LECTURE 1

The mind performs computations on representations.

Tri-level hypothesis

1. Computational level

2. Algorithm level

3. Implementational level

Classical view, Connectionist view

Computations are parallel in the network.

Mind -body Problem

1.Monism—(Idealism, Materialism) • only one kind of state or substance in the universe

Materialism (physicalism): All things are made of atoms

2,Dualism-(Substance Dualism, Property Dualism) mental and physical substance are possible

3. Functionalism

Functionalism – What the mind does

functionalism mental states are not just physical states but also the functioning or operation of those physical states

Functionalists believe that biological neurons are needed for multiple realizability

Functionalism is the precursor of evolutionary psychology

Functionalism describes the mind as a stream of consciousness

Analogy: Different shapes of clay are different physical states of brain, no non-physical or spiritual substance.

In analogy to chemical elements the Voluntarists wanted to create a periodic table of mental elements

*The brain consists of approximately 100 billion neurons

*There are more possible connectomes than protons in the universe true: (100**10**22 vs. 10**80)

*4 DIFFERENT FORM OF REPRESNTAIONS (CONCEPTS, PROPOSITIONS, RULES, ANALOGIES)

* Feature of representation (Symbolic, semantic, Intentionality, Appropriate casual relations)

What is the symbol grounding problem?(important)

symbols computers use have no meaning or semantic quality. To be meaningful, symbols have to be connected to the environment in some way. People and perhaps animals seem to have meaning because we have bodies and can perceive things and act on them. This grounds the symbols and imbues them with semantic quality. Since machines are not embodied, they cannot acquire meaning

*Concepts are statements about entity.

* computational refers to exact formulation of problem

* inductive reasoning refers to drawing conclusions from several observations of specific instances of the world. (Whiskers the cat has four legs. Scruffy the cat has four legs. All cats have four legs.)

*2 branches of philosophy are Metaphysics and Epistemology

* Dualism and Monism are two theories trying to solve the mind-body problem

* The primary method of philosophy is reasoning.

* Idealism is one sub-theory of Monism.

* Materialism everything consists of physical substance

Primal method in philosophy: Reasoning

● Deductive reasoning: Logic to derive new statements, Given an initial set of statements assumed to be true, philosophers can derive other statements that logically must be correct,

● Inductive reasoning: Draw conclusions based on observations Cat A has 4 legs Cat B has 4 legs Therefore, all cats have 4 legs

* Rene Descartes believed substance dualism

* Psychology exclusively studies internal events (e.g. perception), also investigates the behavior

* Psychology young compared to philosophy

* Dependent variable is the parameter that is measured in the experiment

* Systematic errors have to be prevented by randomization and counterbalancing

* Systematic errors are not regarded in inferential statistics (e.g. t-tests)

* In experiments at least two groups have to compared (experimental group and control group)

* IQ is just one number

* Historic IQ-tests had a strong cultural bias

* A major criticism of IQ tests is that intelligence cannot be represented in a single number

*ID is the mental structure, which always tries to maximize pleasure

* Pavlov's dog is an example of classical conditioning

*The skinner box is a tool to investigate operant conditioning

LECTURE 2

Psychology as a science since late 19th century

philosophical behaviourism: behaviours are indicators of mental states They believe the environment controls a person's actions, not mind.

Early psychologist relied on introspection and phenomenology

independent variable: manipulated by experimenter

• Dependent variable: what is measured or observed

• Minimum of two conditions: experimental group vs control group

Any difference in dependent variable between 2 groups should be caused by manipulation (independent variable)

Voluntarism

• Mind consists of mental elements assembled into higher cognitive components through the power of will (= voluntary effort of the mind)

Two types of conscious experience

• Immediate experience: direct awareness of something (we see a red rose)

• Mediate experience: mental reflection (mental reflections about an object)

Tridimensional theory of feeling" -> all feelings characterized by three dimensions (experiments with metronome) Pleasure – Displeasure, Tension – Relaxation , Excitement – Depression

Structuralism

Combination of elements not affected through active will

Focus on mental elements, structure of mind between elements and their combinations

*The main method of Voluntarists and Structuralists was introspection

* In contrast to Voluntarism in Structuralism subjects were trained on performing introspection to improve the scientific rigor

* Functionalism : functionalism mental states are not just physical states but also the functioning or operation of those physical states

Early psychology concentrated on techniques such as introspection and phenomenology

Modern psychologists ● Hypothetico-deductive approach : a hypothetical conjecture about the way the world works, is tested deductively. testing

Three-tiered system of consciousness

* Sigmund Freud proposed the three-tiered system of consciousness (unconscious, pre-conscious, conscious)+

• Conscious mind (contains thoughts and feelings which we are aware of, home address)

• Pre-conscious mind (thoughts we can bring to consciousness with efforts, recall what one did last Friday)

• Unconscious mind (thoughts and experiences that can never be brought to consciousness, childhood memories)

Three other mental structures with different operation modes

ID_contains unconscious impulses and desire,

Super Ego,- is responsible for ethical sense

Ego- balances the demands of super ego and id

Three goals of psychology according to Titchener:

○ Describe consciousness in terms of most basic components(Like voluntarism??)(element is basic if remained constant over numerous introspective trials)

○ Discover the laws by which these components associate

○ Understand relation between elements and psychological conditions

Behaviorism

Behaviorism rejected introspection

Behaviorism was highly influenced by animal research (animal experiments were performed)

Behaviorists assume the mind as a black box and investigate the behavioral responses of subjects after presenting a stimulus

Classical Conditioning: Pavlov's experiment: Studying the dog's digestive systems

Operant Conditioning: Skinner Box (with the rat) ● Which conditions causes animals to act in a certain way

Learning through (conditioning) ● Reinforcement (behaviour strengthened) ● Punishment (behaviour diminished)

Gestalt psychology

*Gestalt psychology is a counterreaction to Voluntarism and Structuralism

* Main method of Gestalt psychology is phenomenology

*Max Wertheimer defined the principles of visual perceptual organization

Gestalt principles of perceptual organisation:

-Proximity (Parts that are close are perceived as a whole) –

Similarity (Parts that are similar in lightness, colour ,shape group together.

-Closure (A coherent whole because of closure.

-Pragnanz (Parts that are simple will group together.

Neurons

Brain Contains Two main cells(Neurons, GLIA)

Neuron-information processing and concentrated on cerebellum

Consists of : Dendrites(input signal), Cell body(cell soma), Axon(output signal)

Multiple dendrites = multiple inputs

Different types of neurons:

● Bipolar: cell of retina,

● Ganglion cell of dorsal root(which cell body is not between dendrite and axons, they carry pain signals, Unipolar)

● Motor neuron of spinal cord(multipolar)

● Purkinje cell of cerebellum(with a planar dendritic tree)

Excitatory or Depolarization if total signal be large enough to active neuron

Inhibitory or hyperpolarization if the total signal is not large enough to activate neurons

An action potential is a rapid rise and subsequent fall in voltage across a cellular membrane with a characteristic pattern.

Glia- supporting and cocentrated on cortex

Cortex(Astrocytes, Oligodendrocytes,Microglia)

Synapse

Connection between two neurons (transmitter / nerve terminal).

● Presynaptic terminal (sender)

● Postsynaptic dendrite (receiver)

This transmission happens: electrically or chemically

Two kinds of nervous system:

● Central nervous system (Brain, spinal cord, brain stem)

● Peripheral nervous system

Oligodendrocytes are in the Central nervous system

Schwann cells are in Peripheral nervous system

Microglia : 15% of total brain cells, clear plugs and remove damage or unnecessary neurons ,react to infections and injuries and try to regulate the inflammatory

Astrocytes to the control of the blood brain barrier(BBR) and blood flow.

Inside a neuron: cytoplasmic site

outside a neuron: extracellular site

Both full of ions: K + , Na + , Cl - , Ca(potassium, sodium, chloride and calcium respectively

The difference in total charge outside and inside the cell is called the membrane potential

When the membrane potential increases relative to the resting state(bigger than -60 which was resting voltage) we call it depolarization

● When it decreases(less than -60), hyperpolarization

The ion concentrations when action potential is going to happen:

● high concentrations of potassium (K+) in the cytoplasmic site and low concentrations in the extracellular site.

● high concentrations of sodium and chloride ions (Na + , Cl -) in the extracellular site and low concentrations in the cytoplasmic site

In resting state, when the neuron doesn't send any signal the concentration of sodium Na outside the cell(extracellular) is more than inside(cytoplasmic), Potassium K inside is more than outside , which Causes difference in charge across the membrane, called electrical gradient

Brainstem: pre-processing of the signal coming from periphery

• Thalamus: controls which signal is transmitted to cortex

Grand Central Station of the Brain"

Hypothalamus: Connection of the brain and the endocrine system

o The thalamus is the 'gate to consciousness' o The thalamus filters out 'irrelevant' information

• Cortex: Higher processing an perception: conscious perception, voluntary movements, language, math reading, memory storage and retrieval

• Hippocampus: spatial orientation, memory formation and distribution

The hypothalamus has very similar functions as the thalamus-→False, : Hypothalamus controls endocrine system

All sensory input (except olfactory input) has to pass through the thalamus

o The thalamus consists of several nuclei (e.g., lateral geniculate body, medial geniculate body)

Broca's Area: Lost the ability to speak, only word(left posterior inferior frontal gyrus)

Wernickes's area →comprehension of written and spoken language after injury to the left superior temporal gyrus

occipital cortex→total or partial loss of vision in a normal-appearing eye caused which magnitude is the resting membrane potential of neurons?

• 10 different pathways from eye to the brain have been identified

Epilepsy:--> loss of consciousness, shaking

Henry Gustav Molaison unable to form new memories

Prepared By Mr. RAMRACHAI MARMA (It took lot's of time hope everyone will get benefit)

• Unable to form new explicit memories: experiences • Only short-term memory of a few minutes • Still able to learn new motor skills: playing an instrument

sensory and motor pathways cross in the brain -> right visual field, right hand input -> processed in left cortex -> left cortex controls right hand

Neurons below the anode become depolarized -> more excitable

• Neurons below cathode become hyperpolarized -> less excitable

Hebb‘s rule

“neurons wire together if they fire together,”

Structural plasticity: A connection has to be established when both neurons fire at the same time.

If the first neuron's presynaptic fires before the second neuron’s postsynaptic, Long Term Potentiation happens, meaning the connection becomes intensified

If the first neuron's presynaptic fires after the second neuron’s postsynaptic, Long Term Depression happens, meaning the connection becomes weak.

BRAIN

Each part of the brain exists twice: left and right side (except glands and corpus callosum)

Cerebral Cortex: left and right hemisphere

• Corpus Callosum connects both cortical hemispheres

• Left hemisphere represents right side of the body and vice versa

Right hemisphere: extraction of big picture

• Left hemisphere: more detail oriented

Left hemisphere shows:

• larger total specific gravity • larger insular cortex • larger gray matter (neurons‘ cell bodies) fraction • larger inferior temporal lobe • larger primary sensory areas • smaller association areas

Wada test was used to evaluate the strong bias of language processing to the left hemisphere

Spinal Cord (connects CNS to PNS)

○ Brain Stem (connects brain to spinal cord. Maintain control functions, breathing, heart beat, blood pressure)

Wernicke’s area is on the left side of the brain

The right cortex hemisphere is important to process the prosody (rhythm) of speech

The cochlea contains the inner hair cells, which transduce the mechanical signal to a chemical signal (inner hair cells = sensory cells)

Pons: connection between brain and cerebellum, important for eye movement (saccades), responsible for generating rapid eye movement (REM) sleep

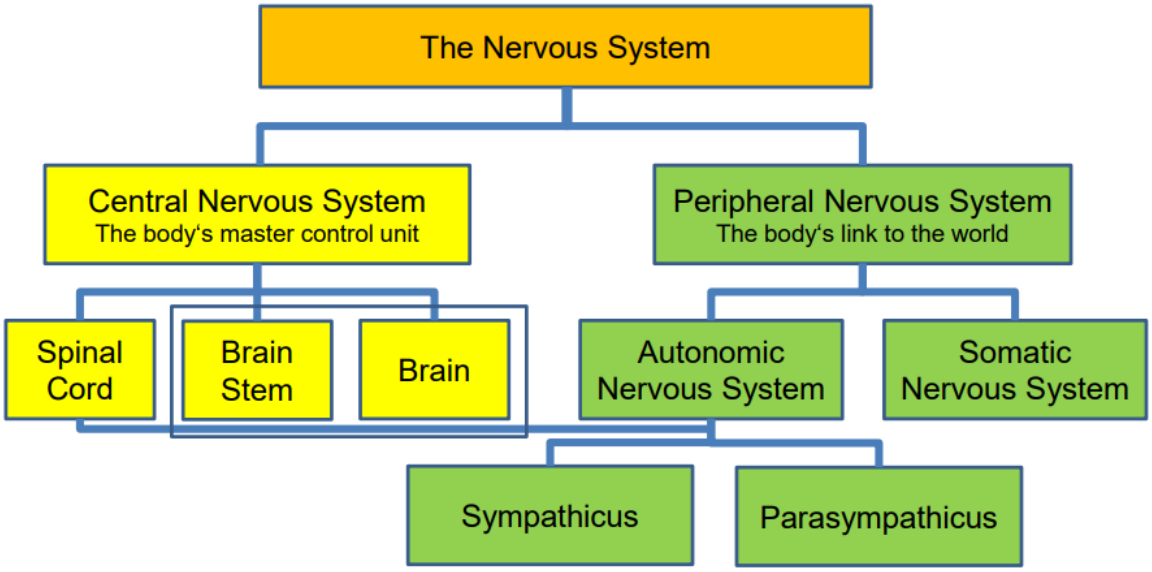
Functional asymmetries

Left hemisphere:
- Language: Word detection/generation
- Verbal
- Right visual field
- Right body motor control
- Reading
- Problem solving
- **Sequential processing** (math…)
- **Analytic**

Right hemisphere:
- Melody, Pitch, Intensity
- Non-verbal
- Left visual field
- Left body motor control
- Drawing, **face recognition**
- Visio-spatial tasks
- Parallel processing

Causal inferences are a specialized ability of left hemisphere -> left hemisphere is the interpreter

NERVOUS SYESTEM



The autonomous nervous system mainly controls smooth muscles of the intestines, e.g. the heart and glands

The autonomous system can be divided is sympathicus and parasympathicus

The sympathicus is responsible for stress related responses of the body and accelerates the heart rate. increases heart rate, prepares body for action (fight or flight)

Parasympathicus slows heart rate stimulates digestion

The parasympathicus increases its activity when a threat is perceived-→FALSE

The central nervous system consists of spinal cord and the brain (including brainstem)

Cerebral Cortex

Made of large sheets of layered neurons (contains cell bodies and dendrites, input axons

outer layer of neural tissue of the cerebrum in humans' and other mammals' brain.

4 Parts(frontal lobe, Parietal lobe, Occipital lobe, Temporal lobe(Language))

*semantic memory,auto-biography memory,

Responsible for: Voluntary movements + Conscious perception

Association functions: Important for language expression

Approx 16 billion neurons

o Gyri are indentations (valleys) and sulci are the elevations (mountains) of the cortex→FALSE gyri=mountains

Cortex can divided anatomically, cytoarchitectonic, and functional

The cortex consists exclusively of neuronal axons (white matter)→FALSE, cortex is gray matter, layers of cell bodies and dendrites

Cortical Layers

*Nissl stain(cell bodies of neurons)

*Golgi Stain(: dendrites and axons of a random subset of neurons)

Left: Nissl-stained visual cortex, adult Middle: Nissl-stained motor cortex, adult Right: Golgi-stained cortex of an infant

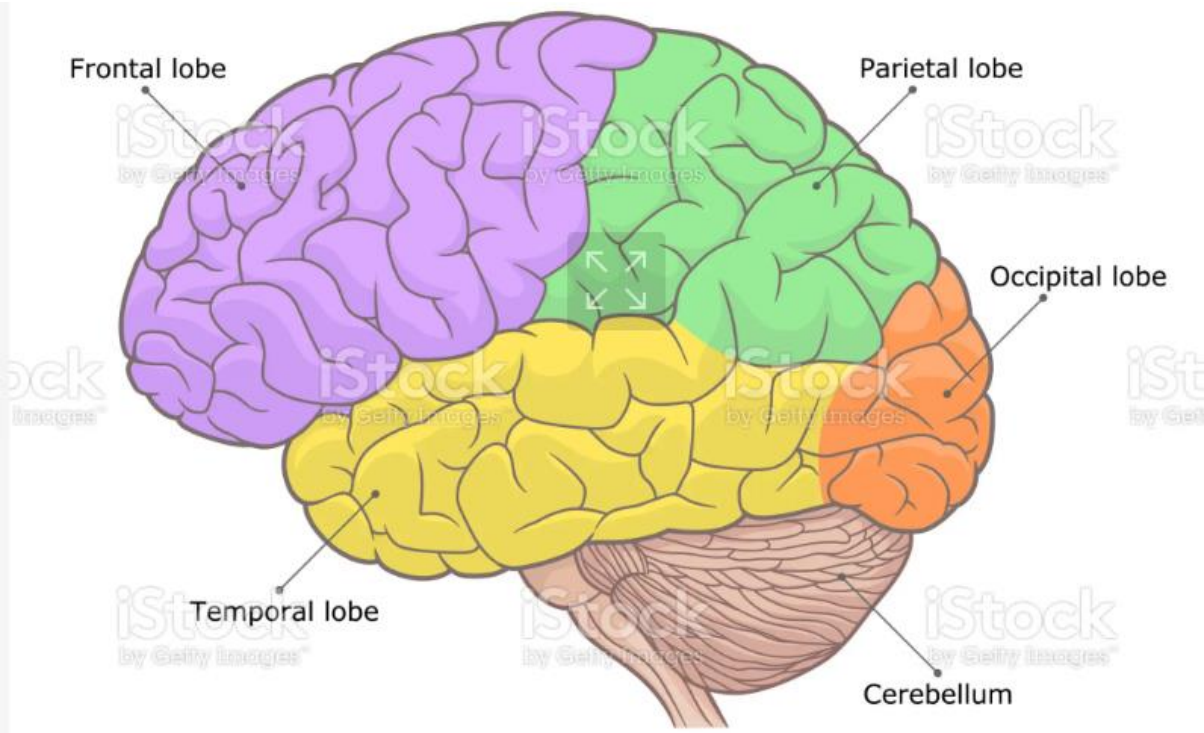
Six layers with characteristic cell types in each layer

- Layer 4: input layer (stellate neurons)
- Layer 5: sends signal from cortex back to thalamus (pyramidal neurons) -> Later more

1 cortical sheet 20 billion neurons, 200 milion minicolumns, 2 milion macrocolumns

1 macrocolumn- 100 minicolumns, 10,000 neurons

1 minicolumn—100 neurons



Brodman areas: classified cerebral cortex to 52 different areas based on the structure of the cortical layers

The cortex is described in 3 parts: (Sensory, motor(Voluntary movement), association)

Primary sensory cortex

- Senses of hearing: Primary Auditory Cortex
- Senses of touch: Primary Somatosensory Cortex
- Senses of vision: Primary Visual Cortex.

Primary motor cortex: which executes voluntary movements

. ○ The supplementary motor areas and pre-motors cortex which selects voluntary movements.

Posterior parietal cortex: which guides voluntary movements in space

○ Dorsal prefrontal cortex: decides which voluntary movements

Neocortex(yellow part) is formed of six layers, from the outermost layer,near the skull(number 1), to the innermost layer to the underlying white matter(number 6).

Cortical Columns

A cortical column, also called hypercolumn, macrocolumn, functional column or sometimes cortical module, is a group of neurons in the cortex of the brain.

10000 neurons

Minicolumn (80-120 neurons)

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Amygdala

● Highest control unit of Emotional responses Controls of fear, anxiety, aggression

Hippocampus

● Able to build new neurons even in the adult brain and save new experiences and new memories

● Spatial Navigation

● Episodic Memory

Inside the Cerebral cortex, we can find three parts:

● Limbic system (Forebrain) : located within the cerebrum of the brain

● Basal Ganglia : Servo-mechanism“ for cerebral cortex , Collection of nuclei near the thalamus, Tasks: action selection, motor preparation, motor learning, reward-based learning

● Shortcuts from sensory association areas to motor control areas

● Thalamus: “Gate Keeper“ of cerebral cortex

Cerebellum

Error correction of movements

Learning of new motor skills

Contains most neurons of the brain: 69 billion neurons from 86 billion neurons in total

The brainstem is evolutionary older than the cortex

Damage to the brainstem is life threatening in most cases

The cerebellum is the brain structure that contains approximately two thirds of all brain neurons

The brainstem consists of medulla, pons, midbrain (mesencephalon)

The pons is a substructure of the cerebellum→FALSE, Pons is a part of the brainstem together with medulla and mesencephalon

Purkinje cells only output from cerebellum

mV

Which of the following ions is barely involved in membrane potential generation?

Fe2+(Iron)

Which statement is true in respect to neuron-neuron communication?

Chemical connections allow signal adjustments

Single perceptrons cannot compute

Logical XOR

What statement is true w.r.t. neural anatomy?

Some neurons in the retina are bipolar

The Nernst equation is very important for calculating the equilibrium potential for ions. It is defined using the following formula:

E= (RT/zF) ln [ion outside cell]/[ion inside cell]

R: The gas constant 8.314j/mol.k

T: Temperature (in K) 273.15

z: Valance of the ion K+ for z= +1

F: faraday constant F 96,485 c/mol

The relation of the outside and the inside concentration of the ion x

Neural plasticity include (apoptosis not included)

A. Synaptic plasticity

B. Brain growth

C. Reorganization

D. Structural plasticity

Which of the following statements applies to Hebb's rule?
Hebb's rule only allows LTP

What of the following algorithm optimizes artificial neural network architectures?

Neuroevolution of Augmented Topologies

Which of the statements w.r.t. Hodgkin-Huxley (HH) models is CORRECT?

They rely on three dynamic variables: n, m and h

Image technique

Which statement on imaging techniques is correct?

In fMRI studies the blood oxygenation level is measured in order to draw conclusions on the underlying neural activity

EEG has a low spatial resolution (cm scale, Million neurons) fMRI good resolution

PET was developed to measure small currents in the brain -FALSE

Reason: Tracer is injected in blood. Positrons from the tracer annihilate with electrons. Photons are emitted by annihilation -> blood flow is measured -> no electrical signal

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Imaging Techinque

CT (computed tomography) and MRI are used to measure the structure of the brain and take advantage of the different physical properties of the brain tissue

o fMRI in contrast to standard MRI is used to draw conclusions on neural processing

o In CT, a 3D volume is reconstructed from 2D x-ray images

o MRI exploits the effect that hydrogen nuclei have a spin that creates a tiny magnetic dipole

The magnetic field strength in MRI scanners is approximately 10 fT- FALSE

MRI uses field strengths of up to 7 T; MEG measures small field strengths on fT scale:

Which statement on PET is not correct?

PET like MRI relies on the spin of hydrogen nuclei

PET measures photons from annihilation process of electrons and positrons (coincidence detection)

o For PET measurements a radioactive tracer is injected

o The tracer decays and emits positrons that annihilate with the electrons of the tissue to be measured

o The annihilation of an electron and a positron emits two photons that move in opposite directions
o PET can be used to draw conclusion on neural activity as it measures local variations in cerebral blood flow which are correlated to mental activity

FMRI

BOLD stands for blood oxygenation dependent response

o fMRI exploits the magnetic properties of haemoglobin

MEG has better temporal resolution THAN fmri

in fMRI the fraction of oxygenated and deoxygenated hemoglobin is measured called the blood oxygen level-dependent (BOLD) effect

fMRI scanners are very loud; no magnetic earphones are allowed in the scanner

Which statement on lesion studies is true?

o For transcranial direct current stimulations (TDCS) a coil is used to create a transient magnetic field to induce a transient brain lesion

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o Brain lesions in lesion studies are always generated by a physician

o Phineas Gage was an important neuroscientist

X Stroke is a vascular disorder TRUE

o To treat epilepsy the brainstem (including medulla) is removed

: Which statement on lesion studies is not true?

o Phineas Gage is a famous example for a person with an unwanted brain lesion, which caused changes of the personality

X Broca's area is important for word understanding and has nothing to do with speech production->FALSE Broca is important for speech production

o Wernicke's area is important for language understanding and is placed posterior to the Broca's area (temporal)

o Cortical blindness is caused by lesions in the occipital lobe

o People suffering from cortical blindness sometimes behave as they have seen the presented objects, but are not aware of the fact that they have seen the objects (potentially due to several different ancient visual pathways)

Neuron maturation

> Initiation > Outgrowth > Branching > Spine formation > Stopping/pruning

Pruning happens over a lifetime.

Two important events: birth and adolescence

During pruning Unnecessary connections are removed and important ones are strengthened

Two ways to prune:

● Pruning synapses: means set certain weight's value 0, Make network sparse

● Pruning neurons: means set certain activation function 0, Make network dense (Dropout in DL)

Cortical development: The cortical layers develop gradually over time during birth.

Voltage clamp:control the voltage measuring the resulting current

Current clamp :measure the voltage and control the current

Ion Channels: After the polarisation, the channel opens(channel is always binary, ie, completely open or close):

1) Resting (channel closed)

2) Activated (channel open)

3) Inactivated (channel closed)

ECoG (Electrocorticography): is a method where we measure signals on the open brain without harming the tissue

electroencephalography or short EEG that measures electrical potentials on the skull meaning. Bone and skin remain intact. Higher activity when relaxed.

In it's design they use a standard system called 10-20 system

Left hemisphere: odd numbers

Right hemisphere: even numbers

Middle line: C

Magnetoencephalography (MEG): Based on magnetic fields and electrical current flow. It is a functional neuroimaging technique for mapping brain activity by recording magnetic fields produced by electrical currents occurring naturally in the brain

* closer to the neuron we are, the more invasive the method is but with higher localization

: (Signal processing view) As white noises are Gaussian by nature, so adding gaussian signal, increases the Gaussianity of the sum of the signals(something called central limit theorem)

AI part: Using white noise feature to eliminate noise from image: Noise2Noise and Noise2Void are methods of removing noisy signals without affecting the quality of an image

Noise2Noise: uses the fact that L1 or L2 minimization converges to the median and mean respectively. and as a result loss function allows the training with images that contain zero mean noise

*If we wanna take a picture of neuron activity, they should reflect some lights, but they don't generally,

GFP - green fluorescent protein Are Proteins that absorb blue light, emit green light. Nobel prize in 2008

GFP allows the visualization of cell structures, when CELLS ARE ALIVE

Knowing the circuitry helps in identifying the purpose

: GFP itself doesn't not provide an option for calcium sensitivity

Solution: Artificial gfp(cpEGFP) is made by adding more domains to gfp and making it able to bind with calcium. in the presence of Ca 2+ we can see green light again!! No calcium, no light.

fluorescence : is a physical phenomenon. When an electron gets energy, it goes from its ground state(S0) to an excited state(S2)(this process is called absorption), but in an excited state it is so unstable because it wants to release the energy and returns to its ground state(Relaxation process)

Light that has 480 to 490 nanometer wavelengths can excite electrons, this wavelength belongs to blue.

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Emitted light has a wavelength 500 to 550nm, which is green. Use blue light, bacteria glow green!!

Voltage Imaging: Calcium imaging is way more robust with higher signals and lower technical requirements but is also not able to resolve single action potentials due to the lower signals. Here Voltage imaging helps. Compared to electrophysiology that can measure only a few neurons simultaneously,

Question: Why is calcium imaging used instead of voltage imaging?

● The voltage signal is very fast. ● Thus, action potential lasts only for one or two milliseconds which means we have to image at least 100 hertz. If not even faster to resolve the signal.

● However, calcium can be imaged at way lower frequencies that one can still observe.

● Calcium increases over time that means one can utilise normal camera hardware for custom imaging.

Optical approaches to measure neural activity

• RSA combines data from different sources by using a common representational space.

• RSA is unique in its ability to incorporate data from a variety of source

A visual scene is analyzed in 3 levels (low-level, intermediate-level, high level)

Vissual pathway

Photoreceptor->Bipolar cell->Gamglion cell-----→ Lateral geniculate nucelus---> primary visual cortex

Retina Thalamus Occipital lobe cerebral cortex

The light sensing cascade

Opsin: The light-sensing channel

PDE: Phosphodiesterase

cGMP: circular Guanosine monophosphate

Bipolar cells can bypass signal or invert signal, can amplify signal

Ganglion cells encode signal using action potentials

Inverted cell nucleus organization acts as a focusing lens

Bayer pattern image generation (incoming light, filter layer, sensor array, resulting pattern)

Demosaicing Most frequent artifact: Moiré patterns

Our communication channel: the optic nerve

Our night vision (Rhodopsin absorption)

The ON bipolar cell depolarizes upon hyperpolarization of the center photoreceptor

High level features

Receptive fields size	Features
V1>V2>V4>IT (Visual fields)	edges and lines>shapes>objects>faces

CNN depth LOW-MID-HIGH(level feature)-Trainable Classifier

IMAGING

Relaxation: the process of spins realigning themselves with the main magnetic field after excitation.

FMRI: Functional MRI aims to visualise neural brain activity.

*Functional magnetic resonance imaging or functional MRI measures brain activity by detecting changes associated with blood flow. an area of the brain is in use, blood flow to that region also increases.

*Used to compare the neural activation of one group of stimuli to the neural activation of another group of stimuli by creating a contrast that averages the response of stimuli within a group.

The BOLD effect(IMPORTANT): Able to differentiate oxygenated and not oxygenated blood, so you can measure a difference in signal depending on the amount of oxygenation in the blood.

The lower the concentration of oxygen in the blood, the higher the chance of having a high metabolism that happened there. Because metabolism burns oxygen. Can be done using fMRI.

PET/CT: (Positron Emission Tomography/Computed Tomography) Used to measure the pet signal.

PET may detect the early onset of disease before other imaging tests can.

Nuclear medicine. Observe the concentration of a specific molecule inside of the body.

In cognitive study 3 modalities exist:(Complete this part please if you understood better)

- Activity
- behaviour
- stimulus

RSA (Representation Similarity Analysis) (combines data from different sources)

Representational Dissimilarity Matrices RDMs can be created from the behaviour data by collecting the response from each individual stimulus.

Lesioning(function of a certain part of the brain)

Phineas Gage:Patients, 19 century, damaged parts of his left frontal lobe. This accident had an effect on his personality, and behaviour,

Pierre Paul Broca: A French physician, anatomist and anthropologist, left posterior inferior frontal gyrus(cerebral cortex), Broca's area, ability to produce language due to an injury

Carl wernicke a German physician, anatomist and anthropologie, written and spoken language, e left superior temporal gyrus, a part of the **neocortex** that is now known as Wernicke's area.

Broca's area + Wernicke's area important for processing language.

Henry gustav molaison severe side effect: he became unable to form new memories, Surgery was: bilateral medial temporal lobectomy

His case played an important role in

❖development of cognitive neuropsychology(

❖link between brain function and memory

❖ Unable to form new explicit memories: experiences

❖ Only short-term memory of a few minutes

cortical blindness: phenomenon of cortical blindness is the total or partial loss of vision in a normal-appearing eye caused by damage to the brain's occipital cortex.

functional deficits occur due to

● damage of a certain part of the brain

● damage of certain connections between different parts of the brain

Antonio Damasio, ● Professor of psychology, philosophy, neurology (don’t memrise :)) ● Created world's largest database of brain injurie

Transcranial magnetic stimulation (TMS): technique for simulating brain lesioning

Deep neural networks work as black-boxes. That means they are not well understood. In contrast to biological brains,

- Lateralization of Brain Function

tendency for neural functions or cognitive processes to be specialised to one side of the brain

Each part of the brain exists twice: left and right side Cerebral Cortex: left and right hemisphere divided by Corpus Callosum.

- homologue cortex areas at both sides have different functions

Left hemisphere represents the right side of the body and vice versa

Broca‘s and Wernicke‘s area is located exclusively in the left hemisphere in 95% of right-handers and 70% of left-handers.

Left hemisphere shows:

● larger total specific gravity ● larger insular cortex ● larger grey matter (neurons‘ cell bodies) fraction ● larger inferior temporal lobe(nucleus lateralis posterior of the thalamus) ● frontal lobe is narrower ● larger primary sensory and motor areas ● smaller association area

Wada test: hemispheres reversibly blocked(using imaging techniques such as magnetic resonance imaging not with surgery)

Left hemisphere :

Language (word/generation),

Verbal,

Reading,Analytic,

right visual field,

right motor control

sequential processing

Right hemisphere

Drawing, face recognition

Synthetic, holistic

Birdsong: left hemisphere

Right-Shift Theory: language dominance of the left hemisphere is due to a single gen

Computational Considerations I

● Larger primary motor and sensory areas at left side

●Smaller primary motor and sensory areas at right side

Damage in the left hemisphere could not recognize local shape, so local shape should be recognized in this hemisphere, maybe because of Larger primary motor and sensory areas and Smaller association areas in this hemisphere that enable higher resolutions.

Auditory System

The auditory system transforms and processes sound • Sound: Longitudinal wave (pressure fluctuations)

Best hearing at approx. 3.4 kHz

• sensory system for the sense of hearing -> includes the sensory organs (the ears) and the auditory parts of the sensory system

The Auditory System – The outer ear

• Funnel

• Pinna: Directional Hearing

• Transmission from pinna to tympanic membrane is not linear: -> Resonance frequency at 3.4 kHz -> frequency of best hearing

The Auditory System – The middle ear 3 ossicles(**malleus**-- malleus is connected to the eardrum, **incus, stapes**---connected to oval window), 3 bones in the middle ear

Pressure fluctuations have to be transmitted to fluid • 98% of the sound would be reflected at the border from air to fluid • 3 ossicles of middle ear -> impedance adjustment • Instead of 98% only 40% of the sound is reflected • Better hearing of 27 dB

The inner ear- The cochlea, Inner ear- has cochlea contains 3 fluid filled sections(Scala Media, Scala Tympani, Scala Vestibuli)

There are two windows here: oval window, round window, stapes pushes oval window inside, causing perilymph fluid to vibrate,and the Round window pushed outside, (the blue part in image below is inside of cochlea, and arrows show the sound(fluid) way

stapedius reflex of the middle ear saves the inner ear from damage by reducing the transmission of sound energy

stapes muscle is activated in response to sound

Cochlea

looks like snail

Organ of corti transduces mechanical signal into chemical signal (neurotransmitter release)

two type of hair cells: Inner hair cells: connected to more than 30 nerves Outer hair cells: connected to one nerve

Inner hair cells

are moved by the flow endo lymphe (not connected to tectorial membrane)

Transduce mechanical deflection to electrical/chemical signal • Tip links at top of stereocilia pull on

Outer hair cells move to further enhance the amplitude of the stimulus, no sensory cells

Outer ear- Auricle, auditory canal

hair cells convert the fluid waves into nerve signals

Cochlear Nucleus

dorsal cochlear nucleus, nucleus integrates auditory signal with somatosensory signal

Dorsal stream: Sensori-motor integration Speech production „Where stream“

ventral cochlear nucleus, nucleus extracts temporal an spectral structure of the signal

Ventral stream: Phonological processing Auditory objects Speech comprehension „What stream“

(Thalamus in diencephalon, not brainstem

Primary Auditory Cortex: • gets input from thalamus • Tonotopically organized • Processes input from both ears -> dominant contra-lateral ear • Structure with six layers

Tinnitus demonstrates that we hear not with the ears but with the brain

Tinnitus is related to hearing loss -> synapses in the cochlea are damaged -> less input in the cochlear nucleus

Decreased lateral inhibition -> does not fit to observations

Central gain increase -> amplification of low signal along auditory pathway

Central noise -> internally generated neural noise is added to the auditory system

Vestibular system: • 5 Vestibular organs •

* Utricle: Linear motion • Otoconia: inert mass • Macula: sensory epithelia • (Horizontal movements) •

* Saccule: Linear motion •

* semicircular canals (anterior vertical, posterior vertical, horizontal): Rotation • When head rotates cupula is sheared • Stereocilia are bend

The **sense of smell, or olfaction**, is the special sense through which smells (or odors) are perceived.

Chemical sense like gustatory sense

Smell is triggered by odor molecules -> odorants, Odorants bind to odor receptors/

Bipolar neurons send signal to olfactory bulb (glomeruli)

Fruit fly generates a tag for every odor (sparse representation, little overlap in active neurons between different odors) in 3 steps:

1) **Feed-Forward** connection from odor receptor to projections neurons in glomeruli (50 dimensional vector to 50 dimensions), make coding concentration independent ("centers the mean")

2) **Random projection** of 50 dim vector to 2000 Kenyon cells (40 fold expansion) via a sparse, binary random connection matrix

3**) Winner takes** all algorithm via strong inhibitory neuron (5% of 2000 neurons remain active) -> tag of an odor is firing rates of 5% active neurons (tag = hash)

Fruit Fly Algorithm outperforms standard locality sensitive hashing for all hash lengths

Perhaps locality sensitive hashing through random projections and dimensionality expansions is a standard algorithm in the brain!

The **sense of taste, or gustation** is the sense through which tastes are perceived. • Chemical sense like olfactory sense

Papillae on the tongue contain several taste buds

Taste buds contain several taste cells • Five basic tastes: salty, sour, bitter, sweet and umami

• Taste begins when a tastant stimulates a receptor

For bitter, sweet, umami -> complicated protein cascade

salty and sour -> change of ion concentration

Signal transmitted to gustatory cortex (in insular cortex) via brainstem, thalamus

Orbitofrontal cortex is important for processing the pleasantness of stimulus (chocolate)

Olfactory System(Sense of smell)

Chemosensory system: the olfactory system and the gustatory system are often referred to together as the chemosensory system as they both send information about the **chemical composition of objects to the brain**, through a process called **transduction**.

Transduction: process of sending smell and taste information from the olfactory or gustatory system to the brain

Sense of smell(olfactory system) and taste(gustatory system)

Olfaction occurs when an odour binds to a receptor in olfactory epithelium(in the nasal cavity) Glomeruli cells aggregate signals from these receptors and relay them to the olfactory bulb where sensory input begins to interact with parts of the brain that are responsible for olfactory recognition, memory, emotions and flavour.

The olfactory nerve fibres are at the back of the nasal cavity olfactory.they transmit information about odours from the peripheral olfactory system to the central olfactory system of the brain.

Gustation(Taste buds at pupillae)

Types:

○ **circumvallate (large)** ■ we have only 7 to 12 ■ at the border of the tongue base

○ **Foliate** ■ Close together towards the back of the tongues ■ Only 15 to 20 present

○ **Fungiform** ■ Largest group

taste buds are located in the walls and valleys

The Different Tastes

***salty** (ion)

***sour** (ph scale)

*__Bitter__(Denatonium ■ most bitter tasting compound known till date) Bitter tastants are detected by a family of roughly 30 g protein-coupled receptors called T2Rs

***Sweet** (The G protein receptors are called T1R2 and T1R3)

*__Umami__(Japansese) in general elicited by amino acids and ribonucleotides such as guanosine monophosphate (GMP) or inosine monophosphate(IMP). The major amino acid that drives taste is **glutamate.**

SOMATOSENSATION

sensory perception : : the perception of all mechanical stimuli that affect the body including the interpretation of signals that indicate the position of your limbs and position of your head as well as our senses of temperature, pressure, touch and pain.

somatosensation subgroups:

*Proprioception-> The sense of oneself letting for proprius one's own

* Exteroception(sight,sound,smell,touch,taste) -> Sensing the outside world ,direct interaction with the external worlds, used for identify objects

*Interoception(Headaches, hunger, proprioception)->sense of the function of the body's major organ systems

primary sensory receptor cell of the somatosensory system

neuron cell body is located in the dorsal root ganglion

the axon has two branches:

*One projecting to the peripheral target(skin)

*One projecting to the spinal cord of the brainstem

Nerve Fibre Classification

large diameter myelinated axons

small diameter axons that are either unmyelinated or thinly manipulated

The Sense of Touch: from periphery to brain

These action potentials are entering the dorsal root of the spinal cord and are sent to the brain along the dorsal column

primary sensory cortex is located in the outer surface of the brain and is posterior to the central sulcus

The postcentral gyrus contains the somatosensory cortex that can be divided into S1 and S2.

Touch We have two types of touch: active touch passive touch.

PAIN

We have three types of pain: (acute, persistent,chronic)

A-fiber(thinly myelinated) – first pain(fast)

C-fiber(unmyelinated) – second pain(slow)

Nociceptor

We have four types of Nociceptor:

1. Thermal (Aδ fiber)

2. Mechanical (Aδ fiber)

3. Polymodal (c fiber)

4. Silent (c fiber)

VISION

The principle of good continuation is also seen in contour saliency.

Object recognition depends on separation of a scene into foreground and background.

Expectation and perceptual tasks play a critical role in what is seen(use something called Priming Image). I

A visual scene is analysed in 3 levels

- Lower level processing
- Intermediate level processing
- Higher level processing

Rods and cones

Both rod and cone cells have specialised regions called the outer and inner segments.

The outer segment is attached to the inner segment by a cilium a

The circuitry for cone signals has three pathways :ON, OFF, LATERAL INHIBITION

the human eye can detect wavelengths from 380 to 700 nanometer)

Remember **Cones were responsible for colour detection**, we have Blue cones(Detecting Blue), Red cones, and Green cones. Also we have Rodes which could detect B and W, this is why we see four charts here

Colour weakness or blindness is transmitted by the mother, not the father.

The Optic nerve does not contain any photoreceptors and on this spot.

Our night vision Mainly the light we see in the dark is **greenish**(because green is more in light/nature). But since we are mainly **using Rods in the dark**, we see grayscale images.

The visual system uses information about local orientation and contrast to construct the contours and surfaces of objects

Object representations can be stored in working memory and recalled in association with other Memories

BOLD response in the lateral occipital cortex is responsive to shape, even if the boundaries of the objects are never physically presented. The BOLD response is high when an object is perceived, either defined by luminance or a correlated pattern of moving dots. The response is low when the dots move in a coherent direction or at random.

MOTOR SYSTEM

The motor system allows us to navigate and behave in the environment

Two kinds of behaviour: 1. Voluntary 2. Involuntary

We have three kinds of muscles(CARDIAC muscles, skeletal muscles, smooth muscles)

alpha motor neurons

Electromyography (EMG) : ● to record the muscle activity

Basal ganglia: play a very critical role in movement initiation.

Basal ganglia and the cerebellum are two prominent subcortical components of the motor pathway.

Language

Language is to the mind more than light is to the eye“

William Gibson, Author

There is no real animal homolog for language

Language enables us to learn from experiences

• Language areas: Left temporal cortex: **Wernicke's area** in posterior superior temporal gyrus,

inferior parietal lobe (supramarginal gyrus), Left inferior frontal cortex: Broca's area, Left insular cortex

Aphasia: collective term summarizing deficits in language understanding and production

• Broca's aphasia ("tan"): problems with speech production (Broca's view) but also with grammar (syntax -> agrammatic aphasia)

• Wernicke's aphasia: problems with speech understanding, produce fluent speech but sentences make no sense (modern view: areas around Wernicke's area have biggest influence)

Damage of white matter tract from Wernicke's to Broca's area called **arcuate fasciculus**

the brain must store words and concepts -> mental lexicon

Semantic relationships in mental lexicon • Example: A quick priming study to explore your mental lexicon

Distance between words is determined by sematic relations of words

Auditory system has to solve several problems:

1) phonemes sound different for male and female speakers,

2) Auditory speech signals are not clearly separated (even not between words

Prosody (rhythm and intonation) helps to segment the speech stream

28 feature demons decode features in the iconic representation

After identification of a phonological or visual representation semantic and syntactic information must be retrieved

Interactive models: all types of information can participate in word recognition

Hybrid models (in between): the context reduces the number of possible word candidates in the mental lexicon

lexical selection is indeed influenced by context

N400 wave is a negative voltage peak in ERPs and is sensitive to semantic aspects of linguistic inputs • Semantic violations lead to larger N400 (more negative) wav

P600 also called syntactic positive shift • 600 ms after syntactic violation

Broca's area and inferior frontal cortex involved in syntactic processing

Models of language comprehension involve unifying from linguistic inputs with stored knowledge

MEMORY

Memory is the brain's ability to encode, store and retrieve data or information when needed

Memory as information processing system: Sensory processor → short-term / working memory → long-term memory

Acquisition: Bringing sensory stimuli which are stored in sensory buffer to short-term memory • **Consolidation:** Changes in the brain are stabilized to form long-term memories

Types of memory (potentially mediated by different neural mechanisms):

• Sensory memory (unconscious) Sensory Memory holds information from sensory organs <1s

• Short-term memory (conscious) very limited capacity: 4-5 items, Capacity can be increased by **chunking**

• Working memory (conscious)

• Long term memory

Types of memory:

Declarative / explicit memory: conscious - semantic, episodic, autobiographic

Non-declarative / implicit memory: unconscious - procedural, priming, perceptual

Anterograde amnesia: Loss of all memories after a lesion -> inability to from new memories • **Retrograde amnesia**: Loss of memories before lesion (sometimes only temporal loss

Neuroimaging studies also confirm that **hippocampus** is involved in retrieval of episodic memories

hippocampus to encode information

The sensory processor enables the perception of information from the external world in the form of chemical and physical stimuli

The working memory

● serves as an encoding and retrieval processor

● information in the form of stimuli is encoded by the working memory processor according to explicit or implicit functions.

● also retrieves information from previously stored material.

● Also performs manipulations on the memory whereas short term memory does not perform manipulations.

Long-term memory ● to store data through various categorical models or systems

Types of Long-term memory(declarative/explicit),(Non-declarative/implicit/procedural)

The memory process can be damaged by physical damage to areas of the brain associated with memory storage such as **the hippocampus.**

Retrieval of information from long-term memory can be disrupted due to decay in **long-term memory**

Sensory memory

● stores information derived from the senses for less than a second after an object is perceived

. ● beyond cognitive control and is an automatic response

Types of sensory memory:

● Iconic : store of visual information , briefly stores an image perceived for a short duration

● Echoic: store of auditory information , briefly stores sounds perceived

● Haptic: database for touch stimuli

The Libet Experiment

unconscious brain activity of the readiness potential (RP) leading up to subjects' movements began approximately half a second before the subject was aware of a conscious intention to move