals through small tube implanted in brain. Chemicals go in tube, which is then removed, frozen, and analysed.



Locating Neurotransmitters and Receptors in the Brain



- Dye or radioactive labels used to visualise
- **Immunocytochemistry:** based on binding of labeled protein-specific antibodies:
 - Inject foreign protein into animal's body
 - Antibodies created to fight infection, bind & remove it.
 - Neuro-chemist locates neuroprotein by labelling antibody with dye or radioactive substance.
 - Once brain is sliced, marked location show where neurotransmitter or receptor are located.

Genetic Engineering



- **Gene knockout techniques**

- Create an animal that lacks certain gene to examine what the gene controls.
- Difficult to interpret results – most behaviour controlled by many genes and removing one may alter expression of others
- Also, need to consider compensation for missing gene

- **Gene replacement techniques**

- Insert pathological human genes in mice – e.g., for schizophrenia, to examine behaviour.





Assessment of Species-common behaviours: those displayed by all members of species: e.g., grooming, eating, building nests, etc.

- Main tests

1. **Open-field test:** place animal in empty chamber, record activity (does it move around/stay close to wall, how much droppings it produces, etc.).

2. **Tests of Sexual Behaviour**





3. Tests of Aggressive and Defensive Behaviour:

Colony-intruder paradigm: no. of combat encounters between dominant alpha male of & smaller male intruder.

- Dominant alpha is aggressive: biting, putting hair upright.
- Intruder is defensive: goes on back legs to defend from biting & tries to push alpha away with front paws.
- Elevated plus maze: maze mounted 50cm from ground, two arms of maze have sides, other two do not
 - Amount of time spent in closed arms rather than open
 - Give rat anti-anxiety drugs increases amount of time spent in open arms.





4. Traditional Conditioning Paradigms:

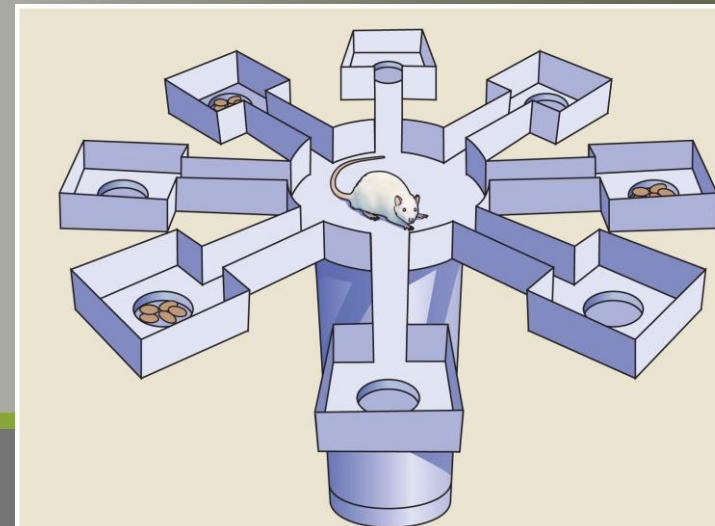
- We can infer sensory, motor, motivational, and cognitive state of animal from its ability to learn and perform various responses.
- Pavlovian conditioning (pairing unconditioned stimulus with conditioned stimulus)
- Operant conditioning & reinforcement





Semi-natural Animal Learning Paradigms:

5. **Conditioned Taste Aversion:** pairing something that makes animal ill with food, so they learn to avoid it.
 - Challenges traditional learning paradigms because taste aversion can be established after single trial.
6. **Radial Arm Maze:** place food at end of same arms.
 - Rat learns not to bother looking in other arms.
 - Shows spatial ability is good because all arms look the same, so they orientate themselves to whole room.
 - When maze is rotated performance is disrupted.





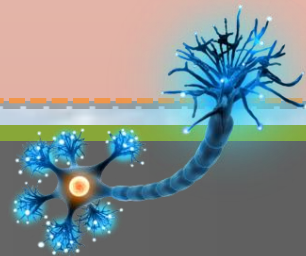
7. **Morris Water Maze:** rat must find hidden escape platform in opaque pool of water.
 - Even when placed in different areas, it quickly learns route, using spatial cues from room.
 - Brain lesions disrupt ability and in severe cases rat swim in circles for long time even if placed in same starting point where they successfully found platform previously.

8. **Conditioned Defensive Burying:** give rat single aversive stimulus (e.g., shock/blast of air) delivered from object.
 - They spray bedding/hay at object to cover it.
 - Anti-anxiety drugs decrease amount of burying behaviour.

Neuropsychological Testing



- **Behavioural methods to examine brain functioning.**
- **Patient with nervous system condition sees neurologist**
- **But neuropsychologist also needed to examine other changes in behavior (e.g., emotions or cognitions).**
- **Time-consuming**
- **Assists in diagnosing neural disorders**
- **Serves as basis for Counselling/caring**
- **Provides info on effectiveness and side effects of treatment**



Modern Approaches to Neuropsychological Testing



- **Single-test approach (1950s & before)**
 - Differentiated structural brain damage from functional (psychological) causes.
- **Standardized-test-battery (1960s)**
 - Same goal as above but used many tests (e.g., Halstead-Reitan test battery)
 - Unable to discriminate between neurological patients (disease of nervous system) & psychiatric patients (thoughts/feelings).....
- **Customized-test-battery (Now predominant)**
 - Characterises nature of psychological deficits

Tests of Common Neuropsychological Test Battery



- **Intelligence:** Wechsler Adult Intelligence Scale (WAIS)
- **Memory:** Digit span
- **Language: Token Test** – How far can patient understand instructions relating to different size, shape and colour tokens.
- **Language lateralisation – used to identify language-dominant hemisphere**
 - Sodium amytal – anesthetize one hemisphere then other to examine patient's inability to speak
 - Dichotic listening – ear contralateral to dominant hemisphere shows superior hearing ability

Tests of Common Neuropsychological Test Battery – Tests of specific function



- **Memory – exploring nature of deficits**
 - Short-term, long-term, or both?
 - Anterograde or retrograde, or both?
 - Semantic or episodic?
 - Explicit or implicit? (repetition priming tests – Purple ;
P u _ p _ _) amnesic patients to do this as well as healthy controls but have no recollection of words.
- **Language – problems of phonology, syntax, or semantics**
- **Frontal-Lobe Function**
 - Wisconsin Card Sorting Task





- Each complex cognitive process results from combined activity of simple cognitive processes (**constituent cognitive processes**)
- Each mediated by neural activity in particular brain area
- Goal = identify parts of brain that mediate various constituent cognitive processes
- Paired-image subtraction technique: compare PET or fMRI images during several different cognitive tasks that only differ on one aspect.
 - But brain activity takes places even when sitting still & not engaging in a task (default mode)