Intro to Cognitive Science

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- Cognitive science - how the mind works and what constitutes the mind
    - Interdisciplinary study of the mind and intelligence with a focus on computation
    - It is basically thinking about thinking
- Top down processing - Experiences guide how someone perceives something
    - Memories influence how we perceive something
    - Draw up on your experiences and memories - illustrated through visual and auditory illusions
- Bottom up
    - Building up a perception right from the fine details
- Color constancy
- The binding problem
- Memories are core part of who we are
- Childhood amnesia - pruning
- Neuroplasticity - the younger the brain, the more plastic the brain is and therefore the connections formed then are stronger
- Interference - when young you don't have to learn a lot or have too much responsibility and hence you retain information but when you grow up, you learn a lot of skills at the same time - more worrying and stress - this has profound influence on learning and memory
- Process, learn and remember information - experience has a lot of influence
- Chunking is dividing up streams of information into little meaningful chunks
- Fluid intelligence and crystallized intelligence
    - Crystallized intelling, even while growing up, is fully intact, that is, facts about the world and so on
        - Mind grows with age, this kind of intelligence is probably what we are talking about
    - Fluid intelligence tests when you have to flexibly do some tasks
- How are we able to rapidly process and interpret external information
    - Neurons - the brain's communicators
    - Electrochemical signalling in the brain happens in these neurons and between neurons
    - 100 billion neurons
    - Many neurons forge ten of thousands of connections with other neurons leading to 160 trillion connections in the brain
    - We are not sure if each of these connections retain memory
    - Attention - a lot of information is coming to the brain and we have to selectively process some parts of the information and not attend to other parts/ discard information about other parts to be efficient ; you cannot pay equal attention to all parts of the information
    - Memory - experiences come to bear upon how you process current information

        - Replay - replaying past experiences ; just to remember
        - Preplay - related to stimulating the future ; predict the future
        - Most people now think, one of the primary reasons we have memory is to predict the future which is the core part to our survival
    - Mental simulations - depend on memory
        - They are imagination of a sort
    - Bayesian/predictive brain - mathematical theory of how you come to use your experiences to construct probabilities of what you are about to see, and how you update those probabilities based on what you end up seeing
        - Aspect of prediction
        - Aspect of checking whether your prediction was right
        - Aspect of prediction error between what you predicted and what you saw
    - Multisensory perception and regulation - when you process information in the world, you have auditory, visual, tactile (feeling on your skin) information coming to you
        - Pulvinar is thought to be involved in multisensory perception
        - Pulvinar is the nucleus of the thalamus and is connected to all region in the cortex area (outer surface) of the brain
- Imagination is a very related concept to memory
- Since everyone has lived a different life, everyone's brain is different
- The binding problem
    - Perceive an apple as a unified object
    - Size, smell, shape, etc are processed in slightly different brain regions/neurons
    - How do these different components and senses integrate into a single perception is the problem of binding
    - In neuroscience, coherence of activity ; neural activity in different brains regions and coherence helps bring together information from different brain regions to form one associated concept
- Practical applications
    - Brain - Computer Interfaces (BCIs)
        - Involves having an implanted recording electrodes on the surface of the brain to something who has lost the ability to speak
        - Record signals from brain and apply machine learning techniques to predict what word the person intended to say and then you augment those machine learning models with natural language processing models
        - Population coding
            - Neuroscience concept - trying to understand how neurons/ little populations of neurons actually code for different aspects of information
            - Cluster of neurons and motor cortex that indicate a certain movement that you want to make
            - High gamma band for 70-150hz - to create this you need to know filter your data and know how to construct your filter

            - Word classification/real time classification, predictive text processing
- Applications of cognitive science (due to the above reasons - how many fields and models belonging to different fields and concepts) has to have
    - Division of labor
        - Psychology, linguistics, neuroscience, computer science, philosophy
- Cognitive science as a interdisciplinary study was founded in the 50s
- Behaviorism
    - Early thinkers thought that there was no insight that the animal brings to the problem
    - It all trial and error learning and behavior changes because of the consequences it has - The law of effect
    - Later thinkers realized that yes we can study the organism and what the organism and its mind bring to the problem
    - Thus behaviorism led to cognitive
    - Radical behaviorism says cognitive models is not possible since thoughts are unobservable
- Cognitive models ask the question of “where does thinking come into play?”
- SOR Models : Stimulus-Organism-Response
    - Organisms interpretation of the problem and how it solves the problem is just as important as understanding the stimulus and the consequences of that behaviour
- Latent Learning
    - Rats learn from their own experiences without having the need to be reinforced by reward like food
    - Cognitive maps then established through these experiments and were a challenge to radical behaviorism and thus people moved on from radical behaviorism
    - Latent learning in a maze suggested to people that you can change behaviour as also a consequence of cognitive learning and not just reinforcement
- Cognitivism
    - Idea of latent learning / cognitive learning led to the idea of mind is like a computer
    - Mind gets some information, processes the information and outputs a behavior - how do you understand this process?
- Computer model
    - Mind is an information processing system and there are two important components to this
        - Operate on symbols - true of computers and people think true of humans
        - Programs that operate on symbols in the computer
            - Neural computations which are programs which act on mental representations in order to perform your computations that result in your behaviours and how you understand the world
    - Mental representations

        - In the mind, we have mental representations which actually are stand ins for concepts out in the world and then there are functions and programs within the mind that operate on these mental representations
        - They are symbols in the brain that have meaning or encode information
    - Information processing in the mind
        - Perception - acquiring real time information about the surrounding environment
        - Language use - making use of information about syntax, semantics and phonology
        - Reasoning - combining different sources of information, deriving new information, testing consistency of information, etc
        - Action - making use of information in action planning and guidance
        - Memory - storing and retrieving information
    - Marr's Three Levels of Analysis
        - What causes us to remember?
        - Read the chapter of Marr's book
        - A complete understanding of computation system involves three levels
            - Computation
                - Understand the problem - what is the input? Output? What information is needed to be extracted to solve the problem?
                - You need to make some assumptions about the problem to make the problem tractable
                - Specifies the problem
            - Algorithm/Representation
                - basically the software
                - What kind of representation you need to solve the problem you identified in the computational problem
                - How does the system do what it does? - specify and hypothesize the operations that go on in the brain - what assumptions, computations and representations should you choose
                    - Eg : for color vision you do through psychophysics - basically, you ask people what they see
                - Specifies the way the problem is solved
            - Implementation
                - Basically the hardware - here come the neurons, brain regions that implement the computations!
                - But first, understand the problem to be solved
                - How is the computation physically realized in neurons and brains and even computer models?
                    - Via brain recordings, computer simulations, etc
                - Specifies the medium or physical substrate in which the problem-solving procedure is executed

- Color constancy
    - Light rays that come to your eyes are a function of the reflectance (reflectance of the block here) and the source of illumination
        - $L(\lambda) = R(\lambda) * I(\lambda)$
- Ill posed problem
    - Without access to 'I' you are supposed to decipher R
    - Not enough information to solve the problem
    - Many problems in cognitive science are ill posed
    - Therefore, to begin to solve these problems, you need to bring in additional assumptions to make these problems tractable
    - Example : Problem of reference
        - When one does not know what something refers to so you make assumptions to understand
- Methods in cognitive science
    - Thinking/theorizing, writing code, analysing natural stimuli, physics, ecology etc
- Beyond mental representations
    - Embodied cognition - you are not just your brain, but pay attention to your body and bodily experiences of the environment as well
    - Mind arises from the nature of our brains, bodies and bodily experiences
    - Dynamical systems - study of cognitive systems, systems that change over time therefore your focus now is on the dynamics of these systems, you reject the information processing view of the mind, reject the need for representations. A lot of mental phenomenon can be explained with dynamical systems

History of Cognitive Science

- Cognitive science rooted in the history of philosophy like rationalism vs empiricism and arithmetic and logic (thinking about mind and how human study the mind)
    - Plato (Rationalism) - all phenomenon can be understood by thinking and reflecting on how one acquires knowledge - reflecting thinking gives rise to knowledge and understanding
    - Aristotle (Empiricism) - phenomenon are to be observed and experienced through systematic way of observation leads to knowledge
    - Theory of knowledge (nature and origin of knowledge) (Epistemology)
- PDP - Parallel Distributed Processing
- History of Cognitive Science
    - Vygotsky and Piaget - Influential theorists on Cognitive Revolution
        - Piaget
            - children go through 4 stages of development
            - Stage 1 - sensorimotor period - out of sight, out of mind
                - Birth to 2 years
            - Stage 2 - Preoperational period

            - 2 to 7 years
        - Stage 3 - Concrete operational period
            - 7 to 11 years
        - Stage 4 - Formal operational period
            - 11 through adulthood
        - Offered epistemological knowledge
    - Vigotsky
        - Emphasized the individual embedded in the society
        - Culture, society and individual gives rise to cognitive gains in the individual through the interactions between these cultural setting
        - zone of proximal development - what individual can do alone and with the support system around them (ecological surrounding) - skills and development of an individual is contingent not only on individual ability but also culture and society in which it is embedded
        - Thinking and language
- Origins of Cognitive Science - early to mid 19th century thinking
    - Plato's rationalism - all knowledge can be acquired through thinking
    - Aristotle's empiricism - knowledge about the world is gained through observation and systematic way of observation
    - Descarte - how we really know something based on the doubt, uncertainty and reflection upon the question gives rise to knowledge.
    - Epistemology - study of origin and nature of knowledge
    - Locke - sensation and reflection
    - Kante - introduced the idea of how our mind makes representations of concepts ; parallel development within philosophy
    - Wundt - emphasized lab methods for investigating these mental operations ; emphasis on experimentation
    - Behaviorism - all behaviours can be explained by carefully understanding stimulus and the resultant response that comes from the organism. Stimulus response association needs to be carefully studied through careful experimentation - behaviorist view
    - Cognitive revolution - mid 1950s ; researchers in this field acknowledged the entity called mind, the theories of mind
    - William James - he wrote 'principles of psychology' - father figure for psychology ; unlike later behaviorists, he talked about stream of thought ; thinking is like a flow, based on observation said new born baby's impression of the world one 'great blooming buzzing confusion' ; infant experiencing the world and not able to organize this information
- What sets the cognitive revolution
    - Watson wrote purpose of psychology is to predict the reaction to a given stimulus
    - Wolfgang Kohler - from behaviorist paradigm moved on to being a cognitive theorists ; did work on apes, chimpanzees and monkeys

‘mentality of apes’ ; suggested “aha” moment in monkey’s life when they discover a new technique ; “aha” is a taboo for behaviorist since “aha” needs you to know what you are doing and this mental element is banned from behaviorist notion ; “Vestal Psychology” - branch of psychology

- Edward Thorndike - behaviorist - looked talked about associative processes in animals that lead to animal intelligence - associationism
- Albert Bandura (developed cognitive theory - individual and environment ; individual responsible for the environment that they create), Jerome Bruner (main emphasis - information processing theory of psychology - mind is a way of processing information and mind can be looked at as an instrument for information processing) and George Miller(limited capacity of short term memory (working memory) - we may receive information but Q is how does organism cope with it; not all information is processed - online maintenance currently working on something and limited capacity of that) responsible for turning from behaviourism to cognitive - architects of this revolution
- Jerome Bruner - gave emphasis on individual ; experimental subject as active participant rather than merely a passive receiver of external stimuli ; behaviorists on the other hand - individual in between stimulus and response is just a passive entity, doesn’t have any internal representation or any active participation of this organism, it's the association that forms that predicts the behavior in the future
- Geroge Miller - also the key device to this semantic network (popular graph structure for representing knowledge - organized structure of network)
- Leon Festinger - Cognitive Social Psychology - social psychology (is the study of groups of people; society as an entity is a near receiver of stimuli and generator of responses) provided an alternative to behaviorism.
    - Cognitive Dissonance theory says there is a dissonance, that is, the inconsistency that the organism or the person experiences ; these inconsistencies leads them to generate a response motivated by the feeling of dissonance or inconsistency in what they see or experience and leads to certain coping behavior/ explanatory behavior.
    - Dissonance is the internal feeling of inconsistency that leads to rationalization ; it generates a rationalization that is trying to make sense of discrepancy and coming up with a way of coping with this.

- Modern Theories of Cognitive science (based on neuroscience)
    - From the notion of ‘there is no mind, no representation’ to the cognitive revolution that legitimizes the notion of mental entity and representation and actively looking for neural basis for these representations
- Turning point

    - acknowledging there is a mental component, there is representation. Cognitive map/ a spatial map of the world embedded in your neural system and that can be empirically investigated.
    - John O'Keefe, May-Britt and Edvard Moser - place cells (found in hippocampus and grid cells in entorhinal cortex) and cognitive maps
    - Residue to representation is laid down in cortex which is used for future behaviors
- Modern Cognitive Theories (AI, NLP, Cognitive Science)
    - Birth of cognitive science from the conference in the mid-50s from linguists, computer scientists, psychologists - common interest formed cognitive science
    - Marvin Minsky - father figure of AI applied computational mechanics to human psychological processes ; his idea is that mind is not one entity but a society (collection of people each with one mind) of minds
    - General purpose problem solver, logic theory etc
        - Herbert Simon - proposed the idea of 'bounded rationality'
        - Alan Newell - 'unified theories of cognition'
    - Alan Turing - important contributions to compatibility theory ('Imitation Game' - movie) - Turing test ('Eliza')

Sensation & Sensory Systems

- Psychology the emphasis was more on observing and studying behavior, experimenting empirical methods that investigated behavior
    - The behaviorist school in its extreme form banished the idea of any representation or any cognition or any mental content was removed from the scientific study of the brain and behavior
    - Later, people realized mental content through cognitive revolution (place cells and cognitive maps, PDP - turning point)
- Parallel distributed processing (PDP) - memory and mental representation of object in the world is distributed and is parallel processing on top of that that gives rise to right intelligence and thinking that we see in humans ; revolutionized the use of neural networks in tech and in fields like AI and cog sci ; used as explanatory device of how information is represented in the brain ; foundation for deep learning revolution
- Debates in language and linguistics - Is language innate or developed during maturation of the brain? (Nature vs Nurture Debate)
    - Noam Chomsky - language acquisition device which is innate in the brain and is pre tuned for language processing and during the maturation (set up in a particular environment), tuning of brain happens ; capabilities are innate to the brain and depends on tuning ; infants productivity in acquiring knowledge points towards the innateness of language
    - Rethinking innateness (Jeff Elman and Annette Karmiloff-Smith) - position was we don't need to invoke these innateness ideas, language can be learned by a network

- Philosophy of mind - The Consciousness Debate
    - Central to issue of cognitive science
    - Does the machine understand what the human does?
    - Intentional stance (Daniel C. Dennett) - conscious entity can have an intention and uses this intention to direct its behaviour. Anysystem that exhibits this intentional stance can be considered conscious ; consciousness is a tentative position - brain in an editorial revision mode (this idea is identified by a conscious agent)
    - Colin McGinn - we are cognitively unequipped to understand the relation between brain and consciousness. Therefore, consciousness is a mystery.
    - Global neural workspace theory - consciousness arises from the global decisions made in the frontal cortex and it is broadcast all over the cortex. Conscious event activates both temporal and frontal lobe
    - Integrated Information Theory - correlates of consciousness are posterior activation and there is no activation of the anterior system.
- Sensation and Sensory Systems
    - Sensation - input
        - input can come from multiple sources eg: touch, visual, etc
        - Receiving the raw data
        - Relates to the actual raw data that is experienced by our sensors
        - Gathering info from the environment via your senses
        - Registers information in the brain
    - Perception - organization of information
        - Interpretation of raw data by the brain
        - What your brain is organizing and interpreting based on the sensory information
        - Illusion (subject to influence like biases) of reality
        - Process by which sensory information is actively organized and interpreted by the brain
        - Understanding of what the reality is comes from this perceptual capability
        - Best guess of the source of what is being currently experienced
    - Peripheral nervous system - exposed to the external environment
        - Has sensors, transducers that take information from external media and environment and send it to the CNS
        - Further divisions - autonomic nervous system (automatic reactions - can't command it, communicates with internal organs and glands eg:neural signals that activate your gut, excretion system, digestive system), somatic nervous system (bodily - involuntary - muscles that activate your legs and hands)
        - Autonomic nervous system
            - Sympathetic division - Activates and arouses the system - fight or flight - eg: sweat glands, all muscles that activate organs, etc
            - Parasympathetic division - rests and calms the system - rest and digest - eg: pupils, blood vessels, etc

        - Somatic nervous system
            - Sensory - send information to the brain - afferent
            - Motor - generated from the brain and goes down - efferent
    - Central Nervous System
        - CNS corresponds to brain and spinal cord
        - Receives information from PNS and generates outputs to activate muscles
    - Santiago Ramon y Cajal and Camillo Golgi - neural system is made of individual cells called neurons - neuron doctrine ; earlier reticular theory - nervous system is a clump of tissue/ tangled system
    - Information comes in from dendrites -> processed in the cell body -> pulse generated which travels along the axon.
        - In CNS, the information received is from other neurons whereas in PNs, it is stimulus from environment/external media
        - Everything transformed to an electrochemical signal within the system
    - Neurons
        - Soma - cell body - contains nucleus, mitochondria etc which keep the cell alive
        - Dendrite - receives signal from other neurons
        - Axon - extension which transmits (through change in ions) signals from cell body to other neurons
        - Synapses (connections between neurons is through a gap) - gap between end of neuron's axon and dendrites of another neuron
            - Myelinated axon facilities faster transmission
            - Gap has exchange of chemicals - chemical transmission
            - Electric and chemical synapse
    - Glial cells
        - Scaffold to keep the neurons intact
        - Provide support, form myelin
        - Protective cover to axons in both CNS and PNS, acts as support structure, gives neurons immunity, also medium for neurons to communicate with blood vessels to receive nutrition
        - More than neurons in number
    - Neurons
        - Have different shapes and sizes - Unipolar, Bipolar(eg: retina of the eye), multipolar
        - Sensory neurons smaller in size - thermoreceptors, photoreceptors, chemoreceptors, mechanoreceptors perceived through this neurons etc
        - motor bigger in size
        - Action potentials - temporary shift from negative to positive in the neuron's membrane potential caused by ions suddenly flowing in and out of the neuron ; input is analog (membrane potential is continuously valued) and output is discrete (neuron spikes or not)
        - Action potentials to perception

            - Brain function is organized in a modular fashion - visual, sensory, etc - local sensors correspond to a particular sensory domain
            - There are specific functional areas for processing phase
        - Information in the brain - localized or distributed processing?
            - Specific functions are processed by many different areas that are associated with representation
            - In more higher areas - distributed eg: face perception
        - Neural code - specificity or distributed
            - The neural code or the way neurons code the information about visual stimulus, they are all through neural firing
            - In distributed advantage is that in the same set of neurons, you can have more stimuli compared to specificity coding
    - Decoding/ Mind Reading - Reconstructing stimulus from the firing of the neurons or the measurement from the neural system

Empirical Approaches in Cognitive Science

- Psychophysics - used to study sensation and perception
- How to collect data to answer questions in cognitive science?
    - Behavioral approach - psychophysics, behavioral experiments, survey methods, experience sampling, etc
    - Neural approach - data from the brain, EEG, stimulation methods (electrical stimulation, etc) etc - to establish cause and effect relationships
- How to analyze data?
    - mathematical , statistical models, approaches from other sciences
- Psychology as an empirical (relies on observation and experimentation) science
- Wilhelm Wundt - believed in very systematic introspection (think yourself how you are perceiving your stimuli, infer how the brain works from perceiving stimuli)
- Types of Research
    - Theory-driven - start off from a theory, generate a hypothesis from a theory, understand the different variables you want to study to understand your hypothesis, operationalize these variables and then design an experiment
    - Exploratory - start with a data set or collect data, then use exploratory visualization techniques, descriptive stats to understand the variables you have captured, correlational analyses (how is one variable related to another), how are components related, form hypotheses or develop a theory and derive hypotheses, test hypotheses in an experiment, loop through until a solid theory is built
    - Confirmatory and exploratory research can go hand in hand while building theory in cognitive science
- Modes of research - behavioral and neural modes
- Behavioral investigations in cognitive science

Sensory

- All senses goes to the thalamus and then their associated areas except smell sense which goes directly to the olfactory cortex
- Small hair on cells moves based on the frequency content and that is what sends the information to the brain
- Touch - free nerve endings (sense pain) and Meissner corpuscle/ basket cell fibres (heat, pressure, light sensation of touch etc)
- Sensory systems necessary for survival
- Tactile
    - Important in early development
    - Mechano receptors - related to pressure
- Input is analog but output is discrete
- Intensity of the stimulus is related to the nerve firing grade
- Somatosensory Cortex
    - Homunculus - sensory map of our body ; significance of sensory receptors in different parts of our body
- Gate control theory of pain

Perceptual Learning & Neuroimaging techniques

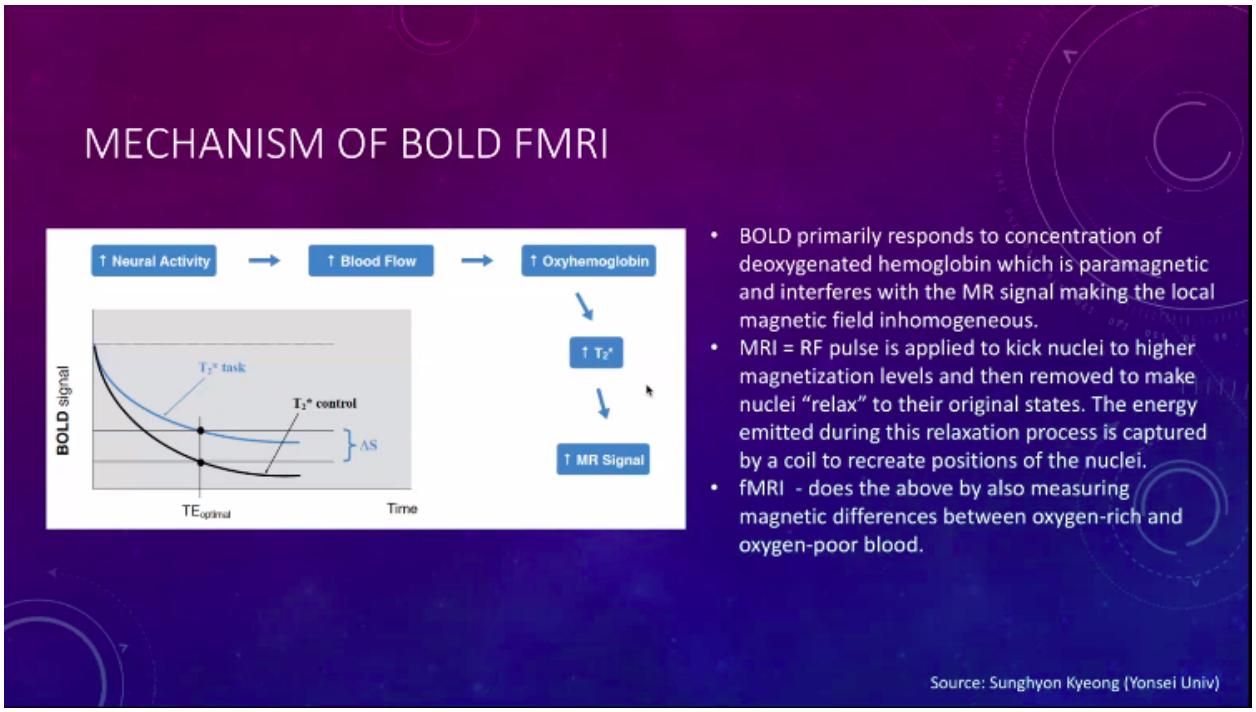
- Brains as prediction machines - perception based model and action oriented model of predictive processing
- Perception based model - attempts to match the incoming sensory information based on the modification on the predictions we make
- Action oriented model - make sense and navigate the world by minimizing prediction error by engaging the motor system and this engaging can be in an overt or covert way
- Dissociation in functioning in the brain
    - Close connection between perceiving and interacting with objects
    - Two streams - ventral stream (perception) is the What pathway and dorsal stream (closer to motor area) is the Where pathway (action)
    - Dysfunction of one particular pathway will only hinder only one functionality
    - Object discrimination task and landmark discrimination task
    - We understand action because the motor representation of the action is activated in our brain
- Mirror neurons
    - 1996 - Rizzolati investigated the premotor neurons in monkey
    - Neurons in the premotor cortex respond not just to action but to watching an action
    - Audiovisual mirror neurons respond also to sounds that are associated with actions
    - Anomalies : Someone with ALS, animal movements, Moebius syndrome etc

    - A motor representation cannot distinguish between the range of possible meanings associated with such an action (can't understand the action unless some goal is associated with it in such cases)
    - Perception is grounded in covert action - internally stimulating
    - Action is grounded in perception, that is the motor system needs the sensory system to perceive things and not the other way round. - Gregory Hickok
- Perceptual Learning
    - Our perception system learns and develops as your grow
    - Benefits the organism by tailoring the processes that gathering information to suit the uses and needs of the organism
    - 1963 - E.J. Gibson - long-lasting changes in perception that result from practice or experience mainly for adaptation and survival
    - 1998 - Goldstone - involves relatively long-lasting changes to an organism's perceptual system that improve its ability to respond to its environment and are caused by this environment. It involves changes in perception and not belief. Long term changes that result from practice and experience.
    - Types of Perceptual Learning
        - Attentional weighting
            - Increase attention to important aspects and decrease attention to irrelevant ones
            - Shifts may be strategic choices and not perceptual in nature
            - Based on the task at hand
            - Phenomenon of categorical perception - better able to distinguish between physically different stimuli when the stimuli come from different categories than when they come from the same category. This is naturally done by us. Category-relevant dimensions are sensitized and irrelevant variation is deemphasised
        - Differentiation
            - Through exposure, experience and training we can perceive differences between two properties where the coud not perceive this difference before
            - Stimuli that were once psychologically fused together become separated
            - Learning typically accelerated by training in which the objects are associated with different labels or responses
            - This differentiation can happen in a broader sense with categories
        - Unitization
            - Opposite to differentiation
            - Perceive a single property, what they previously perceived as two or more distinct properties (perceive written words as a single unit eg : we read a word the same way even if the letters are interchanged, U and M together)
        - Stimulus imprinting
            - [whole stimuli]

- Unitization is in the end state
- You detect a whole pattern but no need for that pattern to have previously looked like two or more objects, properties, or events
- Through imprinting (creating impressions), the detectors/receptors are developed that are specialized for stimuli or parts of stimuli
- Internalized detectors develop for repeated stimuli(template models), and these detectors increase the speed, accuracy, and general fluency with which the stimuli are processed
- Eg : we can identify spoken words more accurately when they are spoken by familiar voices since we become tuned to the particular instances to which they are exposed therefore you learn a stimulus by repeated exposure
- [features]
- We can also imprint parts of the stimulus instead of the whole stimulus, the parts which have more importance for us in other words if a stimulus part is important, varies independently of other parts, or occurs frequently, people may develop a specialized detector for that part.
- You develop new “building blocks” for describing stimuli
- Whether a functional detector is developed will depend on both the objective frequency and subjective importance of the physical feature
- [topological]
- Rather than simply developing independent detectors, topological imprinting implies that a spatially organized network of detectors is created that is we draw associations between dimensions
- Based on natural tendency to draw associations between dimensions
- Howells’ experiment - associated color with sound

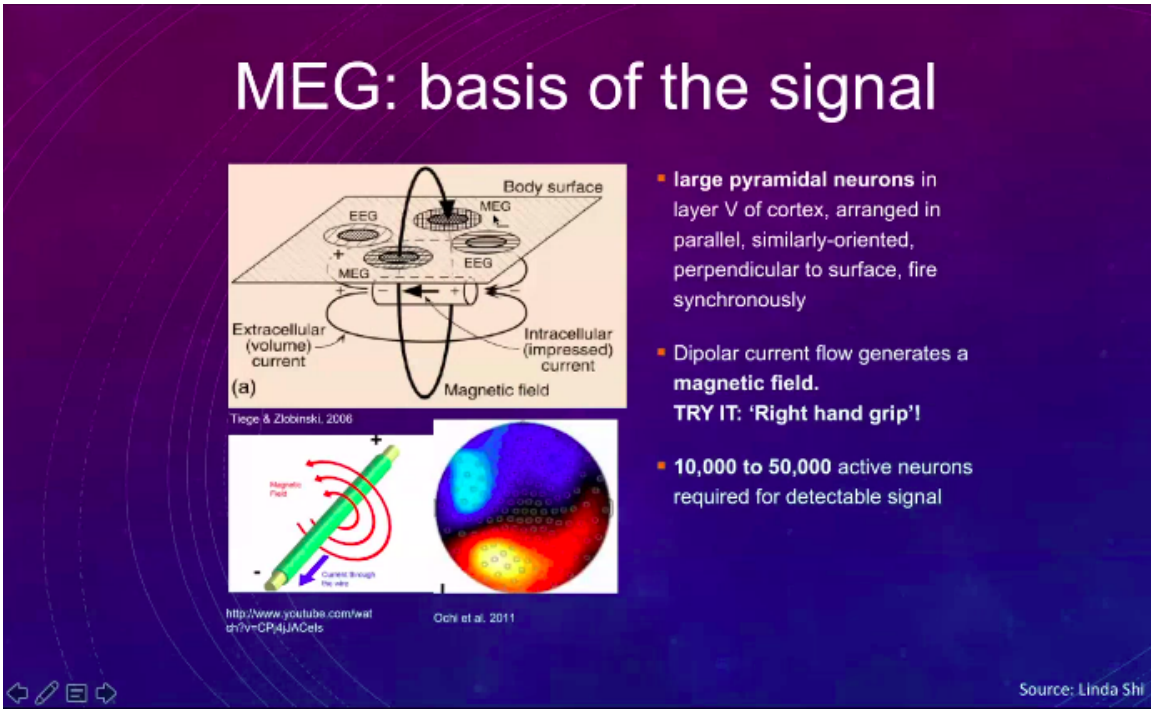
- Neural investigations in cognitive science - neuroimaging techniques
    - Specific choice of technique you use depends on what you want to study, also on the various aspects of what you want to study, temporal scale of your question (to what degree of precision in time do you want to understand these brain processes), spatial scale (how precise do you want to be within the brain), invasive vs non-invasive studies (typically want to study non-invasive), and get more to the causation question in the brain (what brain mechanisms cause you to behave in a certain way)
    - CT & MRI (better for soft tissues) give good static (still) images which are good for studying structure
    - PET (invasive due to the injection of tracers which are short half-life radioactive isotopes), fMRI (non-invasive with high spatial resolution but low temporal resolution), MEG & EEG (non-invasive with high temporal resolution) are functional image techniques

- More invasive techniques include ECoG, LFP - requires surgery and hence cog studies is done only when surgery is required for clinical purposes
- fMRI measures blood flow into the brain. If certain region in the brain is active, it needs nutrients which is done by blood flow to that region and fMRI is done by measuring this blood flow
- Assumptions : flow of oxygenated blood to where it is needed in the brain, blood contains iron which is magnetic. Oxygenated and deoxygenated blood have different magnetic properties.
- BOLD fMRI



- To understand fMRI it is also necessary to understand the hemodynamic response which is basically the change in MR signal as a function of some neuronal activity. This process is slow and takes over several seconds. Over many different empirical studies you come up with model fits of the link function which takes you from neural activity to the BOLD response called the hemodynamic response, modeling neurovascular coupling. The hemodynamic response lags the generating neuronal activity by a few seconds. Therefore, the temporal resolution of fMRI(several seconds) is poor relative to EEG or MEG (millisecond resolution)
- BOLD fMRI
  - Pros : high spatial resolution, non-invasive
  - Cons : low temporal resolution, claustrophobia can be an issue, noise in the scanner, movement can influence recordings, etc

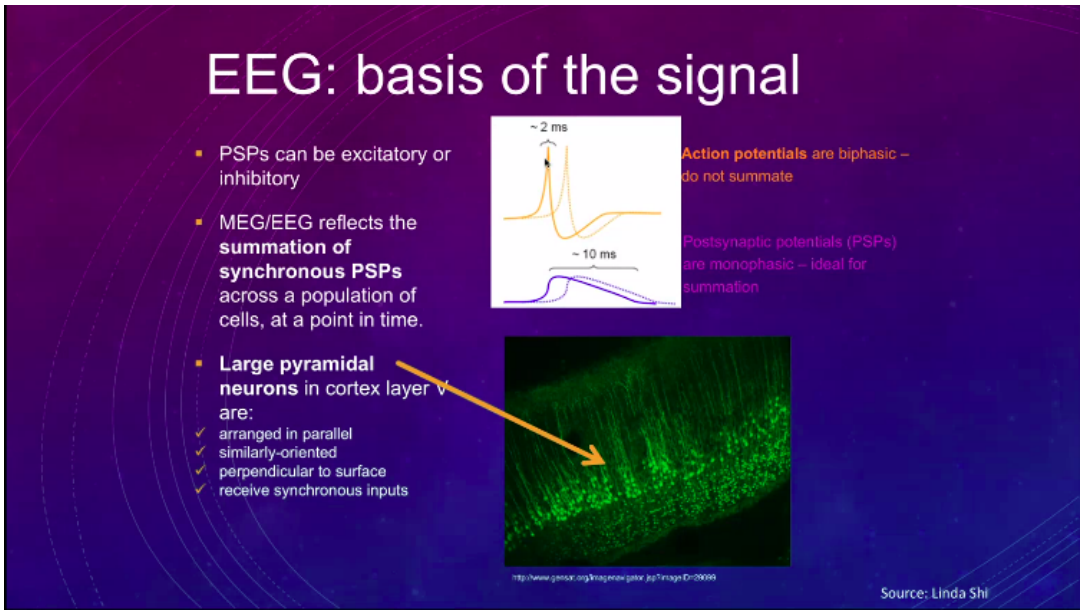
- MRI scanner is really good at picking up anatomical features and was reprogrammed to pick up functional differences. It was invented based on the physics of magnetic resonances.
- PET
  - Hemodynamically based like fMRI, but can also detect glucose intake
  - Inject with radioactive tracers where the glucose will go to the brain regions most involved in a certain task, these traces can emit these radioactive emissions which can be detected on certain crystals
  - Invasive in nature and has low temporal resolution with good spatial resolution
- MEG
  - External recordings of magnetic fields which are created by electric currents in cortex within and between neurons
  - Role
    - Neural correlates of cognitive/perceptual processes
    - Localize affected regions before surgery, determine regional and network functionality
  - Basis of the signal
  - The MEG magnetic field is not distorted by conductive properties of scalp/head and the MEG coil is not sensitive to perfectly radial sources. In practice, only a small proportion (<1%) of cell populations are perfectly radial that is on top of gyri but the MEG signal is very tiny and is

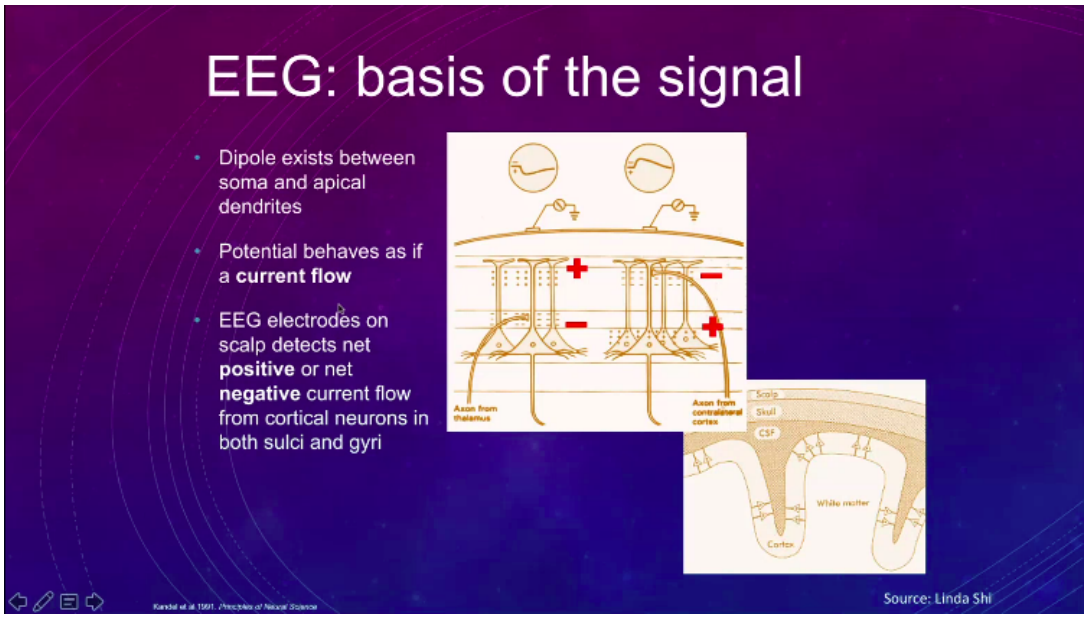


susceptible to interference from electrical equipments, traffic, earth, participant's heartbeat itself and thus requires magnetically shield rooms and super sensitive magnetometers

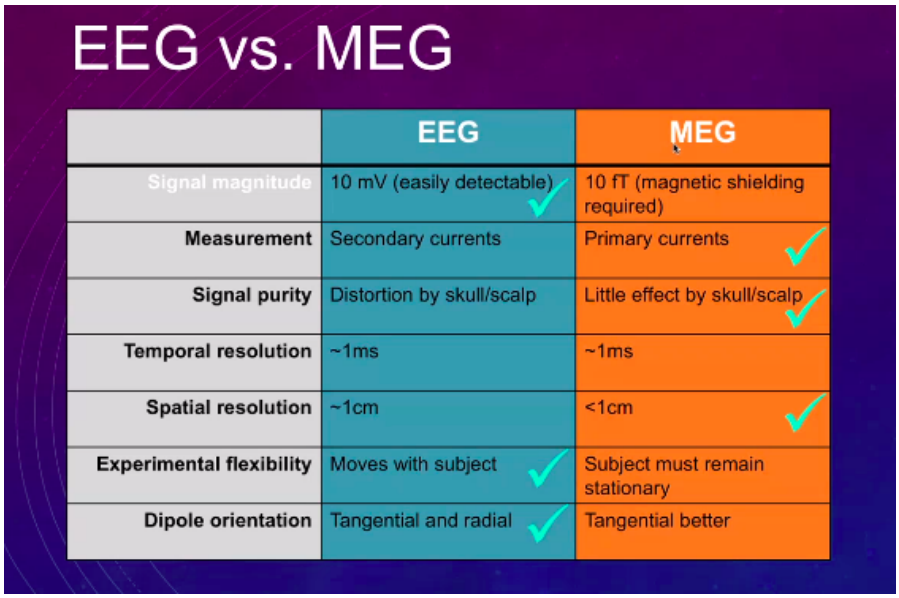
- It has high temporal and spatial resolution but needs to be highly shielded, measuring really small magnetic fields generated by neuronal currents

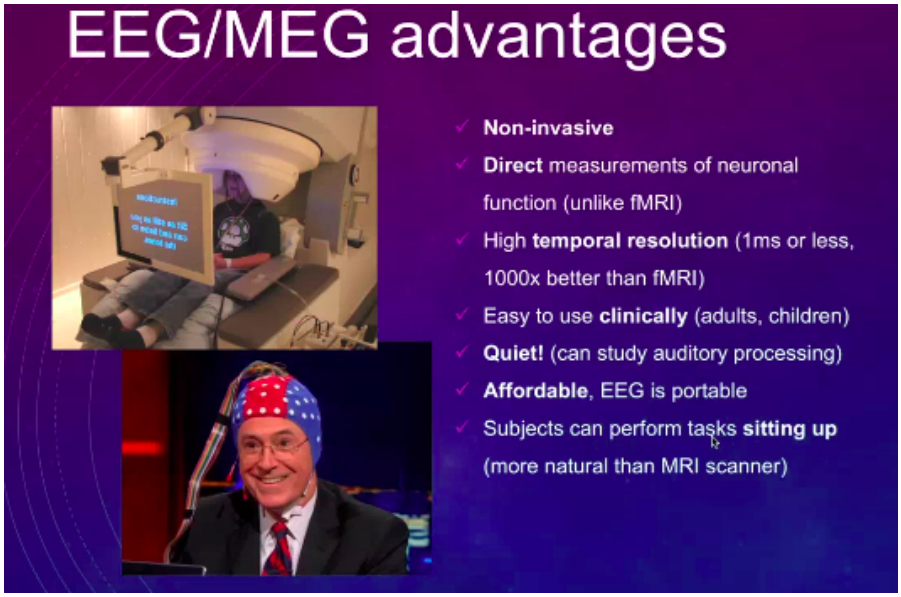
- EEG
  - Measure electric fields ; small signal measured in microvolts; its role id to identify neural correlates and diagnose epilepsy, sleep disorders, anesthesia, coma and brain death ; the scalp recording of electrical activity of cortex is in the form of waveform signals
  - Spatial resolution is smaller than MEG and fMRI and temporal resolution is similar to MEG and higher than fMRI ; signals are small and they are highly attenuated signals that come from potentially deeper sources of the brain

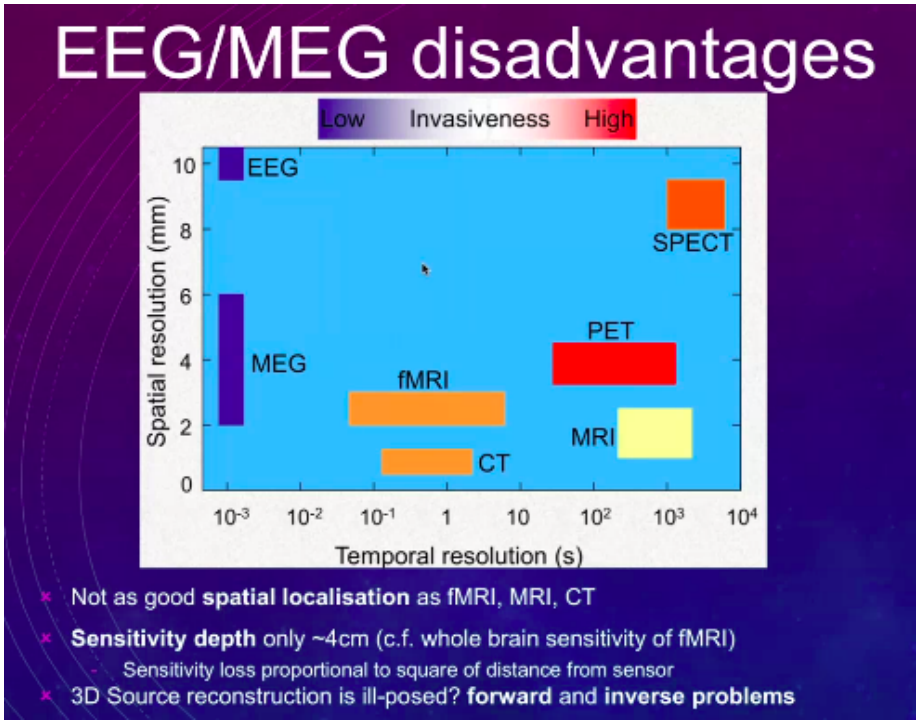




- In EEG it's not much of an issue with capturing dipoles in either radial or tangential configurations ; the magnetic sensors outside the scalp will have trouble detecting magnetic fields which are generated by radial dipoles - difference between EEG and MEG





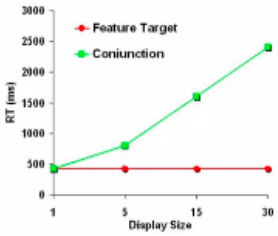


    - Look at the above image to find the best technique for your research question
- For neural approaches, pay attention to the temporal and spatial resolution of the neuroimaging technique you choose and choose a technique based on your research question

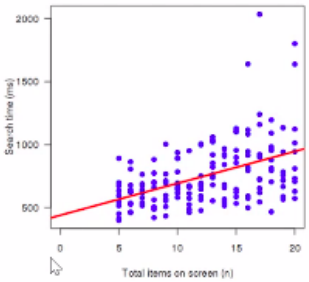
Attention, Perception, & Performance

- Identify the object -> take the input + act upon it is the perception action loop
- When you are searching for an object, how you system decided what and where to search is directed and oriented from attentional processing
- Demanding your system to selectively look at something - first job of attentional processing
- Your machine needs to be trained to identify objects from any perspective
- Basic - Self terminative search is when your search ends as soon as the target is found
- Thorough - Exhaustive search - you continue to search till you have looked at all the items
- Lesser the distraction, better the search ; With the pop out effect, the set size does not matter but without the effect, it does.
- The interfaces in the real and virtual world is designed is primarily oriented using visual cues

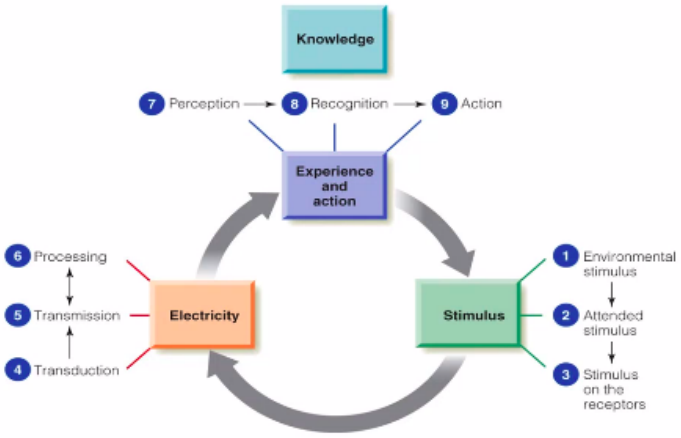
“where’s Wally?” – Pop-out and serial search (singleton and conjunctive search)



- Feature targets pop out
  - flat display size function
- Conjunction targets demand serial search
  - non-zero slope



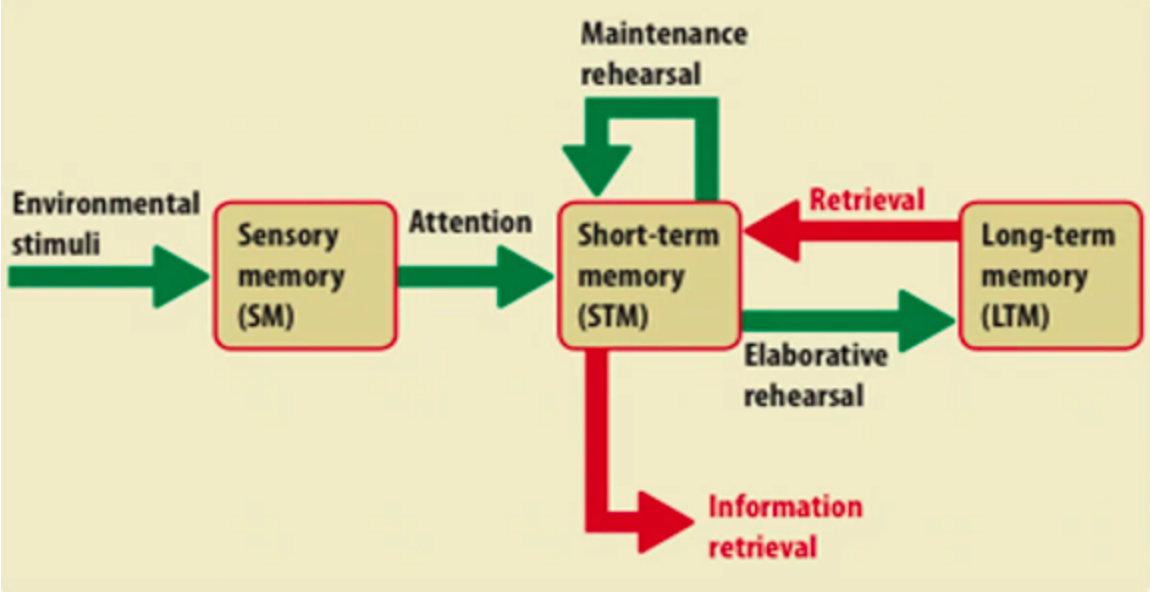
- RT - reaction time
- Attention helps you to select(primary feature), filter (taking away irrelevant information) and focus. It works as the **gatekeeper** to direct the flow of information for further processing. How much information passes through that “gate” depends on multiple factors which could be your experience & expertise, task demands, expectations, kind of stimulus you’re interacting with change how you accomodate the information.
- Selective focus or **spotlight** - directing your attention to look at what is important in that particular time and space and remove all unnecessary information
- Attention enables focus on relevant information selectively while ignoring irrelevant information
- Attention lets you shift, alternate, divide and perform dual tasks or multitask.
- Attention works as a mental resource that helps you perform multiple/dual task ; the way the task is performed when juggling between multiple tasks depends on what modalities of task has been shared there eg : visual, visual-auditory etc ; the efficiency of juggling between task depends on practice, task complexity, stimulus features, task demand, sharing of stimulus features/ actions between two tasks
- Why is attention important? [Influence Perception]
  - Inattention blindness is the failure to perceive the object that are not the focus of attention
  - Change blindness is the failure to detect changes to the visual details of a scene
  - Brain interprets the world as 3D by integrating different features (different regions of the brain for different processing of information and then the brain integrates this information) together.
- 7 stages of perception



The perceptual process. The steps in this process are arranged in a circle to emphasize that the process is dynamic and continually changing.

The BINDING PROBLEM

- Feature Integration Theory (Anne Treisman)
    - Overall process from the moment stimulus is presented to you and moment you identify and recognize the object - 2 stage processing
    - Stage 1: Pre-attentive stage - prior to attention (feature map) - different features of object is taken into account
    - Stage 2 : Attentive stage - based on the relevance of the target it works as a spotlight, you focus and the integration happens
    - Attentions works as a glue which integrates different features
    - And when you don't, illusory conjunction happens - combining features present in the environment and you made a new object out of it since brain could not integrate the information properly
- Why attention is important?[Influence memory]
- Sperling Experiment - If you are delaying the ability/ delaying the direction to attend you would not be any better than no attention



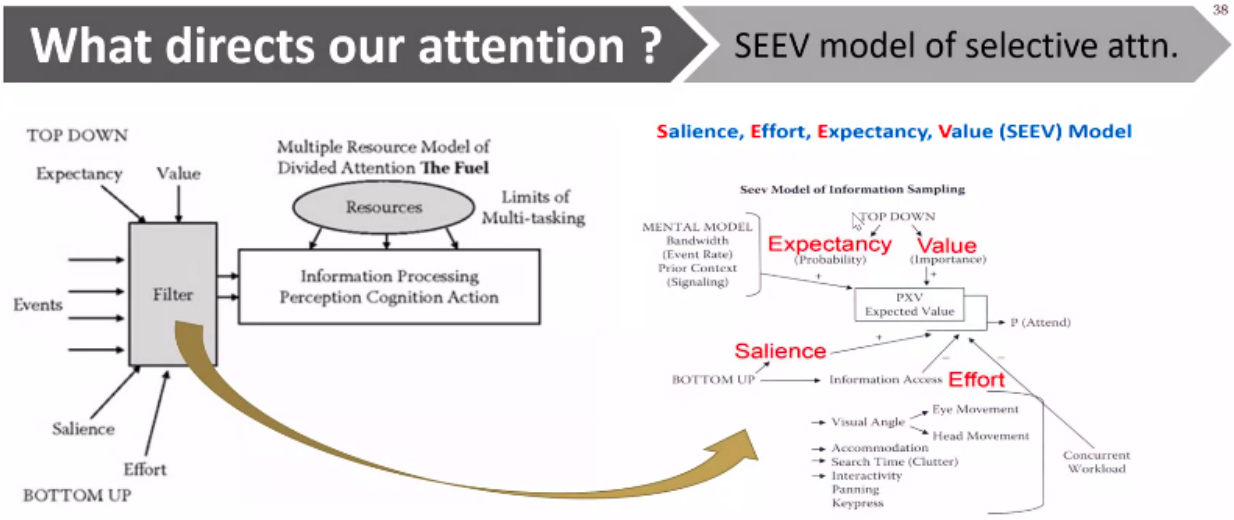
- Above picture by Atkinson and Shiffrin - 1968

Attention, Perception, & Performance - 2

- Nature of attention is selective
- What directs our attention?
    - Factors that affect the orientation of attention is the external cues/features available in the environment and these external cues should have some level of conspicuity, saliency (relative term - the relevance is determined by how the surrounding objects are) compared to rest of the objects present in the environment
    - Top-down attentional bias
        - Saliency is one of the basic feature level processing and it is a multiscale feature extraction done - orientation intensity to color - how the depth of layers is evaluated is one of the components looked at. From seeing various features that are extracted and then seeing a combination of at least two determine the saliency - the compilation of that is evaluated
        - Center-surround differences in terms of evaluation you look at
        - The object of your difference is taken as the center object/focus and then the surrounding is evaluated
        - The first component that highlights there is “winner take-all” principle which is going to process further
        - Inhibition of return : selected something (particularly based on stimulus driven feature lets say), once selection is done and the object is taken for further processing, you take a halt and move back from the object and you are reluctant to come back to that selected area/region for a while.

Therefore, this concept highlights the reluctance to come back to an already processed area.

- When something is not fitting to your knowledge representation of a particular scene/ concept then how would you be paying attention to therefore, knowledge plays an important role.
- Given the intention you have, the goal you have in mind, the task that demands you to look at also has an ability to direct your attention
- SEEV model - salience, effort, expectancy, value by Wickens and McCarley - 2008
    - Bottom-up approach - is how stimulus is salience in nature with the surrounding and has an ability to capture/direct/orient your attention ; since it is coming from external cues in environment it is bottom-up processing

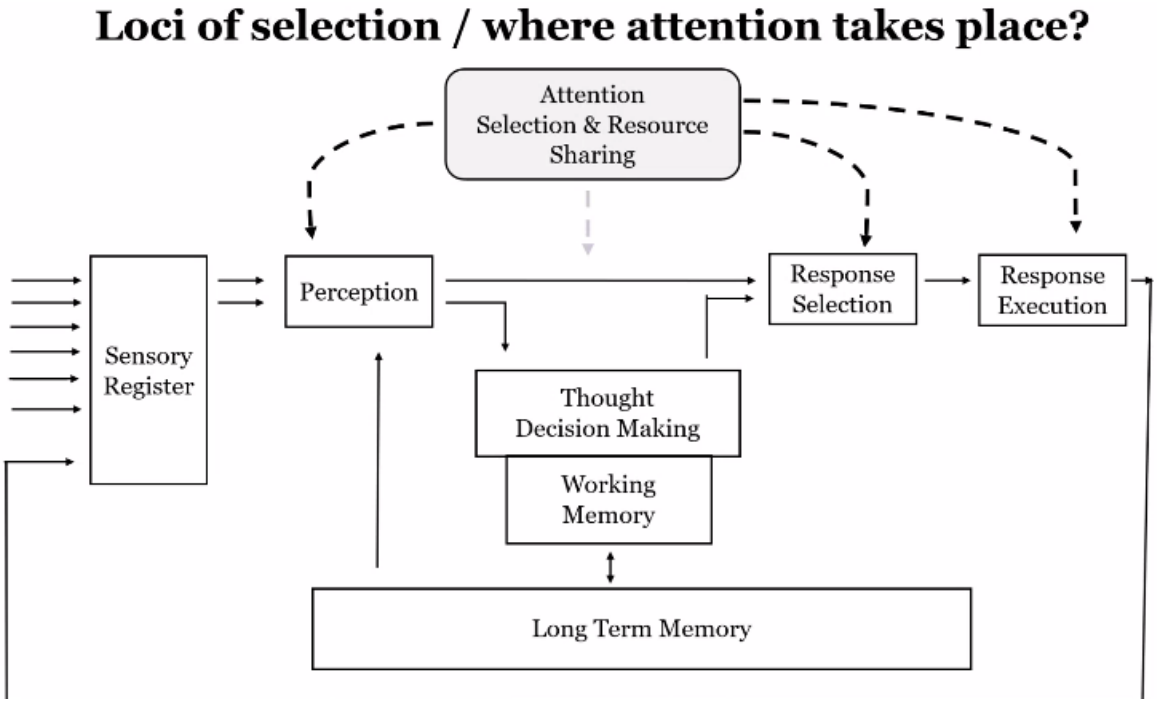


Attention helps prioritizing between competing stimuli, using top-down and bottom-up processes. (Wickens and McCarley, 2008)

- Effort refers to how you are able to scan the environment ; how difficult or easy that search is going to be is referring to effort / how easily you can comprehend something or not - if it is easy it is going to help you facilitate your attention else inhibit your attention
- effort works more negatively since it is going to reduce the probability of attending to anything in the environment therefore more the effort, less the attention to the environment
- Higher the salience, better the attention

- Top-down approach - At times your goal or the intention to do something is more powerful/valuable than the saliency in the environment which reduced the importance of it
    - Expectancy (probability) - What you are expected to attend to - you have been given a goal to attend to something

            - Value (importance) - how valuable the task is could be determining how you attend to tasks
        - Among the competing stimuli only few will be processed further ; these few are prioritized by attentional processing/systems which could be top-down or bottom-up
- Where does attention take place?



        - Bombarded with enormous information that is the sensory register/input of any form of modalities which helps you interact with the external world in signals which are different than the signals your brain is equipped to process
        - First thing you do is identify/recognize any object
        - What you see as output is the response and the two stages in response is response selection and response execution
        - Attention exists at every stage of processing that you are doing to interact with the environment effectively and efficiently that is perception and response (both stages) - works at stages to understand and what and when
        - Attention happens before identification which is the perceptual processing or before the response (response selection)
            - [Late selection theory] When attention happens at the response level we are looking more at the semantic descriptions of things in which you have identified the objects and processed the information and then you decide which requires more attention
                - If you are paying attention to the unattended channel then still you are actually selecting at the action level
                - The problem with this theory was that it was still referring to all or none process

        - [Early selection theory] While doing physical discirmination one looks at the basic primitive features for filtering out
            - The moment you select something only one is going through that filter, rest of them are not paid attention to therefore either you process all or none. You selectively pay attention to some things and ignore the rest
    - First came early selection theory and to debate against it came Treisman's Attenuation model and then came late selection model
    - Trisman's Attenuation model
        - The analyzer helps you decide whether the attenuated signal (yellow) will be passed or filtered out and in working memory the information needs to be worked on/processed
        - Positive point about this was that it was not an all or none process but was more flexible in nature ; depending upon the context in which something is working you highlighted what you would be attending to
    - How do we test what is being attended? - Dichotic listening task (Cherry, 1953)
        - Where is the filter is happening is coming from the unattended channel
        - From the attended stream people could only report the male/female voice, loudness, strongly emotional words, taboo words
    - When you have an easy process you have late selection so you accommodate as naive whereas when you have a difficult scenario in terms of perceptual processing, the naive people go for early selection and the more experienced go for late selection or semantically oriented selection.
    - Perceptual Load is the the amount of information involved in the processing of the task stimuli ; it plays an important role in how accurate you could be about something that is suggestive in nature rather than otherwise
- What gets selected?
    - Covert is doing an action without any explicit movement of it whereas overt has some movement
    - Generally the task are been defined using covert attention
    - Whether we attend the space/location of the object or the property of the object - early debate focused on the spatial property of it ; other debate said that it is difficult to disentangle space with the property of the object, that is, the object property is inherited to the space itself
    - Speed of processing = reaction time ; quality = accuracy
    - Later people could separate the object property from space of the object - when you select an object, the selection extends to other irrelevant property of the object as well
    - Depending on task you would pay attention to location and depending upon task and requirements you would be paying attention to object properties
    - Invalid - within object and invalid - different object

Attention, Perception, & Performance - 3

- Focusing for an extended period of time is called sustained attention whereas
- Vigilance refers to your preparedness or your ability to detect the target which are uncommon/ very low probability of occurring
- Central attention/capacity/resource - helps you juggle between different tasks ; this juggling can be affected by the task complexity, the kind of stimulus features you are dealing with, the demand of the task and how the sharing from the input to action has been done - how we allocate our attention and how this allocation is determined by different aspects
- Two theories shaped multitasking - by resource/capacity : single resource theory (Daniel) and by observation of applied scenario : multiple resource theory (Christopher)
    - Key difference between the two theory is
        - Single theory highlights if attention is resource and determining what to select - one resource to allocate to, that is, you have one resource to be performing more than one task and if you are performing depending on the complexity you will not be able to perform more than one task ; if single resource, multitask would be a challenge since it is fighting for one resource to be taken so that further processing can be done
            - Note : you have multiple sensory channels
            - How you are acting to the stimuli could be verbal - vocal in nature or could be manual
        - If multiple resources then it is the modality specific, cognitive processing specific or action specific resources would be at cost therefore division of labor is happening, competition is located as per the nature of the stimuli/action/processing
    - Look at input, manual tasks and how central cognition was playing a role.

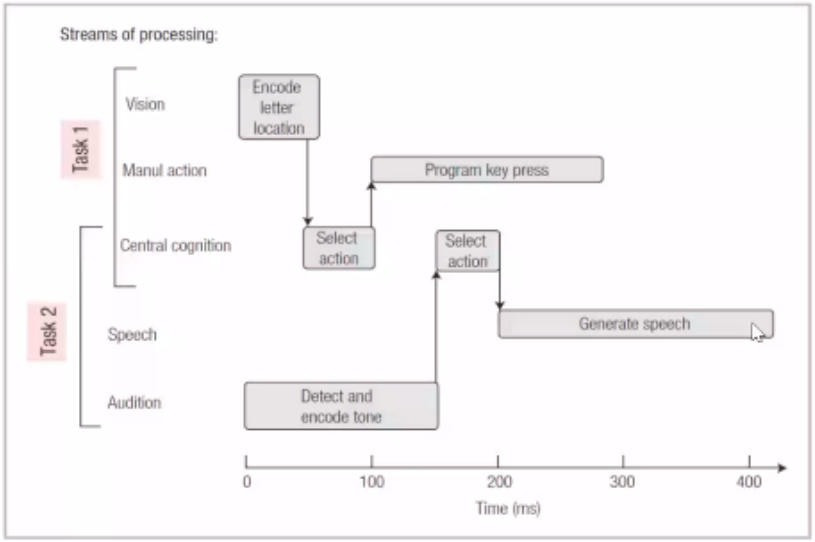


FIGURE 3.23 An analysis of the timing of events in five streams of processing during execution of the dual task in the Schumacher et al. (2001) experiment: (1) vision, (2) manual action, (3) central cognition, (4) speech, and (5) audition.

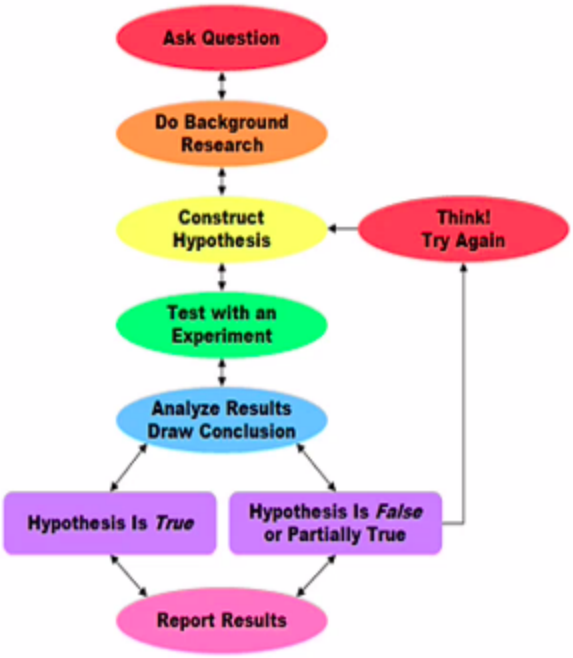
    - Below diagram for overlap and different times of select action/response ; to distractions in attention - if more overlap ; dual single task difference noticed
- Dual task - automaticity and control
    - Automatically is a result of higher practice and with higher practice, lesser central control is required to execute the task
- Attention deficits
    - Perceptual problem - Agnosia - inability to form and identify an object - two broad categories are apperceptive (early stage of object identification) and associative (higher level of complex processing) [Benson and Greenberg - 1969]
        - Apperceptive - inability to recognize simple objects - form is not been taken into place
        - Associative - inability to recognize complex objects - associative meaning is lost / may not be able to categorize the object
    - Attentional problem - Visual neglect / Hemi neglect - Parietal lobe as major reason for this : if left visual field is neglected along with the ignorance to the speaker on the left side, miss to eat or explore the left side if using touch then the right parietal lobe is damaged and vice versa
        - Attention is both spatial (location where the object is present) and selective in nature (category selection process) whereas perception is more of organization, interpretation and category identification process
        - How to differentiate between attentional, perceptual and memory problem - see above point
        - Representational neglect - patients with parietal lobe lesions have show problem with imagery and their contralateral side memory performance
        - Disengagement - contralateral side problem

Research Methods

- Empiricism - accurate knowledge can be built through observation
- Scientific method - offers a way to do it (empiricism) in an objective way
    - Set of principles about the appropriate relationship between ideas and evidences (causal ideas have different sets of evidence compared to other ideas)
    - Develop theories and derive hypothesis from the theories then test your theories based on evidence and after that you may have to modify your theory
- Theory is a general hypothetical explanation of a natural phenomenon - framework for understanding a larger phenomenon
- hypothesis is a specific falsifiable (can find evidence to prove theory is false if the theory is false) prediction made by a theory - specific prediction for a single event
- Scientists design experiments in such a way that it maximizes the probability of disapproving a theory if in fact the theory is wrong
- Confirmation bias

The Scientific Method – A Review

- Provides a logical framework for examining scientific questions.
- Allows other researchers to replicate studies.



- Make your data available for other researchers to conduct their studies
- Human biases
    - Representative heuristic - representative ideas you've in your mind through prior experiences about what domains and their features should look like
    - Availability heuristic - some aspect of negative experiences associated with this that is clearly and immediately available in your mind
    - Human beings are complex, variable (same person in different situations will react differently) and reactive (react to situation) - make it difficult to study human beings
- Observations in psychology of cog science
    - To look for evidence you need to be able to measure and for measurement - define the property you want to study (operational definition) then find a way to detect that property
- Validity - extent to which a measurement and a property are conceptually related
    - Could be valid or invalid
    - Can the measurement tool completely measure the property
- Reliability
    - Inconsistent results over time - unreliable
- Power (in your methods)
    - Power in our method should be capable of detecting small differences - statistical concept

    - If difference tiny then the statistical method you are using should be very powerful
- Demand characteristics
    - Those aspects of an observational setting that cause people to behave as they think they should
    - Solution - participants need to be “blind” (technical term in psychology - you try to hide from the participant the true intention behind what you are doing) - another way is naturalistic observation (observing people in their natural habitat)
- Naturalistic Observation
    - Advantages - high in external validity (extent to which one can generalize their findings to the real world)
    - Disadvantages - low in internal validity (ability to draw cause and effect inferences about what is going on)
        - eg : chimpanzee angry in their natural habitat : you are unsure why this happens ; chimpanzee gets angry in the lab because of some external environment you have created hence you know the cause then
- Experimenter Expectancy Effect / Rosenthal effect
    - When the experimenter unintentionally influences the outcome of the experiment
    - Solution - experimenters need to be “blind” in order to avoid expectations from influencing both the observations and the outcome
- Double blind - when both the participants and the experimenter are “blind” - prevents both demand characteristics and experimenter expectancy effect
- Data
    - First step is to just visualize the data (Data Visualization) - descriptive statistics - to get a sense of what your data looks like
        - Central tendency - mode, median, median - all same values in this case
            - Non - central is skewed distributions which could be negatively or positively skewed in which case mean may not be the same as mode and the median
            - Mode - good description ; mean not a very good way to summarize distribution in terms of skewed distributions
        - Variability - range and standard deviation
    - Normal Distributions
        - Graphic representations -
            - frequency (y - axis) distribution - to compute mode, mean and median
            - normal (Gaussian) distributions

Research Methods - 2

- Find cause for certain phenomenon
- Correlational study - find out what variables are related to one another/ relationships between each other

- One you know what variables are relevant - use experimental design to investigate causal relation
- Correlational designs
    - Associated with, related to, linked with - statements that can be made using correlational designs
    - Correlations cannot lead to causal conclusions
    - Correlation does not equal causation

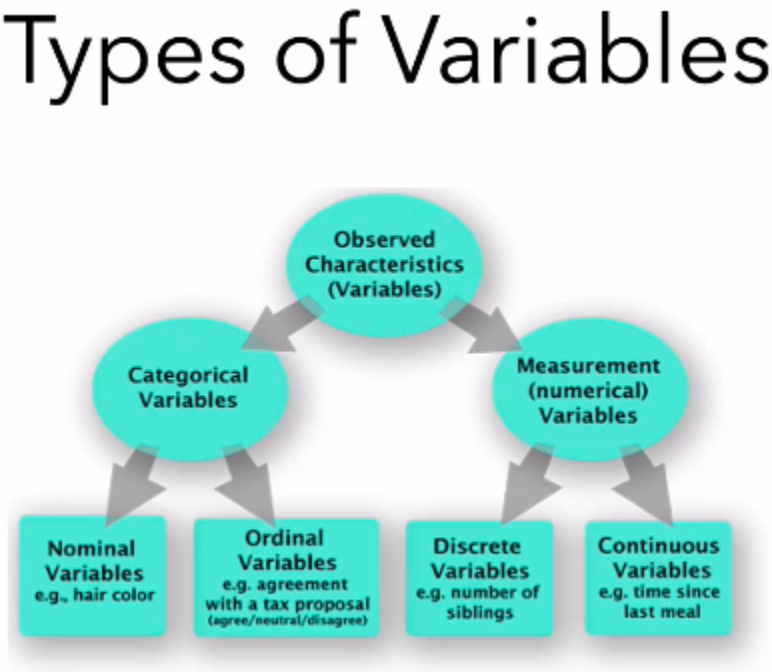
Correlational Study

- Observe relations btw. different things (variables)
  - Example: ice cream consumption and shark attacks or deaths by drowning
- Positive or negative
  - Positive: increasing one increases the other
  - Negative: increasing one decreases the other
- Measured by correlation coefficient *r*
- *r* varies between +1 and -1
  - +1 or -1: PERFECT correlation
  - 0: no correlation
- Ice cream consumption and death by drowning: $r = 0.8$

    - Correlation coefficient you choose based on your problem domain
    - -1 = perfect anti-correlation
    - Slope of the line very close to 1 is very strong positive correlation
    - Causation means cause and effect relationship - one cannot always tell which variable causes the other and sometimes no variable causes the other implying no causal connection
    - The third variable problem - Another variable striving the relationship
    - To make a causal interpretation, do a experimental design
    - Strong or weak correlation depends on the domain - subjective decision
- Experimental studies
    - Random assignment and random selection - remember the difference
    - Control group and experimental group
    - Independent and dependent variable
- Peer Review

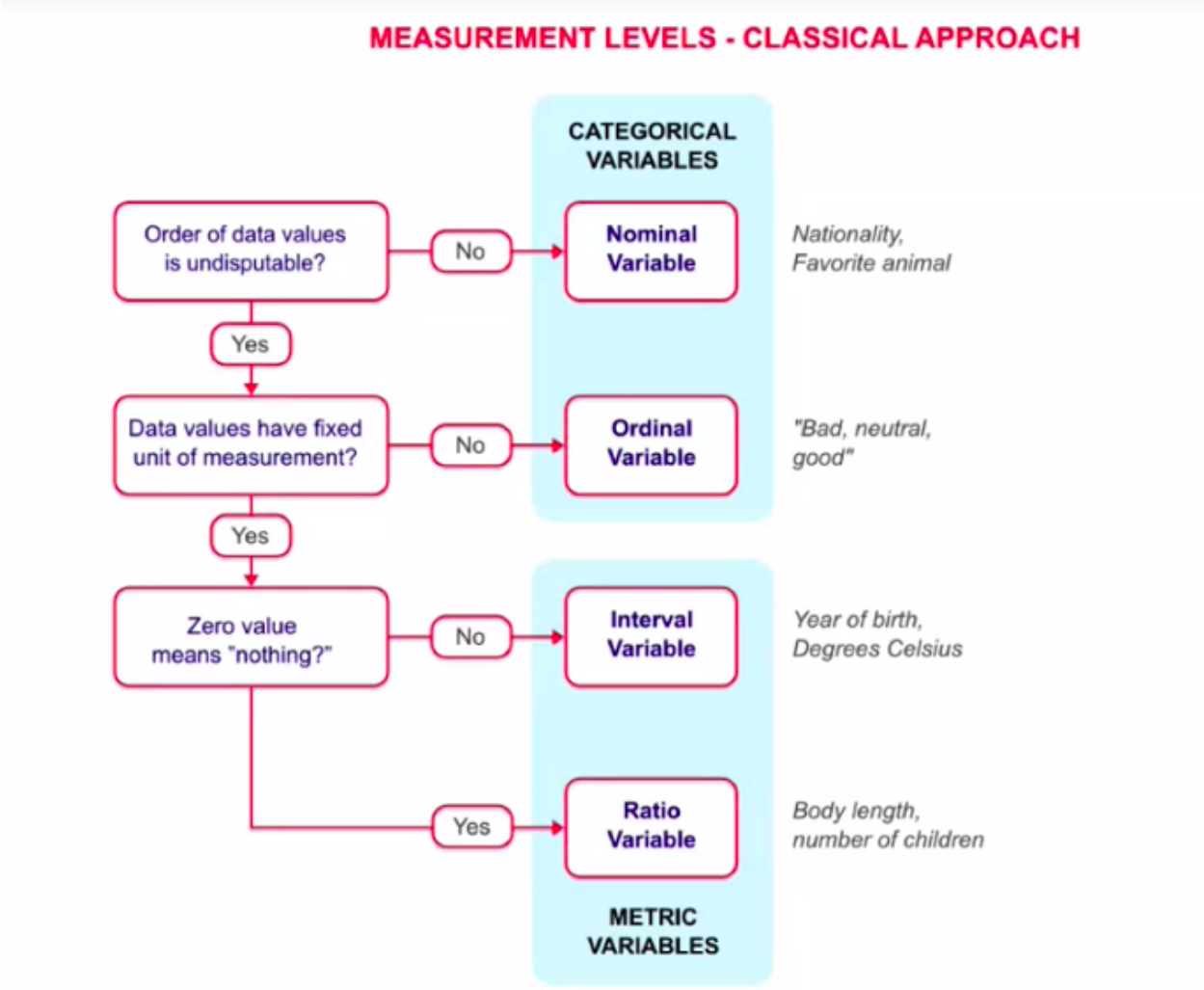
Research Methods - 3

- Hypothesis
    - Theory is a general hypothetical explanation of a natural phenomenon and hypothesis is a specific falsifiable prediction made by a theory
    - Null hypothesis is a form of hypothesis that is deemed “true” until proven wrong based on experimental data
    - Alternative hypothesis - you have a theory and you derive an alternative hypothesis and test it
    - Eg : Q - are adults doing better at mathematics than teenagers?
        - Null - mathematical ability does not depend on age
        - Alternative - Adults are better at mathematics than teenagers
    - Directional : hypothesis based on theory / you predict the direction of the effect - looking at either end of a distribution [two-tailed test]
    - Non - directional : direction of effect not predicted - looking at both ends [two-tailed test]
    - Variable types - you have your theory, frame your hypothesis (kind of hypothesis)
        - Two broad kind of variables

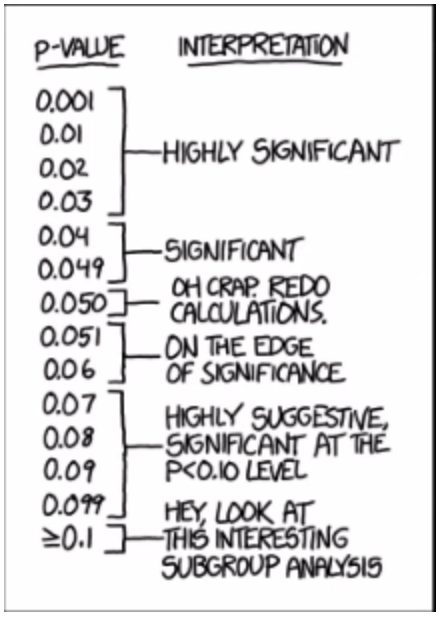


        - Categorical variables : discrete or qualitative ; responses can be placed in one category, not in between categories
            - Nominal - labels like numbers, letters eg : gender, brand of car
            - Dichotomous - similar to nominal but has only 2 categories eg: yes or no questions
            - Ordinal : indicates ordering within a group and does not indicate distance between rank order eg : XS S M L XL clothing size

        - Numerical variables
            - Variables that operate above the level of mere categorizing and are typically quantitative eg : discrete and continuous data
        - Discrete variables are whole numerical values eg : courses taken in the semester
        - Continuous variables can take on an unlimited number of values between the lowest and highest points of measurement
            - Interval level - similar to ordinal but use equal intervals (there is arbitrary zero point) eg : temperature
            - Ratio level - same as intervals but with true zero eg : age, weight
    - Different levels of measurement tell you how responses can be organized in relation to each other ; can tell us what statistical methods can be used in the analysis - amount of acceptable statistical methods increases as the level of measurement increases that is nominal (categorization) -> ordinal (ordered categories) -> interval (continuous) -> ratio (continuous)
        - At least interval level data is needed to perform parametric statistical tests
        - Variables at ordinal level a(IQ) are often treated as variables at interval level (this can be done if data is normally distributed for that variable)



    - [For data check for which test] Statistical test of difference or test of correlation -> check data type -> categorical -> related/unrelated -> parametric assumptions met/unmet
- Types of Statistics
    - Descriptive - used to summarize and describe gathered data ; measures of central tendency and dispersion ; helps in presenting characteristics of the data
    - Inferential - make generalizations from a sample to a population ; test some hypothesis and make predictions
- Inferential statistics
    - Used to draw conclusions concerning a population based only on sample data
- Significance testing
    - Finding the probability that a result would have occurred if there is, in fact, no effect = if the null hypothesis is true
    - P-value is a measure of how much evidence you have against the H_0
    - Central part of all statistical testing ; can be used for associations and differences
    - <0.05 is considered significant



- Tests of Association
    - Correlation
        - Correlation is not causality
        - Descriptive measure of association
        - Testing the correlation for significance is an inferential procedure
    - Pearson's correlation
        - Positive slope implies positive correlation ; negative slope implies negative ; y = c implies no correlation and parabola implies no correlation
        - The variables need to be normally distributed
        - Sensitive to outliers
        - If normally distributed, go for parametric test and if not go for non-parametric test
    - Spearman correlation assumes ordinal data - pearson's correlation coefficient on the ranks of the data ; if there are no repeated values, a perfect Spearman's correlation occurs when each of the variables is a perfect monotone function of the other
    - What correlation to use, refer the table below

Variable Y\X	Quantitiative X	Ordinal X	Nominal X
Quantitative Y	Pearson r	Biserial r_b	Point Biserial r_{pb}
Ordinal Y	Biserial r_b	Spearman rho/Tetrachoric r_{tet}	Rank Biserial r_{rb}
Nominal Y	Point Biserial r_{pb}	Rank Bisereal r_{rb}	Phi, L, C, Lambda

    - Strong relationship shown by correlation coefficient close to +/- 1 but strong relationships may not be statistically significant
    - Partial and semi-partial correlation
    - Measure of association between two variables while controlling or adjusting the effect of one or more additional variables
- Tests of Difference

- Selecting a statistical test - summary

Selecting a statistical test

- Different tests are used for varying amount of groups/ conditions:
  - two samples
  - > two samples
- Different tests are used for related versus unrelated designs:
  - unrelated samples = between subjects designs
  - related samples = within subjects designs & matched pairs
- Different tests are used according to the level of measurement:
  - Interval
  - Ordinal
  - Categorical
- Parametric vs non-parametric assumptions
  - Different types of tests
  - Parametric tests also called T tests

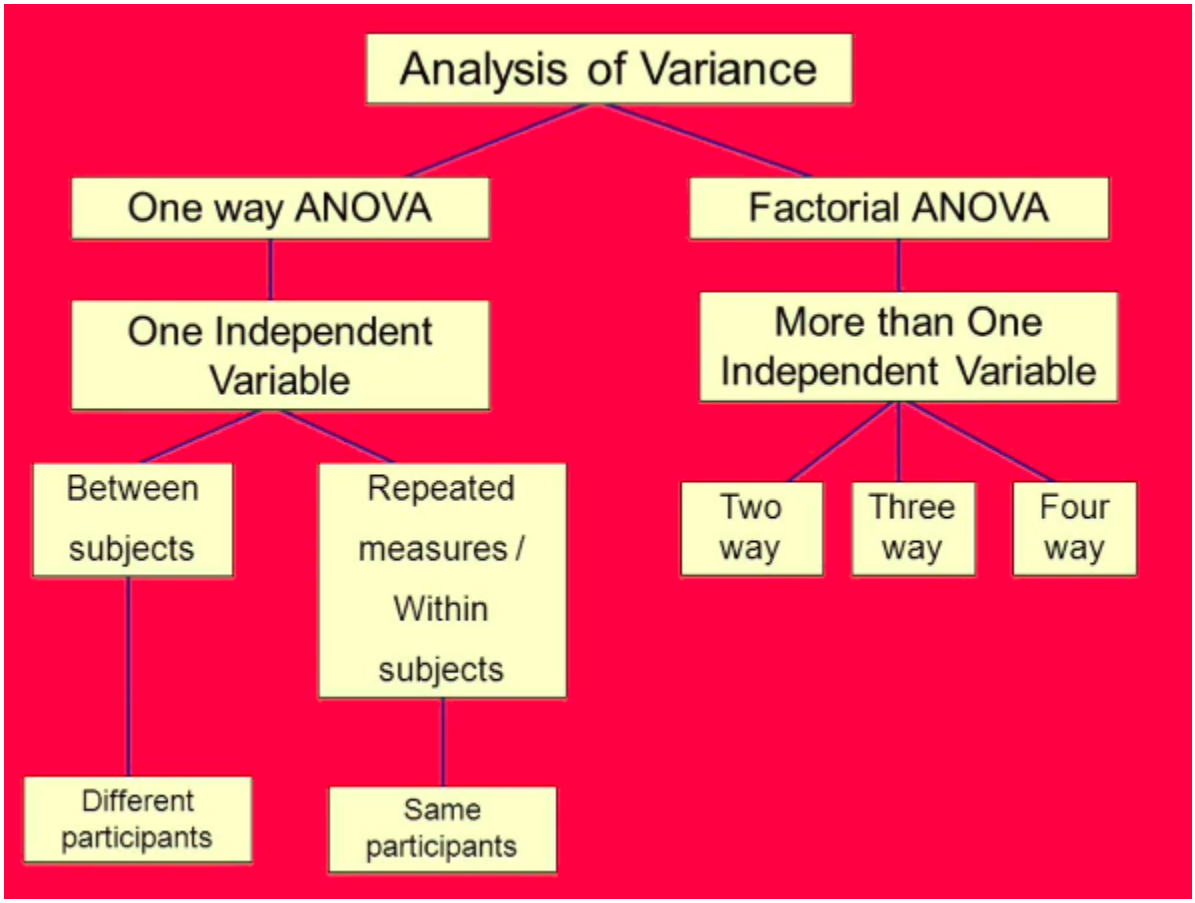
Test type	Between subjects designs (Independent samples)	Within subject designs (repeated measures/ matched pairs)
Non-parametric (for categorical data)	Chi-square	*The binomial sign test*
Non-parametric (for ordinal data)	*Mann-Whitney U*	*Wilcoxon T* *The binomial sign test*
Parametric	*Unrelated t-test (level of data: interval)*	*Related t-test (level of data: interval)*

- Parametric test (for big sample space suggested)
  - T-test are all parametric test where we are assuming normal distribution of data
  - Single sample t-test
    - One sample + specific parameter of population eg : IIIT IQ given India's IQ
  - Two sample test
    - Coming from same or different population

        - Can be related eg : same type of plants in two conditions, quiz 1 vs quiz 2 or unrelated eg : CSE vs ECE, musicians vs non-musicians
    - ANOVA when we have more than two conditions or groups -> check whether eg : 3 groups tested in different conditions or different groups tested in one condition

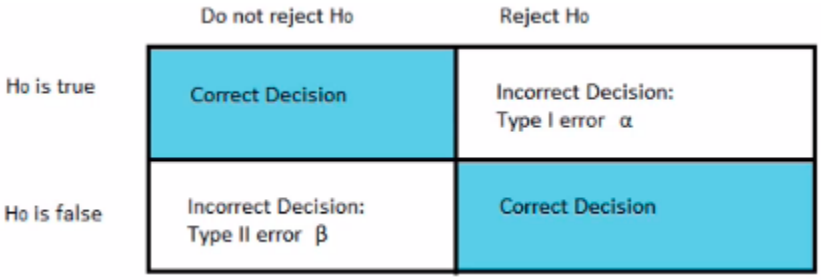
Test type	Between subjects designs (Independent samples)	Within subjects designs (dependent samples)
Parametric	*One-way ANOVA*	*One-way Repeated measures ANOVA*
Non-parametric	*Kruskal-Wallis one way analysis of variance*	Friedman's two-way analysis of variance

    - ANOVA only tells you existence of difference between groups but which groups is not known therefore some post-hoc test is needed
    - Repeated measure ANOVA comes within subject designs (dependent samples)
    - Analysis of Variance [One way ANOVA / Factorial ANOVA]



    - ANOVA is sort of interaction between variables
- Two sample related t-test

    - By increasing sample size, the statistical power also increases
- Power analysis
    - Tools to tell you what sample size is needed for a particular effect
    - H_0 is null hypothesis



    - Type 1 error (false positive) is the chance of finding a difference between groups when one does not actually exist
    - Type 2 error (false negative) is the probability to not identify a difference between groups when it actually exists
    - Power of a test is the probability of correctly rejecting the null hypothesis (= not making type 2 error = 1 - beta)
    - Low power
        - Reduces the likelihood that a statistically significant result reflects a rue effect ; because of law sample size implies low reliability of findings and hence power analysis is required
    - For power analysis - sample size, effect size, p-value and statistic needs to be looked at
        - It determines what SS will ensure a high probability that we correctly reject the null hypothesis - using this we can be sure we used enough data to make a good accurate decision
        - Significance level - 0.05 or 5 %
        - Beta is fixed at least power of 80% or more
        - Effect size - correlation or difference of mean or medians ; if effect is huge then even small SS will be enough
        - Some measures of effect size are as follows :

Effect size	***d***
Very small	0.01
Small	0.20
Medium	0.50
Large	0.80
Very large	1.20
Huge	2.0

Effect size	***r***
Small	0.10
Medium	0.30
Large	0.50

        - If small correlation requires bigger SS
        - Desired power for critical life death research = 95% beta
        - Apriori means determine SS required based on effect size estimated before data collection begins
        - Post-hoc is the determining power based on sample size and calculated effect size

Memory

- Mathematical modeling to make it more precise. Some models mimic each other and in that case go into the brain
- Temporal Context Model (TCM)
    - Retrieval cues help you bring back events to your mind
    - Some retrieval cues can be called context cues ; context is anything surrounding the current event of focus
- The focus of our attention that we learn and remember - items - events that you focus on
- The way that the temporal context model conceptualizes context is with a (What?) weighted average of all the items seen for far
- All the items form the context within which you encode the new experience of your focus
- Retrieved temporal context - If you bind the experience C to the context representation (the ? weighted sum) then when you experience C again, the way in which you can use C to cue your memory system to retrieve a representation of context that was present when you originally experienced item C
- In short, you experience a series of events and each event is bound to a context (now is temporal context the decency ? weighted sum of all of your previous experiences including the current event). Temporal context evolves in time
- t_i -> current state of temporal context ; IN is an input
    - $t_i = (\rho)t_{(i-1)} + (\beta)(t_i)^{IN}$
- Everytime an event and context association is made, you put it into a memory matrix (let's you go from context to item and item to context)
    - Temporal context t and item f - vector representations
    - $M^{TF} = \sum_{i=1}^{L} f_i * (t_i)'$
- Contiguity effect - answers what's the probability of recalling event D after you've recalled item C. If D is the item just after C there is a lag of +1, if just before C then lag of -1 and so on.
    - Eventually come up with the plot that says you are most likely to recall something that happened in the temporal vicinity of the original experience you just recalled
    - This implies maybe memories are organized along the temporal axis
    - Forward asymmetric contiguity effect
- Context cues can explain a lot of empirical phenomenon
- How internal states drift and in turn are associated with things we experience
- Calculate what is the similarity between state of context at time i and at time j using proximity equation and is function of the distance in time and is $t_i * t_j = \rho^{|i-j|}$

- State of contexts tend to be more similar when they are closer to a current time because of how it evolves
- Evidence for forward asymmetry contiguity effects comes from free recall. Problem is during free call people tend to recall in the same order given to them
- Neural contiguity effect
- Conformancy - A sequence of events is given to you and by free recall if you also recall in that order there can be persistent neural activity that comes just by the recall making it seem more activity just before you saw absence – NO IDEA?
    - Choose a task where the order of experimenting is controlled by the experimenter - order of testing has to be random
    - If order of testing is random and then if you get neural contiguity effect that implies more direct neural evidence for this idea otherwise any neural evidence would be because of people recalling events in the same order as they originally saw them
    - Word from another pair is erroneously retrieved in response to the current cue - Intrusion - these intrusions from a temporal adjacent time point might be suggestive of temporal context
- Computational modeling of behavioral data
    - Data could be choices, memory retrieval, reaction times, eye movements. Neural data
    - One needs to make sense of the data by simulating the model, parameter estimation (maximize the probability of your data under parameters of your model ; best parameters of your model that explains your model), model comparison (compare competing models - not only do you want to maximize your log likelihood, minimize negative log likelihood but also want to analyze your model for complexity - more complex your model, the more it can overfit your data which is not good for generalization.
        - Penalty number - limits the number of free parameters you have in the model - way to measure the model's complexity
        - Want the best fitting and simplest model
    - Latent variable analysis - best model fit and analyze the underlying parameters of the model do varying in time or anything
- Therefore, mathematical models give quantitative;y precise predictions, generate predictions about completely new scenarios and help design new experiments to test predictions

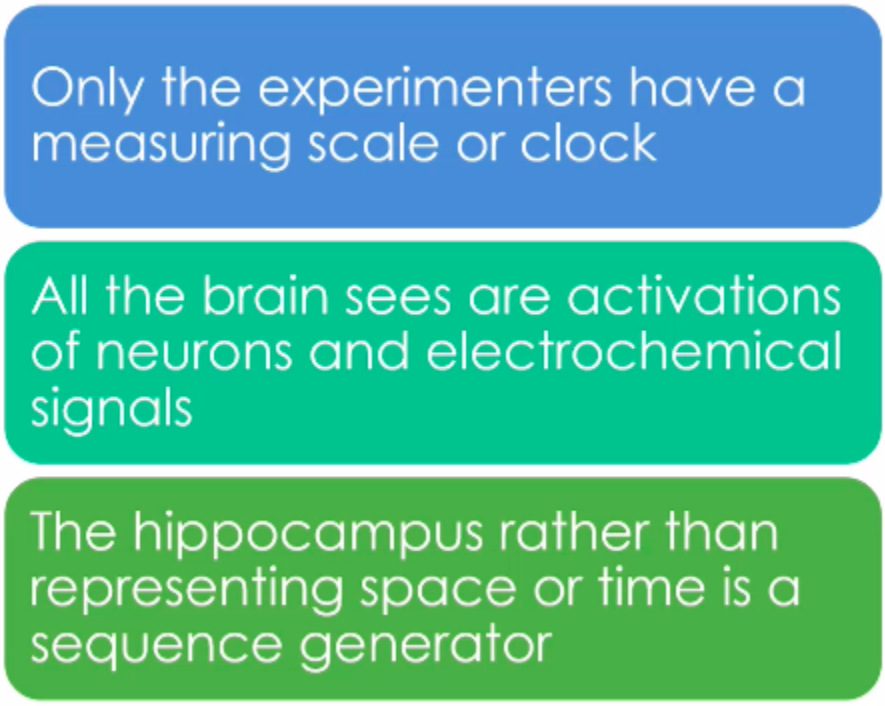
Language and the Brain [PRESENTATION]

- Language is one of the few uniquely human cognitive abilities
- Brain regions implicated in linguistic processing : frontal, temporal, and parietal lobes of both hemispheres
- SEEG - Stereotactic EEG

- Concepts - experiences encoded in symbols. These encoded symbols helps understand the world in a meaningful way
- Chomsky proposed the Nativist idea

Representations and beyond in Cognitive Science

- Symbols and representations you manipulate them using some steps specified in an algorithm in order to solve a problem
- Representation
    - Correspondence
        - Correlation with the pattern of activation and the features in the environment
        - Measuring the rate of neuron firing
    - Causal relation - there has to be this kind of relation between the representation in your mind and some behavior
- Place cells along with spatial navigation also act as time cells so what really is the purpose of place cell representation? -
- The hippocampus is also involved in non-spatial tasks
- Buzsaki says there is no explicit representation of space or time in the brain
    - There are no direct senses in the brain for duration and distance, these are inferred. Some have direct receptors like direction, letters, etc
    - Views hippocampus as sequence generator for the things changing

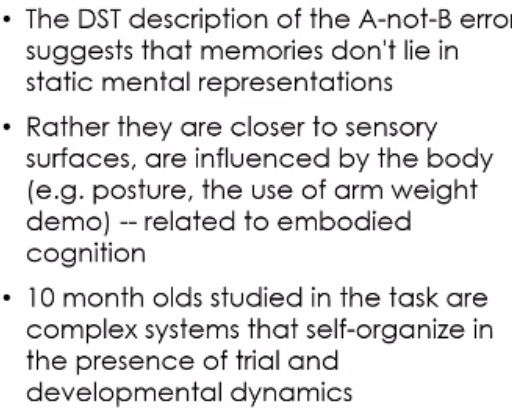


- Hippocampus only looks at the ever changing activities of the brain and therefore, these internal/cognitive activations may not be “representing” things we can measure with our instruments
- Hippocampal indexing theory
    - Modified - instead of single kinds of activations that the hippocampus sends to the cortex, it first generates a sequence and activated cortical modules in sequence as well
    - Hippocampus generates a sequence that context-free therefore it generates meaning by connecting back to the cortical modules which assign meanings
- Computationalism
    - In late 50s made programs made of pure logic
    - Computational view of cognitive sign is that the mind performs Turning style computations - use and manipulate the symbols stored
    - Computation is conceived as a rule governed symbol system in cognitive science
- Connectionism
    - Memory is stored in connections between neurons
    - Donald Hepps - neurons are fired and wired together and hence the connections between neurons are enhanced
    - CTM - computational theory of mind dominated cogsci in 60s and 70s. In 80s influencing book published - parallel distributed processing - interest again in analog neural networks - connected nodes to implement human functions
- Parallel Distributed Processing (PDP) - assumption -
    - Memory is not in one cell or neuron but distributed over a set of cells
    - Memory is encoded (distributed) in the connection strengths [neurons fired and wired together]
    - The encoding and retrieval is through parallel activation of neurons
- Linguistic challenge to connectionism - connectionist models of cognition are incomplete unless they can implement linguistic functionality
    - Linguistic functionality - language is a compositional system, that is, you can combine a set of words in various ways - can combine a finite number of “representational elements” or symbols to generate larger structures
    - Binding is also a general requirement in cognition
    - So in connectionism - you not only need to bind the fillers but also retrieve their individual meaning even after binding (retaining meaning is called the independence property of compositionality)
    - Compositionality of language (two properties for connectionism to satisfy the linguistic challenge)
        - Independence property of compositionality
        - The identity of fillers remains systematic across structures (so that inference and reasoning across this is possible)
- Hinton

- Hinton (1990)
- John = a pattern of activations
- Instantiate that pattern on the SUBJECT pool
- Mary = another pattern of activations
- Instantiate Mary on the PATIENT pool of neurons
- However, no transfer of knowledge from "John loves Mary" to "Mary is the wife of John" as the connection weights learned in network 1 do not help in learning the meaning of sentence 2.

    -
    - Not satisfactory because did not satisfy the systematicity across structures
- Smolensky
    - Smolensky (1990) - a more sophisticated solution
    - Tensor products of activations
    - So John and Mary retain their identities
    - The relations between them are captured via tensor products
    - Downside: combinatorial explosion!

      ij^{th} element of $\mathbf{a} \otimes \mathbf{b}$ is given by the product of a_i and b_j
    -
    - Tensor product
    - Dimensionality increases exponentially with the dimensionality of the individual fillers
    - Problem - combinatorial explosion
- Vector symbolic architecture - Gayler (2003)
    - Inherits the independence properties of Smolensky's solution
    - A certain operation is applied on the binding layer to restrict its dimensionality to N (same as individual filler dimensionalities)
- SPAUN (Semantic Pointer Architecture Unified Network) - Eliasmith (2012)
    - Inspired by VSA (above method) and implemented via spiking neuron models
    - Model could perform human like behaviour
- Dynamical systems theory (DST)
    - Understanding the dynamics internally as well as externally
    - Quantify ways in which things are changing (understand variability)
    - Studies trajectories

- Piaget - A-not-B - object permanence
    - Objects can exist independent of their actions - object permanence
    - A very “representational” view
- DST A-not-B version
    - Looks at the time evolution of activation patterns and these patterns can be self-sustained even if there is nothing out there
    - 

- Mechanism
    - Classical notion - Series of operations on representation - what series of operations on what representations to achieve a certain computational goal
    - DST - entire system self organizes in presence of these dynamics
- Ecological Psychology (Gibson)
    - Affordances - opportunities for actions enabled by matches between environmental properties and organism properties
    - Inspired by behaviorism
        - However, agents play a more active exploratory role
        - Analysis of stimulus in absence of capacities that agent has is deemed worthless
        - Stimulus features and agent capacities need to be matched
    - Embodies, non-representational view of perception and cognition