**

*KRCP Lecture 1*

*Anatomy of the Brain*

**Nervous System Structure**

* Composed of the **central nervous system (CNS)**, brain and spinal cord, and the **peripheral nervous system (PNS)**, **nerves** (bundles of axons and glia) and **ganglia** (clumps of nerve cell bodies) outside of the CNS
* CNS: command-and-control center
* PNS: courier network (delivers sensory information to CNS and carries motor commands from CNS to muscles)
* Activities of PNS are accomplished through 2 systems: **somatic motor system** (controls voluntary muscles) and the **autonomic motor system** (controls visceral functions)
* Autonomic nervous system has 2 subdivisions: **sympathetic and parasympathetic branches** (operate antagonistically e.g. sympathetic increases heart rate, parasympathetic slows it)
* The parts of the CNS (brain and spinal cord) are surrounded by a bony shell and **cerebrospinal fluid** (CSF)
* They are covered by 3 membranes – meninges: outer **dura mater**, middle **arachnoid mater**, inner **pia mater**
* CSF occupies subarachnoid space between arachnoid mater and the pia mater, as well as the brain ventricles, cisterns and sulci and the central canal of the spinal cord
* The two most common organized cluster of neurons are **nucleus** (compact arrangement of nerve cells with functionally similar inputs and outputs) or **layer**
* **Grey matter** is composed of neuronal cell bodies and **white matter** of axons and glial cells
* Axons are grouped together in **tracts** that run from one region to another (within same hemisphere: associations tracts, across hemispheres: commissures – largest one corpus callosum, from cerebral cortex to deeper structures and spinal cord: projection tracts)

**Navigation in the Brain**

* Front: **rostral** end (nose)
* Back: **caudal** end (tail)
* Along the back: **dorsal/superior**
* Along the belly: **ventral/inferior**
* Rostral = **anterior** / caudal = **posterior** in the brain
* Slicing from nose to tail: **saggital** (in the middle: midsagittal/medial / off to the side: lateral saggital)
* Slicing from top to bottom: **coronal**
* Separating dorsal from **ventral**: axial, transverse or horizontal

**Spinal Cord**

* Takes in sensory information from the body’s peripheral sensory receptors, relays it to the brain and conducts the motor signals from the brain to the muscles

**Brainstem**

* 3 main parts: **myelencephalon** (medulla), **metencephalon** (pons and cerebellum) and **mesencephalon** (midbrain)
* CNS between spinal cord and diencephalon
* Contains groups of motor and sensory nuclei, nuclei of widespread modulatory neurotransmitter systems and white matter tracts of ascending sensory information and descending motor signals
* Brainstem nuclei control respiration and states of consciousness
* Medulla, pons and cerebellum make up **hindbrain**

|  |  |  |  |
| --- | --- | --- | --- |
| **Brainstem** | **Midbrain** | **Mesencephalon** | |
| **Hindbrain** | **Metencephalon** | **Cerebellum** |
| **Pons** |
| **Myelencephalon** | **Medulla** |

**Diencephalon**

* Made up of **thalamus** and **hypothalamus**
* **Thalamus** consist of 2 hemispheres
* Involved in relaying primary sensory information and motor information that is on its way to the spinal chord 🡪 information can be reorganized and shuttled
* **Hypothalamus** is the main link between nervous system and endocrine system
* Control functions necessary for maintaining homeostasis

**Telencephalon**

* Includes the **cerebral cortex, limbic system and basal ganglia**
* **Limbic system** contains cingulate gyros, hypothalamus, hippocampus, amygdala, frontal cortex and parts of the basal ganglia
* Emotional behavior and memory
* **Basal ganglia** receives inputs from sensory and motor areas
* Involved in a variety of crucial brain functions (action selection, action gating, reward-based learning, motor preparation, timing, task switching, etc.)
* Combines and organism’s sensory and motor context with reward information and passes it to the motor and prefrontal cortex for a decision

**Cerebral Cortex**

* Made up of large sheets of layered neurons, draped and folded over the 2 hemispheres
* Brodmann divided the brain into distinct regions based on the underlying **cytoarchitectures** (microanatomy of cells and their organizations)
* Contains many infoldings called **sulci** (crevices) and **gyri** (crowns of the folded tissue) 🡪 enable more cortical surface to be packed into the skull, bring neurons into closer three-dimensional relationships to one another and bring nearby regions closer together
* Consists mostly of grey matter
* Cerebral hemispheres have 4 main divisions/lobes: **frontal, parietal, temporal and occipital lobes**
* Lobes can be distinguished from another by pronounced sulci: **central sulcus** divides frontal and parietal lobe and **Sylvian/lateral fissures** separates temporal lobe from frontal and parietal lobes
* **Frontal lobe:** planning, cognitive control and execution of movements
* **Parietal lobe:** receives sensory input about touch, pain, temperature and limb positions and is involved in coding space and coordinating actions
* **Temporal lobe:** auditory, visual and multimodal processing areas
* **Occipital lobe:** visual information

**Ventricles**

* “Empty” chambers in the brain containing CSF
* Reduces shock to the brain and gives structural support

*KRCP Lecture 2*

*Neurons and Synapses*

**Scales of Analysis in the Brain**

* **Macroscale**: Lobes, (Brodmann) areas
* **Mesoscale**: Circuits, Cortical columns, Cortical layers
* **Microscale**: Neurons, Glial Cells
* **Nanoscale**: Synapses, Neurotransmitter

**Neurons**

* Basic signaling units that transmit information through the nervous system
* The standard cellular components are found in neurons as well: A cell membrane encases the body (**soma**), which contains the metabolic machinery that maintains the neuron suspended in **cytoplasm**
* Axons also have **dendrites** (branching extensions that receive inputs from other neurons) and an **axon** (single process that extends from the cell body/output side), which sometimes branch to transmit signals to more than one cell
* Transmission occurs at **synapses** (structure where 2 neurons come into close contact so that chemical or electrical signals can be passed from one cell to the next)
* Axons are wrapped in layers of **myelin**, gaps in these sheets are called **nodes of Ranvier**

**Glial Cells**

* Support the neurons
* 4 main types: **astrocytes, microglial cells, oligodendrocytes and Schwann Cells**
* **Astrocytes** connect the neurons with the brain’s vasculature and form the **blood-brain barrier**
* **Oligodendrocytes** form **myelin** in the CNS and **Schwann cells** in the PNS by wrapping their cell membranes around the axon
* **Microglial** cells are phagocytes, which devour and remove damaged cells

**Resting Potential**

* **Electrical potential** across the membrane (voltage across the membrane/inside the neuron vs. outside)
* Voltages depend on the **concentration of potassium, sodium and chloride ions and charged protein molecules**
* Inside is more negatively charged than outside 🡪 voltage difference is **-70mV**
* **Cytoplasm** (inside the cell) and extracellular milieu are separated by the **neuronal membrane** composed of lipids
* Membrane maintains separation of intracellular and extracellular ions and electrical charge, however, it contains **trans membrane proteins**, which act as channels for ions; there are 2 types: **ion channels** and **ion pumps**
* **Ion channels** allow certain ions to flow down their concentration gradient, they are **selectively permeable** (neuronal membrane is more permeable to K+ ions)
* Unlike other cells in the body, neurons are excitable (can change permeability of their membranes) 🡪 due to **gated ion channels**, that open or close based on changes in the voltage
* Normally there are more Na+ and Cl- ions outside the cell and more K+ inside, however they are able to flow down their concentration gradient by ion channels
* **Ion pumps** act against this: they use energy to actively transport K+ and Na+ against their concentration gradient
* 2 forces acting up on each other: **concentration gradient/entropy pressure** (pushing Na+ in and K+ out), pump acts against it & electrical **gradient/electrostatic pressure** (pushing K+ back in the cell because it is more negative there) 🡪 eventually they equal out at -70mV (**equilibrium**)

**Action Potential**

* Internal transmission of output signals
* Made possible by **voltage-gated ion channels** located in the neuronal membrane and found at the **spike-triggering zone** in the **axon hillock** and along the axon
* Multiple input signals are needed at dendrites to produce an AP: **EPSP** depolarize, **IPSP** hyperpolarize; they can sum **spatially** (at different dendrites) or **temporally**
* Passive electrical currents generated by EPSPs flow across the neuronal membrane in the **spike-triggering zone** depolarizing the membrane
* If the depolarization is strong enough an action potential (AP) is triggered; strong enough = at least -55mV (**threshold**)
* When the threshold is reached **voltage-gated Na+ channels** open and Na+ flows into the cell, depolarizing it even more 🡪 more Na+ channels are opened… (**Hodgkin-Huxley Cycle**)
* Next the **voltage-gated K+ channels** open, allowing K+ to flow out of the cell 🡪 membrane potential shifts back toward RP
* Opening of K+ channels triggers closing of Na+ channels 🡪 membrane potential gets even more negative than RP; **hyperpolarized** (**equilibrium potential**)
* K+ channels close 🡪 membrane potential returns to RP
* During hyperpolarization state Na+ channels are unable to open and another AP cannot be generated (**absolute refractory period**), this is followed by the **relative refractory period**, during which the neuron can generate APs but only with larger depolarization currents
* Consequences of **refractory periods**: neuron’s speed for generating APs is limited and AP can only flow in one direction (from axon hillock towards axon terminal)
* APs must travel quickly; solution: **saltatory conduction**: channels are only opened at nodes of Ranvier and therefore APs can travel a lot faster (otherwise **passive conduction**)

**Synapses**

* 2 major kinds of synapses: chemical and electrical
* Most synapses are chemical:

1. Arrival of action potential depolarizes the **terminal membrane**, which causes Ca+ to flow into the cell
2. Ca+ causes **vesicles** to bind the with the cell membrane at the synapse
3. Release of **neurotransmitter** (in the vesicles before) by **exocytosis** into the **synaptic cleft**
4. Neurotransmitter diffuse across the cleft and bind with the **receptor**
5. Binding induces a change in the receptor, which opens specific **ion channels** leading to either **depolarization** (excitation) or **hyperpolarization** (inhibition) of the **postsynaptic cell**

* 2 different kinds of receptors: **Ionotropic** (from an ion channel pore, fast response) and **Metabotropic** (indirectly linked with ion channels in the membrane, slow response)
* 3 ways to end synaptic transmission: neurotransmitters are returned to postsynaptic or glial cell, enzymes inactivate neurotransmitter, neurotransmitter diffuse out of cleft
* Neurotransmitter: are synthesized and located in presynaptic neurons, released when AP depolarizes terminal, postsynaptic neuron contains specific receptors for it
* Some important neurotransmitter:
  + **Acetylcholine** (muscle)
  + **Monoamines**: dopamine (pleasure, addiction) & serotonin (sleep, eating, depression)
  + **Amino acids**: glutamate (main brain excitatory) & GABA (main brain inhibitory)
* **Electrical synapses** operate by passing current directly from one neuron to another via specialized channels in gap junctions that connect the cytoplasm of one cell directly to each other

*KRCP Lecture 3*

*Sensation and Perception*

**Visible Light Spectrum**

* Longer wave lengths: red
* Shorter wave lengths: blue
* Only a small wave length spectrum, that is visible to us

**Eye**

* **Iris**: responsible for controlling the diameter and size of the **pupil** and thus the amount of light reaching the **retina**
* **Pupil**: hole located in the center of the iris that allows light to strike the **retina**
* **Cornea**: transparent front of the eye, contributes two thirds to the eye’s focusing power (in humans constant 43 diopters)
* **Lens**: helps together with the **cornea** to refract light to be focused on the **retina**, changes shape to do that
* **Retina**: back surface of the eye, picture is projected inverted on it, made up of 10 layers of densely layered neurons
* Image is projected inverted on retina (left is right, up is down)

**Retina**

* **Blind Spot**: **optic nerve** passes through **optic disc** 🡪 no nerve cells to detect light; brain interpolates it based on surrounding information and detail from the other eye
* **Fovea**: area where **cones** are densely packed, near the middle of the retina
* **Photoreceptors**: make up deepest layer of neurons in **retina**, contain **photopigments** (sensitive to light), do not fire APs (decomposition of photopigments alters the membrane potential and triggers APs in the downstream neurons) 🡪 provide translation of the external stimulus of light into an internal signal that the brain can interpret
  + **Rods**: contain **rhodopsin** (destabilized by low levels of light) 🡪 useful for dim light
  + **Cones**: contain **photopsin** 🡪 active during daytime vision; 3 types, defined by their sensitivity to different regions of the visible spectrum: short (blue), medium (green) and long (red) wavelengths 🡪 we can see color
  + Cones are packed at **Fovea**, few cones are in the more peripheral region of the retina, Rods are equally distributed
* **Ganglion Cells**: output layer of **retina**, synapse with **bipolar cells**, axons form a bundle: **optic nerve** (transmits information to CNS)
* **Bipolar Cells**: connected with the **rods** and **cones** and synapse with **ganglion cells**, part of the **indirect and direct pathway**
* Horizontal Cells: located in the middle layer of the retina, part of the indirect pathway
* Amacrine Cells: located in the middle layer of the retina, synapses with bipolar cells

**Visual System**

* **Eye**: organ of vision (detect light and convert it into electro-chemical impulses)
* **Optic chiasm**: part of the brain where the optic nerves crosses
* **Lateral geniculate nucleus** (LGN): relay center in the thalamus for the visual pathway, receives major sensory input from the retina, main central connection for the optic nerve to the occipital lobe
* **Visual cortex**
  + **Micro-electrode recording**: Hubel and Wiesel 1970’s, recorded the brain activity of a monkey 🡪 **Receptive fields**: center surround (due to lateral inhibition)
  + **V1**: primary visual cortex
    - **Simple cell**: responds primarily to oriented edges and gratings
    - **Complex cell**: respond to movement in a certain direction
    - **End-stopped cell**: the longer the stimulus line the better the response
    - **Oriented columns**: respond to visual line stimuli of various angles
  + Visual filed is projected contralateral and upside-down
  + **Retinotopy**: mapping of visual input from the retina to neurons
* Visual pathways
  + 3 pathways from **eye to cortex**: **Magnocellular**, **Parvocellular** and **Koniocellular**
  + 3 pathways **after V1 and V2**: **Dorsal** (motion, location, “where”, “how”), **Ventral** (complex shape, object perception, “what”) and **Color and Brightness**

*KRCP Lecture 4*

*Attention*

**Kinds of Attention**

* **Voluntary** (controlled) or **Reflexive** (automatic)
* **Overt** (direction of attention visible from outside) or **cover** (not)
* **Feature-based** (to feature), **spatial** (location) or **object-based** (object)

**Functions of Attention**

* **Vigilance** (signal detection)
* **Search**: Actively looking for a signal
* **Selective Attention**: Actively focus on some information and ignoring other
* **Divided Attention**: Shift attention between multiple tasks

**Signal detection theory**

|  |  |  |
| --- | --- | --- |
| Signal | Detect a Signal | Do not detect a Signal |
| Present | *Hit* | *Miss* |
| Absent | *False alarm* | *Correct rejection* |

* **Sensitivity**: many hits, few false alarms
* **Specificity**: few misses, many correct rejections

**Search**

* **Targets** and **Distracters**
* **Array size effect**: the larger the array the more difficult
* **Feature (pop-out) search** (targets and distractors are maximally different 🡪 parallel process) and **conjunction search** (targets and distractors share similarities)
* **Feature integration theory** (Treisman): object perception differs from object recognition and features are “registered early, automatically and in parallel, while object are identified separately”
* **Similarity theory**: People are attracted by similar people
* **Guided search theory**: we first process multiple basic features simultaneously across a large field, we then look for one specific element or combination of basic features at a time in a smaller area

**Selective Attention**

* **Cocktail party problem**: many people are talking, listening to one
* **Dichotic listening task**: present 2 different messages to each ear, “shadow” one message 🡪 other messages receives little processing
* **Posner Cuing Task/Endogenous Cuing**: arrow showing where to focus, then object, 3 different trials: valid, invalid or neutral trials; Reaction times for expected locations are a lot faster than for unexpected or neutral locations
* **Early Filtering** (Broadbent): Sensory Register, Filter, Perceptual process, STM (Short Term Memory)
* **Late Filtering** (Deutsch and Deutsch): Sensory Register, Perceptual process, Filter, STM
* **Attenuation Theory** (Treisman): Sensory Register, Perceptual process interacting with Filter Modulates, STM

**Anatomy of Attention**

* **Cortex**: 2 areas: **Posterior parietal lobe** of the cortex (orienting visual attention and shifting it from one location to another) and **right frontal cortex** (maintaining alertness)
* **Dorsal frontoparietal network**: goal directed control of spatial attention; Superior dorsal parietal and frontal lobe
* **Ventral frontoparietal network**: stimulus driven control; Inferior ventral parietal and frontal cortex (lateralized to the right)

**Automatic and Controlled Processes**

* **Automatic Processes**: require no attention or conscious control, can perform multiple at once
* **Controlled Processes**: require attention or conscious control, can only perform one at a time
* **Automatization**: controlled processes becoming automatic
* **Practice effects**: rate of learning slows
* **Stroop effect**: demonstration of interference in the reaction time of a task

*KRCP Lecture 5*

*Memory*

**Memory**

* **Encoding**: processing of new information, 2 forms: **Acquisition** and **Consolidation**
* **Acquisition**: sustaining some of the sensory stimuli to enter into memory
* **Consolidation**: stabilize a memory over time resulting on long term memory
* **Storage**: record the information
* **Retrieval**: accessing stored information

**Types of Memory**

* **Long term memory:** holds information permanently, unlimited capacity, 2 different types: **Declarative** and **Nondeclarative** memory
* **Declarative (explicit) memory**: things you can describe, 2 types: **episodic** (events in your life) and **semantic** (facts you know) memory
* **Nondeclarative (implicit) memory**: things you can do, 2 types: **procedural memory** (skills) and **classical conditioning** (conditioned responses between 2 stimuli)
* **Short term memory**: distraction causes to forget, limited capacity, 2 different types: **Sensory** and **Working** memory
* **Sensory memory**: 2 types: **iconic** (visual) and *echoic* (auditory) memory
* **Working memory**: storage and processing of new and already-stored information, important for reasoning

**Atkinson & Shiffrin’s modal (or multi-store) model**

*Sensory Inputs*

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Sensory Register *Attention*

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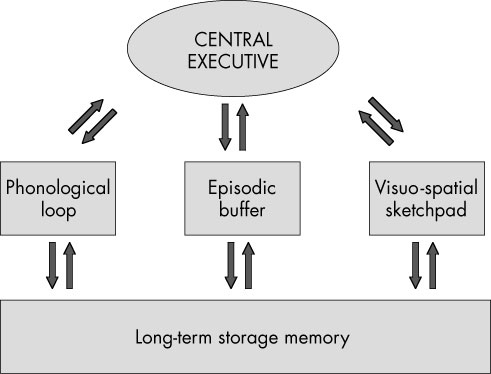
Short-term Storage

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Long-term Storage

**Baddeley’s working memory model**



* **Central Executive**: drives the whole system and allocates data to the subsystems
* **Phonological loop**: part of working memory that deals with spoken and written material
* **Visual-spatial sketchpad**: deals with visual and spatial information
* **Episodic buffer**: “backup” store

**Consolidation by studying/rehearsal**

* **Consolidation**: integrating new information
* **Rehearsal**: **elaborative** (thinking about the meaning) or **maintenance** (repeatedly verbalizing or thinking about something)
* **Distributed** practice is more effective than **massed**
* **Mnemonics**: add meaning to lists

**Free recall experiments**

* Show serial position curve
* **Primacy effect**: superior recall of items near beginning
* **Recency effect**: superior recall of items near end

**Forgetting**

* 2 theories: **interference** and **decay**
* **Interference**: competing information, 2 types: **retroactive** (new interferes with something already learned) and **proactive** (already learned interferes with something new)
* **Decay**: memory trace gradually fades away

**Constructive memory**

* Memory is not only reconstructive
* **Prior experience** has an influence on memory
* **Flashbulb memories** (eg. Where were you at 9/11?)
* **Encoding specificity**: memory performance is optimal when there is a match in processes/context between learning and retrieving (experiment Godden and Baddeley)

**Anatomy of memory**

* **Hippocampus** is essential for memory consolidation
* Standard consolidation theory (Squire): Memory consolidation in hippocampus via **entorhinal cortex**; during sleep consolidation in **other parts of cortex**

**Memory deficits**

* **Amnesia**: **anterograde** (no new memories formed 🡪 no consolidation) and **retrograde** (no old memories remembered 🡪 no retrieval)
* **Alzheimer disease**: Amyloid plaques and neurofibrillary tangles in brain 🡪 memory impairment and general impairment (starts with episodic memory)

*KRCP Lecture 6*

*Learning*

**Types of learning in mammals**

* **Associative Learning**: Classical Conditioning and Operant Condition (modify occurrence of behavior)
* **Non-associative Learning**: Habituation (decrease in response to repeated stimulus) and Sensitization (amplification of response to repeated stimulus)

**Learning over different time scales**

* **Development learning**: learning that takes place as a normal part of cognitive development
* **Behavioral learning**: observable change in behavior
* **Evolutionary learning**: learning that takes multiple generations

**Hebbian learning**

* “Cells that wire together fire together”
* Cells that fire together strengthen synapses
* Cells that fire separately lose synapses

**Long-term potentiation/depression (LTP/LTD)**

* Molecular mechanism for (Hebbian) learning
* **LTP**: (E)PSP is increased after presynaptic stimulation 🡪 Long-term synaptic strengthening
* **LTD**: (E)PSP is decreased after presynaptic stimulation 🡪 Long-term synaptic weakening
* **Associative LTP**: Implementation and Extensions of Hebb’s law, 3 properties: **Cooperativity** (works when more than 1 input is simultaneously active), **Associativity** (weak inputs are potentiated when occurring with string inputs) and **Specificity** (only stimulated synapse shows potentiation)
* NMDA receptor: Central to producing LTP

1. Glutamate binds on receptors
2. Post-synaptic cell is depolarized
3. Mg2+ ejected out of channel
4. Ca2+ enters and facilitates LTP

**3 projection pathways in Hippocampus**

* **Perforant pathway** synapses in the dentate gyrus
* **Mossy fiber pathway** synapses in CA3
* **Schaffer collateral pathway** synapses in CA1

**Types of Machine Learning**

* **Supervised Learning**: teacher
* **Reinforcement Learning**: a bit of help (rewards)
* **Unsupervised learning**: all on your own (Content addressable memories)

**Artificial Neural Networks**

* **Units/Nodes**: have input/output and perform simple computations
* **Connection weights**: synaptic strength between 2 nodes
* **Activation function**: transforms weighted sum into an activation value, 3 types: step, sign and sigmoid function
* **Layers**: single ANN has two, input and output, and multilayer ANNs have hidden layers between those two
* **Bias node**: constant output of 1 or -1
* **Types of general structure**: **fully connected** (all units to all), **feed-forward** (one layer to next) and **recurrent-network** (some back connection)
* **Perceptron**
  + Most simple form of an ANN
  + **Weight learning rule**: learning constant \* error \* output
  + Perceptron can only classify **linear separable** problems
  + Multi layer perceptron:
    - Add one or multiple **hidden layers**
    - Needs a **differentiable activation function**
    - Back-propagation rule (weight change): learning constant \* error
    - Pro: easily parallelizable, can calculate anything
    - Con: Learning takes a long time and depends on initial weights, black-box, cannot find global optimal solution (only local minimum)

*KRCP Lecture 7*

*Research Methods*

**Research design**

* **Correlational**: used to determine if there is a relation, one can never infer a causal relationship
* **Experimental**: manipulate one variable, keep others constant, can show a causal relationship

**Computer modeling**

* 3 main streams: **Symbolic modeling**, **Connectionism** (both algorithmic level) and **Realistic neuronal modeling** (implementation level)
* **Symbolic modeling**: serial and abstract processing (Expert systems)
* **Connectionism**: parallel and distributed processing (ANNs)
* **Realistic neuronal modeling** (EU brain project)
* **Braitenberg vehicles**: simple model, aggression (goes to sensory input), fear (runs away)
* **Pro**: models become more powerful with computers, testbed for studies about human cognition
* **Con**: Models always simplify, may not be biological plausible, different models can generate same behavior

**Lesion Studies**

* **No dissociation**: one lesion impairs A and B
* **Single dissociation**: one lesion impairs A and B, other only B
* **Double dissociation**: one lesion impairs only A, other only B
* **Pro**: provide information about different brain parts
* **Con**: which function ideas?, can have an effect on other regions, it is not a normal, healthy brain

**Structural Imaging**

* **Computer Tomography** (CT or CAT scan): uses X-rays, principle: different tissues absorb different amount of X-rays
* **Structural Magnetic Resonance Imaging** (MRI scan)

**Functional Imaging**

* **Single cell recording**:
  + Pro: highest possible temporal solution
  + Con: no bigger picture, highly invasive
* **Electro-Encephalo-Gram** (EEG):
  + Measures overall brain activity
  + Uses electrodes to measure activity of groups of neurons that fire in parallel
  + **Event Related Potential** (ERP): the measured brain response is the direct result of a specific event
  + **Time-frequency analysis**: one need to repeat the experiment multiple times and average them together in order to “see” something
  + **Electrocorticography** (ECoG): type of electrophysical monitoring that uses electrodes placed directly on the exposed surface of the brain to record electrical activity from the cerebral cortex
  + **Pro**: very cheap, very high temporal solution, non invasive
  + **Con**: very poor spatial solution (flow of current is disturbed by tissue), very noise sensitive
* **Magneto-Encephalo-Gram** (MEG):
  + Measures the same activity as EEG (in a different way)
  + Pro: magnetic fields are not disturbed by tissue, measures selective parts of brain (easier to locate source)
  + Con: measures selective parts of the brain
* **Positron-Emission-Topography** (PET):
  + Uses tracers (short-lived radioactive material) to map functional processes in the brain (measures indirectly), when the material undergoes radioactive decay a position is emitted, which can be picked up by the detector
  + One can vary what to measure by varying the tracer
  + Uses **subtraction method**
  + Pro: good spatial resolution, variation of what to measure
  + Con: invasive, short experiment, very expensive
* **Functional MRI** (fMRI):
  + Based on the principles of MRI
  + **Blood-Oxygenation-Level-Dependent (BOLD) Response**: images the change of blood flow related to energy use in brain cells, uses the change in magnetization between oxygen-rich and oxygen-poor blood as its basic measure, arises 2-3s after activation, reaches peak at 5-6s
  + **Pro**: very high spatial solution, relatively high temporal solution, noninvasive
  + **Con**: relationship between BOLD response neuronal activity is indirect, temporally limited
* **Spatial** (ability to distinguish small detail of an object) and **temporal** (precision of a measurement with respect to time) **resolution**

**Methods to perturb function**

* **Pharmacological studies**: Influencing the brain function’s with medication
* **Transcranial Magnetic Stimulation** (TMS):
  + Uses a magnetic coil to generate an electrical current inside the subject’s brain
  + One can stimulate (**pulsed TMS**) or disable (**repetitive TMS**) the target part of the brain
* **Transcranial direct current stimulation** (tDCS): from of neuro-stimulation which uses constant, low current delivered to the brain area of interest via electrodes, can increase cognitive performance on a variety of tasks
* **Genetic manipulation**: manipulation the genome of an organism in order to produce desired traits
  + **Knockout-procedure**: genetic technique in which one of an organism’s gene is made inoperative; used in learning about a gene that has been sequenced

*KRCP Lecture 8*

*Evolution & Development*

**Brain Evolution**

* Brain size to body issue: Homo sapiens has the largest
* Brain increased exponentially in hominids
* Bigger brain: Mass increased, however, neurons did not increase that much and distribution is also similar; human brain as much more arborized dendrites and synapses

**Radial Unit Hypothesis**

* Explains the human brain expansion

1. Cells divide **symmetrically** in the **Ventricular Zone** (keep same function)
2. After that they divide **asymmetrically** (one cell gets a different function)
3. The cortex is formed from an inside out matter (from the **ventricular zone** to the **cortical layer**, through the sub ventricular zone and the intermediate zone)
4. New neurons migrate to the **Cortical Plate** radially into the newly forming cortex

* Neuron **(radial) migration** happens along **radial glial cells**
* Radial glial cells form **radial units** from the Ventricular Zone (VZ) through the intermediate zone to the Cortical Plate (CP); explains why cortex is organized into **columns**

**Development of the Brain**

* **Synaptogenesis**: increase of synapses (maximum at about one year)
* **Synapse elimination/pruning**: decline of synapses, continues for the first decade of life, competitive process, allows for learning development of higher cognitive functions, “Use it or lose it!”
* **Myelination**: extends way further into life, axons in different areas myelinate at different times (sensory and motor areas first, frontal and parietal areas last)

**Brain Plasticity**

* Brain constantly changes (due to learning, and connectivity)
* Can also repair or reorganize after an accident
* Recruit other areas that are/were used for something else (**phantom-limb experience**: feel amputated limb)

**Basic Genetics**

* **Chromosomes** contain genome (make me an individual)
* Each chromosome consist of **genes** that encode a functional element (protein)
* Code = triplet (of nucleic acids)
* **DNA** = Deoxyribonucleic Acid, storage of genome, consist of 4 base pairs: Adenine, Thymine, Cytosine and Guanine (A and T and C and G pair)
* When we reproduce our DNA is recombined with that of our partner
* **Genotype**: genetic makeup
* **Phenotype**: expression of the genotype
* **Recombination**: Combination of 2 different DNAs; **Crossover**: DNA is recombined ones more by exchange parts of it after recombination
* **Mutation**: parts of the DNA can mutate (change) due to mutagens

**Genetic Algorithms**

* An **individual** is represented by a (binary) **string**, this is the **genotype**
* The expression of the code is the **phenotype**
* **Population**: collection of individuals
* Each individual has a **fitness value** assigned to its phenotype
* **Reproduction**:
  + **Cross-over**: various forms (single/multiple point)
  + **Mutation**: depends on representation
  + **Inversion**: invert the string
* **Selection strategies:**
  + **Elitist**: select top most individuals (very fast, easy/loss of genetic information, genetic degeneration)
  + **Roulette Wheel**: every individual gets share according to its fitness on the wheel, wheel is rotated, individual at selection point is selected (better/close to elitist selection if fitness values are unequal)
  + **Tournament**: select k individuals at random, select best form that selection (very straight forward/a large k boils down to random selection)
* **Pro**:
  + Widely applicable
  + Easy to implement
  + Easy to parallelize
* **Con**:
  + Local minima problem
  + Lots of variation
  + Difficult to find right encoding

*KRCP Lecture 9*

*Language*

**Language and Linguistics**

* **Syntax**: rules that tell us how to organize words (grammar)
* **Phoneme**: smallest unit of speech
* **Grapheme**: smallest unit of written language
* **Semantics**: meaning of language
* **Morpheme**: smallest unit of meaning
* **Lexicon**: mental store of word information that includes: semantic info (word’s meaning), syntactic info (how to make words into sentences) and word forms (spelling and sound patterns); semantic network
* **Prosody**: rhythm and pitch of speech
* **Pragmatics**: knowledge of social rules

**Language acquisition**

* We acquire language in **several states**:
  + Cooing
  + Babbling (6 months)
  + One-word utterances (1 year)
  + Two-word utterances (2-3 years)
  + Basic adult structure
* **Overextension errors**: Use of wrong semantic word
* **Irregular verb errors**: Overgeneralization of grammatical rules
* There seems to be a **critical period**, but one may learn language at an older age, however, never with the same mastery

**Anatomy of Language**

* Language is left lateralized
* Left Peri-sylvian language network: Inferior frontal cortex, Broca’s area, Inferior parietal lobe, Superior temporal gyrus, Wernicke’s area, Arcuate fasciculus

**Aphasia**

* **Aphasia**: language deficits in production and comprehension even though articulatory mechanisms are intact
* **Broca’s aphasia** (anterior, expressive): Damage of Broca’s area, deficits in speech production, also comprehension deficits related to syntax
* **Wernicke’s aphasia** (posterior, receptive): Damage of Wernicke’s aphasia, deficits in speech comprehension, also production deficits related to semantics
* **Conduction aphasia**: Damage of arcuate fasciculus, mainly production deficits (producing and repeating speech)

**Language Comprehension**

* Semantics: the meaning of a word/sentence; Denotation (literal meaning) and Connotation (emotional overtone)
* Syntax: how can words be combines and sequenced into a sentence; Grammar (the set of rules to do this)
  + Phrase structure grammar: hierarchical, tree
  + Chomsky’s transformational grammar: one must understand syntactical relationship between words, transformation rule: how can an underlying proposition be arranged in a sentence
* Perceptual analysis: speech and reading only differ in the first steps
  + **Speech**: Spoken word 🡪 **Acoustic analysis** 🡪 **Phonological input code** 🡪 **auditory word form**
    - Problems: **Coarticulation/Segmentation problem**: identifying the boundaries between words, syllables or phonemes in spoken language; **Invariance problem**: same phoneme can have different acoustic patterns in different syllable contexts
  + **Reading**: Written word 🡪 **Visual analysis** 🡪 **Orthographic input code** 🡪 **visual word form**
    - **Pattern Recognition: Selfridge’s pandemonium model** (Pattern recognition by “deamons”, purely feed forward, bottom-up), **McLelland and Rumelhart connectionist model** (Pattern recognition by recursive ANN, purely feed forward & feedback, bottom-up & top-down)
  + **Lexical analysis** (**lexical access:** activating word-form representations 🡪 **lexical selection**: selecting the best matching lexical representation 🡪 **lexical integration**: integrate words into sentence or discourse) 🡪 **Conceptual analysis** 🡪 Concept

**Speech Production**

* Slips of the tongue help us to make models of language:
  + **Anticipation**: **b**ake my bike
  + **Preservation**: cold **c**urkey
  + Substitution: he is going **up** town
  + Reversal/Spoonerism: The Lord is a **sh**oving **l**eopard
* **Levelt’s model**: Conceptual preparing 🡪 Lexical encoding (Lexical selection 🡪 Morphological encoding 🡪 Phonological encoding) 🡪 Articulation / **Self monitoring:** back to start

**Can computers understand language?**

* Alan Truing**: Turing Test**
* **ELIZA**: structured dictionary, looks for words in sentence and then searches for synonyms, categories and asks question
* **ALICE**: chatbot inspired by alice
* **WATSON**: question answer computer, answers questions in natural language

*KRCP Lecture 10*

*Consciousness*

**Anatomy of Consciousness**

* **Core Consciousness**: **Brainstem** and **Thalamus**, **Reticular Activating System** (RAS, modulates arousal and attention through direct connections to the cortex)
* **Extended Consciousness**: **Cerebral Cortex**

**Clinical Perspective**

* **Impairments**:
  + **Somnolence**: abnormal sleepiness, but acoustically arousable
  + **Sopor**: no spontaneous movements, reaction to pain stimuli adequate
  + **Coma**: no reaction to visual, acoustic or pain stimuli, EEG
  + **Brain death**: no EEG, dies if no life support
  + **Vegetative state**: no voluntary behavior, unconscious, reflexive response, unresponsive to stimuli except pain
  + **Locked-in-Syndrome**: patient is fully conscious, but cannot move or express himself, can use EEG or real-time fMRI to communicate
* **Terri Schiavo Case**: persistent vegetative state, without prospect of recovery, husband and parent fought whether her life support should be stopped, husband: no prospect if recovery, parents: some signs of consciousness (probably vegetative reflexes), died after 15 years

**Sleep**

* **Stages**:
  + **1**: light sleep, awoken easily
  + **2**: **sleep spindle** (burst of oscillatory brain activity generated in thalamus), **K-complexes** (suppressing cortical arousal in response to stimuli that the sleeping brain evaluates not to signal danger, aiding sleep-based memory consolidation)
  + **3&4**: deep sleep, slow brain eaves
  + **REM** (Rapid Eye Movement)/**paradoxical sleep**: Increased activity in pons/reticular formation, temporal and parietal cortex, dreaming, cleaning up memory? (**Echidna** does not have REM sleep)
* **Eye movements and EEG** are recorded during sleep to differentiate between the stages
* **Sleep cycles through the stages**: starts with 1, then 2, then usually 3,4&2 mix up before going to REM sleep (20-25% of sleep), the usually change between 2,3 and REM
* **Functions** of sleep: energy saving, brain restoration, memory: strengthen and weaken connections

**Binding Problem**

* Refers to the process used by the brain to combine (or “bind”) the results of many sensory operations into a single percept
* Clinical neuropsychological evidence for the binding problem:
  + **Apperceptive agnosia** 🡪 shapes 🡪 spatial grouping
  + **Achromatopsia** 🡪 colors 🡪 feature integration
  + **Prosopagnosia** 🡪 faces 🡪 part binding
  + **Semantic dementia** 🡪 semantic-conceptual binding
  + **Simultanagnosia** (Balint’s syndrome) 🡪 location binding
  + **Akinetopsia** 🡪 motion 🡪 serial, event binding
* **Feature integration theory** (Treisman): object perception differs from object recognition and features are “registered early, automatically and in parallel, while object are identified separately”
* **Binding by neuronal synchronization**: binding is achieved in temporal dimension, Synchronous oscillation of neurons

**Free Will**

* **Readiness potential** (RP): Combination of EEG and MEG, 1 second before muscle activity (Kornhuber)
* **Libet**:
  + Experiment: measure time of decision making and compare with RP; move your finger when you want and remember position of clock 🡪 Determine relationship RP and subjective experience of free will
  + **RP** -550ms; **Will to move** -200ms; **EMG** (Muscle Activity) 0; **WS** (Correct will to move) -150ms
* **Soon’s fMRI experiment**:
  + Stream of letters every 500ms
  + Press button when you want, left or right
  + Remember letter when you pressed the button
  + Correct prediction 7s before decision, 10s with BOLD
* **Qualia**:
  + **Chalmers**: easy problem and hard problem
  + **Nagel**: what is it like to be a bat?
  + **Inverted Spectrum problem**: maybe other people see white like we see black
  + **Mary the color scientist**: lived in a black and white world but know all about color, does she learn something new when experiencing color for the first time?

*KRCP Lecture 11*

*Reasoning & Intelligence*

**Deductive Reasoning**

* Conclusion follows certainly from premises
* **Syllogism**: consist of premises (containing quantifiers) followed by a conclusion
* **Atmosphere effect**: Some premises imply a special atmosphere and influence a person in the process of decision making
* **Categorical reasoning**: take two bits of information and conclude a third bit, validity is here not connected to soundness
* **Conditional reasoning**: Syllogistic reasoning
  + **Antecedent** = p, **Consequent** = q, Result, If p then q
  + **Modus ponens** (Method of affirming): P2=p, then the conclusion=q
  + **Modus Tollens** (Method of denying): P2=not q, then the conclusion=not p
  + **Denying the antecedent** error: P2=not p, C=not q
  + **Affirming the consequent** error: P2=q, C=p
  + **Wason Selection task**:
    - 4 cards on the table (letters on one side, numbers on the other)
    - Tell participants a rule
    - Which cards do you have to turn in order to test if rule is correct

**Inductive Reasoning**

* From a large body of evidence, we make conclusions that are probably true
* **Heuristics and Bias** (Heuristics are “rule of thumb”)
* **Availability heuristics**: biased by recency and frequency
* **Representativeness heuristics**: biased by an existing prototype in our minds

**Expertise**

* 3 stages of skill acquisition:

1. **Cognitive stage**: develop declarative encoding
2. **Associative stage**: errors eliminated and good actions strengthened
3. **Autonomous stage**: no more thinking required (procedural skills)

* **Power law of learning**: T=aP-b
  + T=time needed to solve/perform a task
  + a=learning constant
  + P=practice
  + b=scaling constant
* **Tactical learning**: you learn the sequence to solve a particular problem
* **Strategic learning**: you learn to organize solution differently
* **Deliberate practice**: motivated to learn, given feedback on performance, focus on improving performance

**Intelligence**

* IQ Test
  + Result is compared to **relative/normative** group
  + Different **subtests** that try to test different abilities, show correlation amongst them; combined into **factors** (one factor (g), multiple factors, or 2 **crystallized** **intelligence** (acquire knowledge) and **fluid intelligence** (ability to reason in novel domain) according to psychologist)
* **Flynn effect**: substantial and long-sustained increase in both fluid and crystallized intelligence test scores measured from 1930 to the present day
* **Construct validity**: degree to which a test measures what it claims to be measuring

**Artificial Intelligence**

* **Consistent**: a formal system is consistent if it does not contain a contradiction
* **Complete**: a formal system is complete if all the statements that can be made in a system are “decidable” within the system
* **INDUCE**: Medin, Wattenmaker, Michalski (1987), Heuristic (rule based) search, category validity vs. cue validity, humans use category, INDUCE cue
* **DEEP BLUE**: Chess computer, won against world champion
* **Dijkstra**: “Asking if computers can think is like asking if submarines can swim”