Working Memory and Cognitive Control

1. Texting while driving
2. Remembering not to call out the name of an old employee while assigning work to a new employee
3. Remembering to pick up fruits, sanitizer, bread, chips, and bathroom supplies while you walk up and down the aisles at a supermarket.
4. Preparing for your friends a meal consisting of a salad, two side dishes, and dessert and having all the dishes ready to serve at the same time
5. Driving and Crossing Roads in India and USA

Cognitive Control

- *Cognitive control*, also known as *executive control* or *executive function*:
  - higher-order cognition, including reasoning, task flexibility, problem solving, and planning

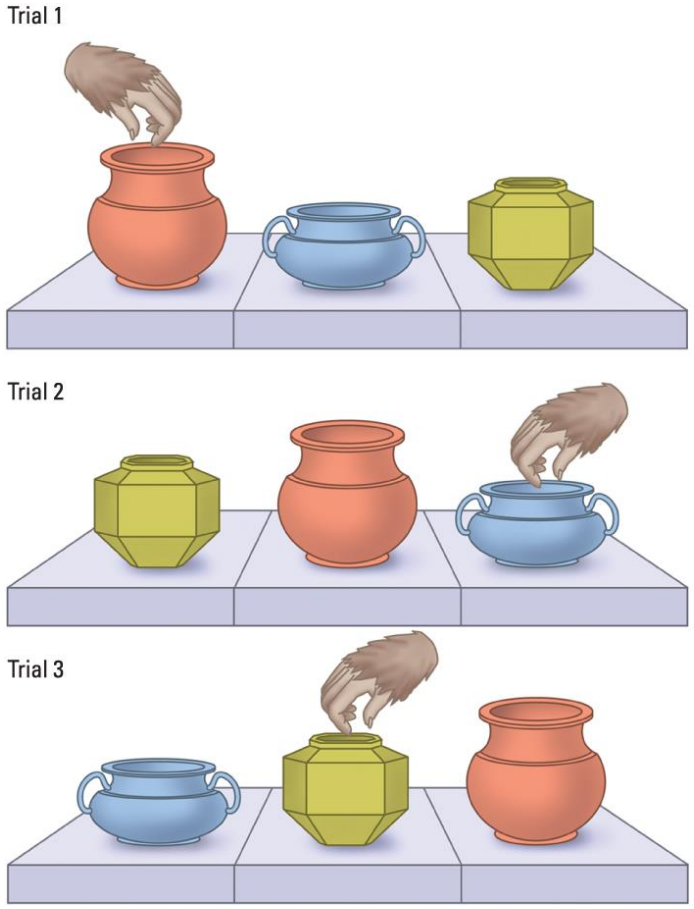
- Classic tasks used to study basic executive function

Behaviors	**Tasks used to explore these behaviors**
Controlled updating of short-term memory	*N*-back task, self-ordered search
Goal setting and planning (goal maintenance)	Tower of Hanoi
Task switching	Wisconsin Card Sorting Test
Stimulus attention and response inhibition	Stroop task

Anyone with an intact brain can do these tasks

Controlled Updating of Short-Term Memory Buffers

Monkey version



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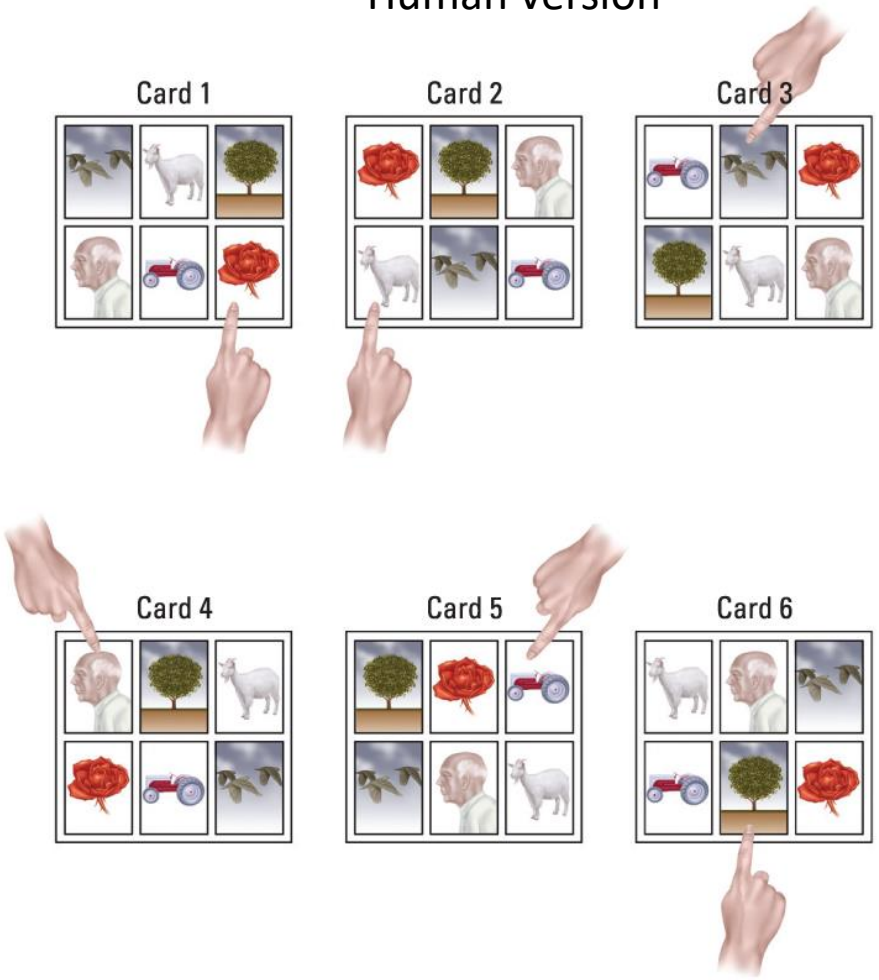
Self-Ordered Memory Task for Monkeys

Self-ordered tasks that ask people to keep track of their previous responses

Mental "To Do" List

Human version



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N-back task

Update contents of WM to keep up with task

3-back task

4 6 5 8 7 3 **9** 1 6 7 0 **3** 5 2 7 5 **1** 4 8 7 8 **9** 5 4 7

Real- life example?

During a conversation, scheduling your project discussions to avoid conflict with class timings and meeting with supervisor

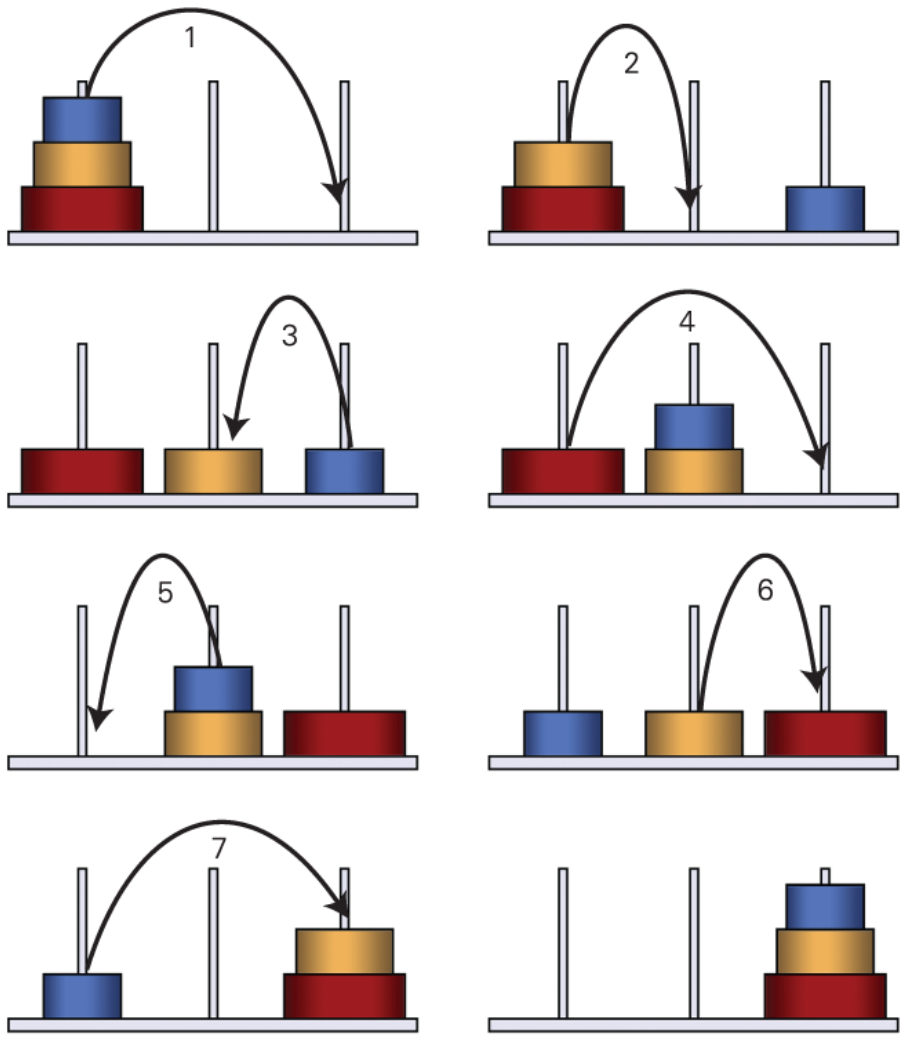
Tower of Hanoi

Goal Setting and Planning

Maintaining a goal in your mind

- Solving the Tower of Hanoi puzzle requires manipulation of working memory because you must remember setting subgoals, tracking completed and remaining goals, planning next goal…

Task originally from a legend of a temple in India
64 gold disks @ 1 per second = 580 billion years!
Adapted by Edouard Lucas in 1883



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Task Switching

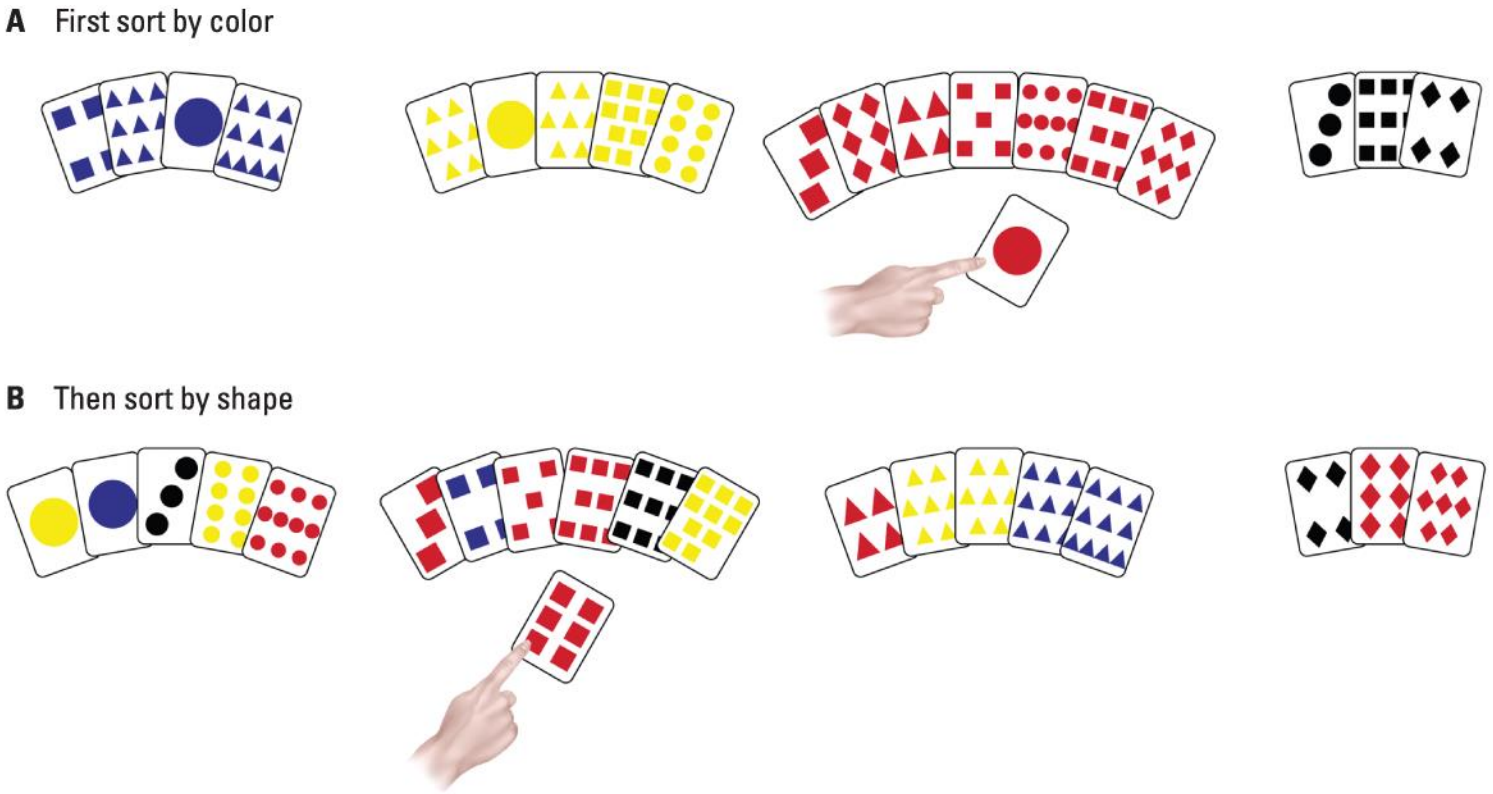
(online exp)

Task switching requires the manipulation of working memory because you must pay attention to the task you are doing at a given moment while at the same time monitoring external cues for information that may signal the need to switch to another task

The Wisconsin Card Sorting Test

- Sorting rule changes without warning
- Maintaining and then switching a rule
- Frontal patients and perseveration (Roberts et al., 1996)

Real life E.g.?



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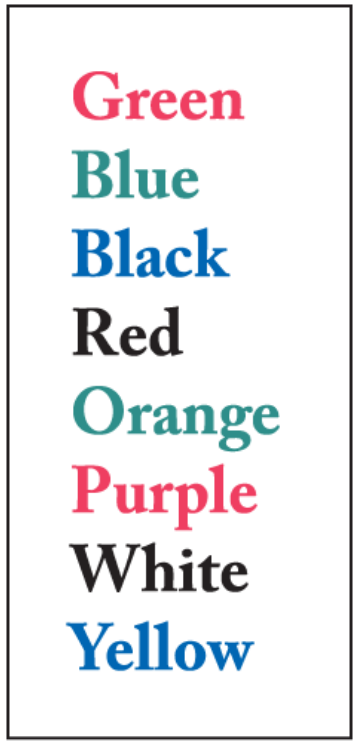
Stimulus Selection and Response Inhibition

- Automatic processes are triggered by situational cues
- Willed, or controlled, actions are mediated by the *supervisory attentional system*
- A well-known test of how well a person's control processes can direct attention to stimuli and inhibit inappropriate automatic responses is the **Stroop task**
  - The Stroop task illustrates the fundamental competition within our brains over the control of our behaviors and thoughts

The Stroop Task



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- The names of colors are printed from top to bottom, each in a color that does not correspond to the name
- The task is to recite the colors that the words are printed in (color of ink) without being distracted by what the words say

Stroop task

Real life E.g.?

- Imagine a 4 × 4 grid (16 squares) with a 1 in the second column of the second row.
- Place a 2 to the right of the 1.
- In the square above the 2, put a 3.
- To the right of the 3, put a 4.
- Below the 4, put a 5.
- Below that, put a 6.
- Then to the left of that, a 7.
- What number is above the 7?

		3	4	
	1	2	5	
		7	6	

Visuospatial Sketchpad + updating short-term buffer

For more online experiments

- https://www.psytoolkit.org/c/3.4.2/library

1. Texting while driving
2. Remembering to pick up fruits, sanitizer, bread, chips, and toothpaste while you walk up and down the aisles at a supermarket.
3. Preparing for your friends a meal consisting of a salad, two side dishes, and dessert and having all the dishes ready to serve at the same time
4. Remembering not to call out the name of an old employee while assigning work to a new employee
5. Driving and turning on roads in India and USA

- CHOICES:
- **A.** *Updating of short-term memory buffers*
- **B.** *Setting goals and planning*
- **C.** *Task switching*
- **D.** *Stimulus selection and response inhibition*

Multi-tasking can drain your working memory

- talk on the phone, listen to music, and surf the Internet at the same time
- Driving and talking/texting on the phone (banned by LAW)

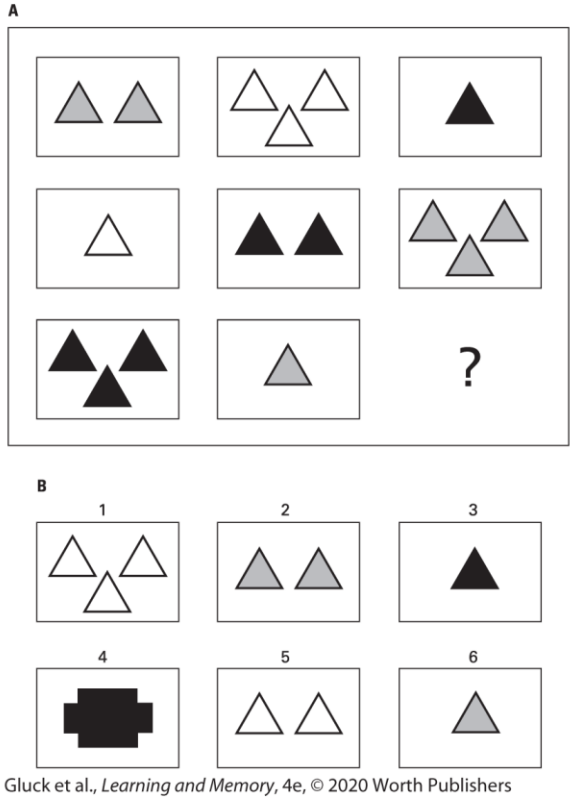
- Too much multitasking can exhaust you mentally

Executive Function and Intelligence

Working memory capacity

Ability control and manipulation of larger numbers of rules, concepts, goals, and ideas

Are Working Memory and Cognitive Control the Keys to Intelligence?



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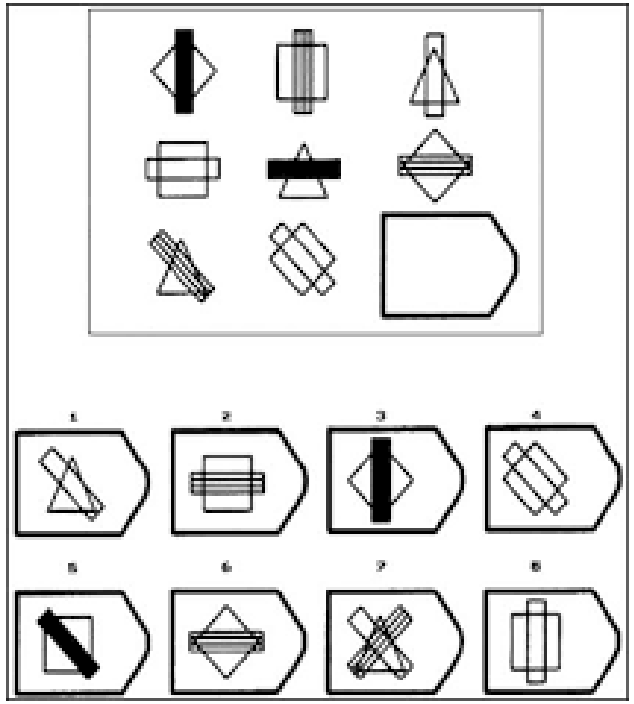
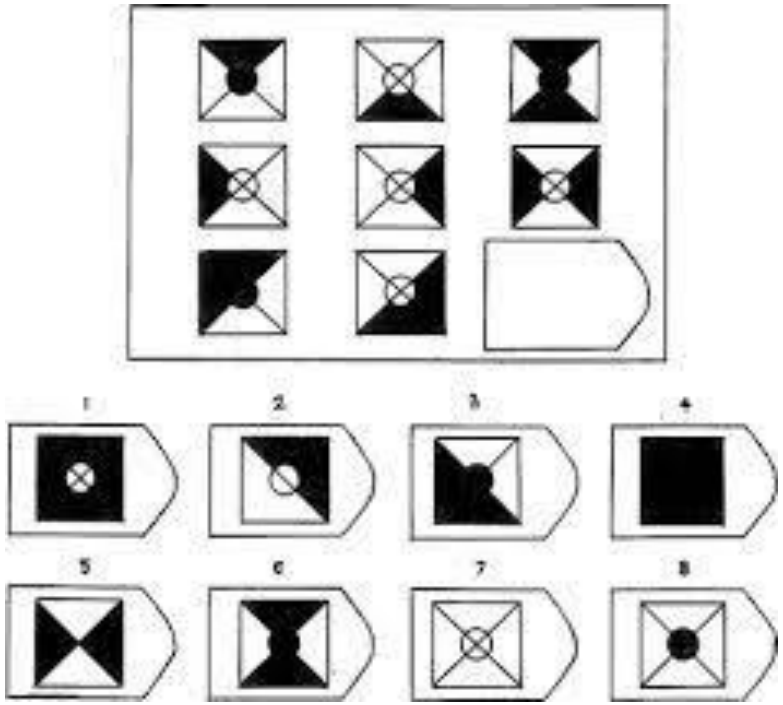
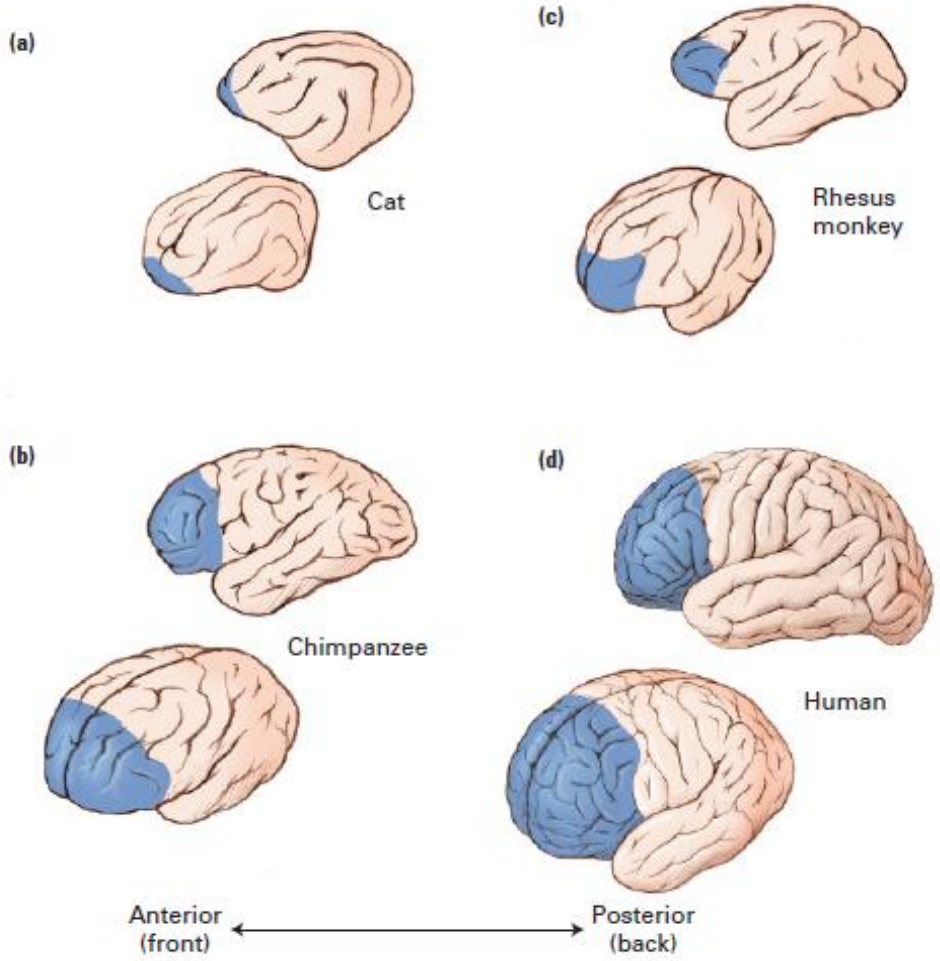
Raven Progressive Matrix Test





Can we train and improve WM?

- WM capacity is predictive of performance in higher cognitive abilities.
- WM has been shown to improve with training. Importantly, improvement in WM can transfer between trained and non-trained tasks.
- prefrontal neurons play the most important part in the maintenance of information in WM.
- Effects of WM training
  - increases in the activity of neurons in the prefrontal cortex,
  - increases in the strength of connectivity within the prefrontal cortex and between the prefrontal cortex and other areas.
- Neural changes after training are found in cortical areas that process spatial information in WM and attention, potentially providing a basis for transfer to other cognitive and behavioural tasks that rely on spatial WM and spatially selective attention.



https://www.nature.com/articles/nrn.2016.43

Without an intact frontal lobe?

Boxers
Rugby players
Stroke
Tumour
Schizophrenia

- World War II Vets (Pfiefer, 1922)

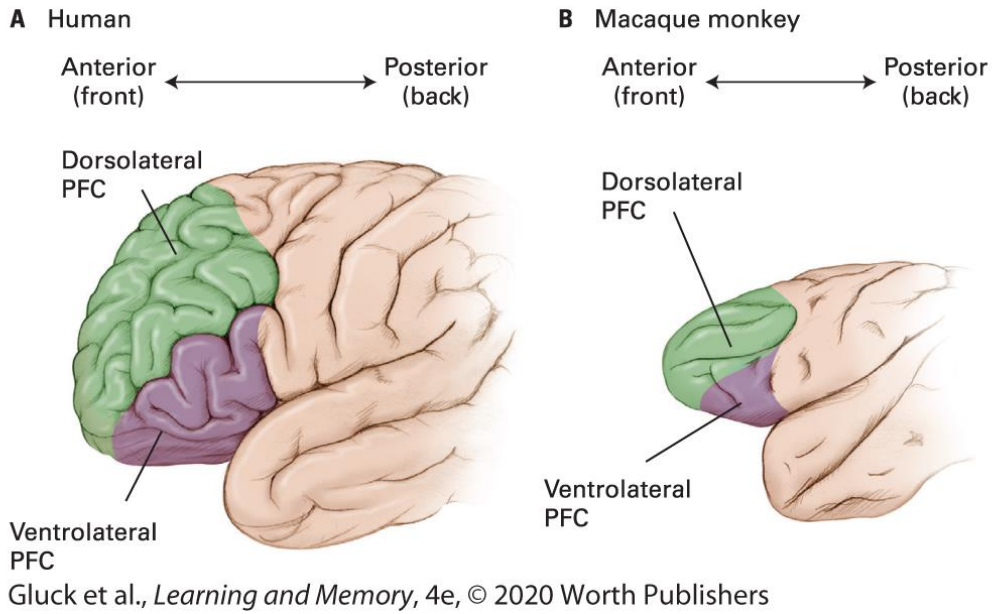
- Baddeley's (1986) patient RJ
  - Bilateral Frontal Lesions

perseveration. A failure to learn a new response, especially as demonstrated by continued adherence to an old, no longer valid response rule. (Task for testing?)

Dysexecutive syndrome: a disrupted ability to think and plan (Task for testing?

Working memory – Frontal Lobe

- Studies of animals and humans implicate the frontal lobes—especially the **prefrontal cortex (PFC)**, the most anterior (farthest forward) section of the frontal lobes—as being critical for working memory and executive control
- In humans, the prefrontal cortex encompasses approximately one-third of the cerebral cortex



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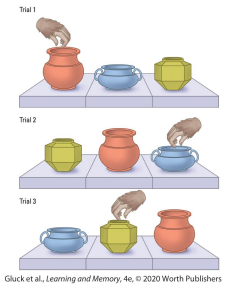
How are the frontal lobes organized?
How does working memory actually work?

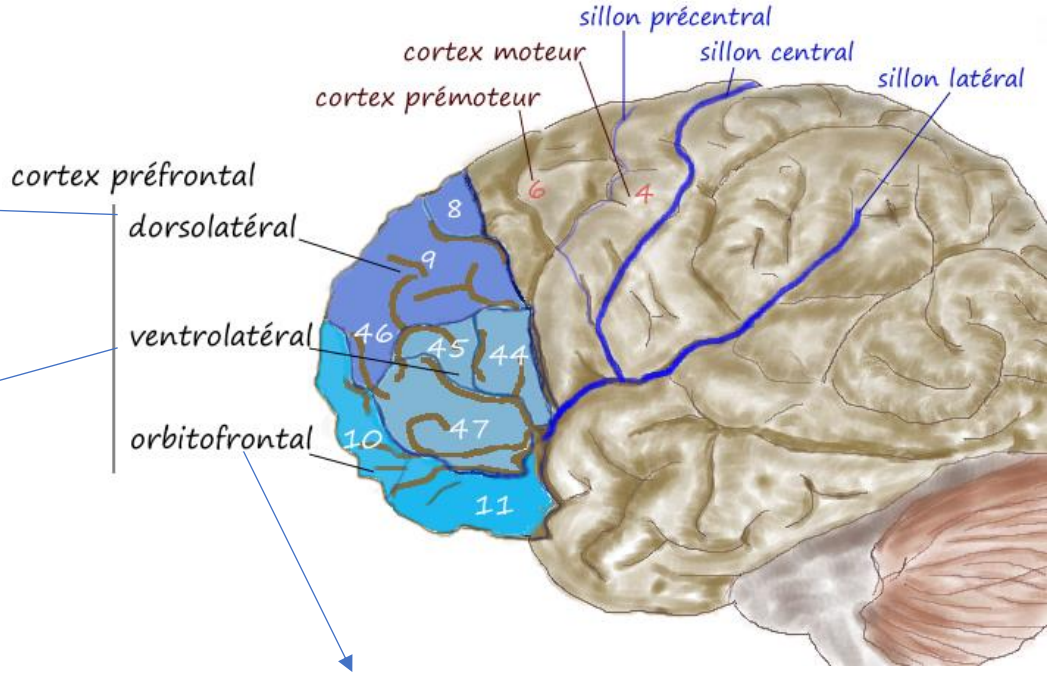
Divisions of the Prefrontal Cortex



Supports higher-order executive-control functions such as monitoring and manipulating of stored information, thus doing the job of Baddeley's central executive

Left vlPFC – phonological
Right vlPFC – visuospatial

Supports encoding and retrieval of information (including rehearsal for maintenance), performing as the visuospatial sketchpad and phonological rehearsal loop proposed by Baddeley

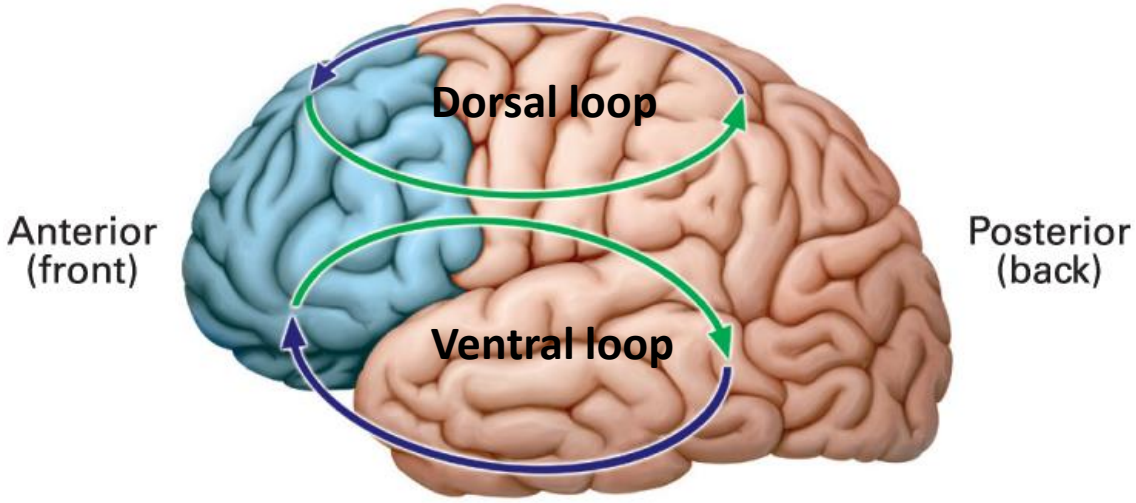


Decision making, prediction, reward evaluation, etc.

- The prefrontal cortex can be divided into three main regions
  - Orbitofrontal cortex (OFC)
  - **Dorsolateral prefrontal cortex (DLPFC):** the left and right sides of the topmost part of the prefrontal cortex (PFC)
  - **Ventrolateral prefrontal cortex (VLPFC):** the lower left and right sides of the PFC

Maintenance in Working Memory Through Frontal-Posterior Circuits

- Frontal-cortex activations reflect the executive *processes* that are needed to maintain the representations of memory items in posterior areas of cortex, where they are permanently stored (Long term memory & working memory areas overlap)
- Working memory emerges from a network of brain regions, all of which send and receive information to and from the prefrontal cortex
- Together, these networks accomplish the active maintenance of internal representations necessary for goal-directed behavior



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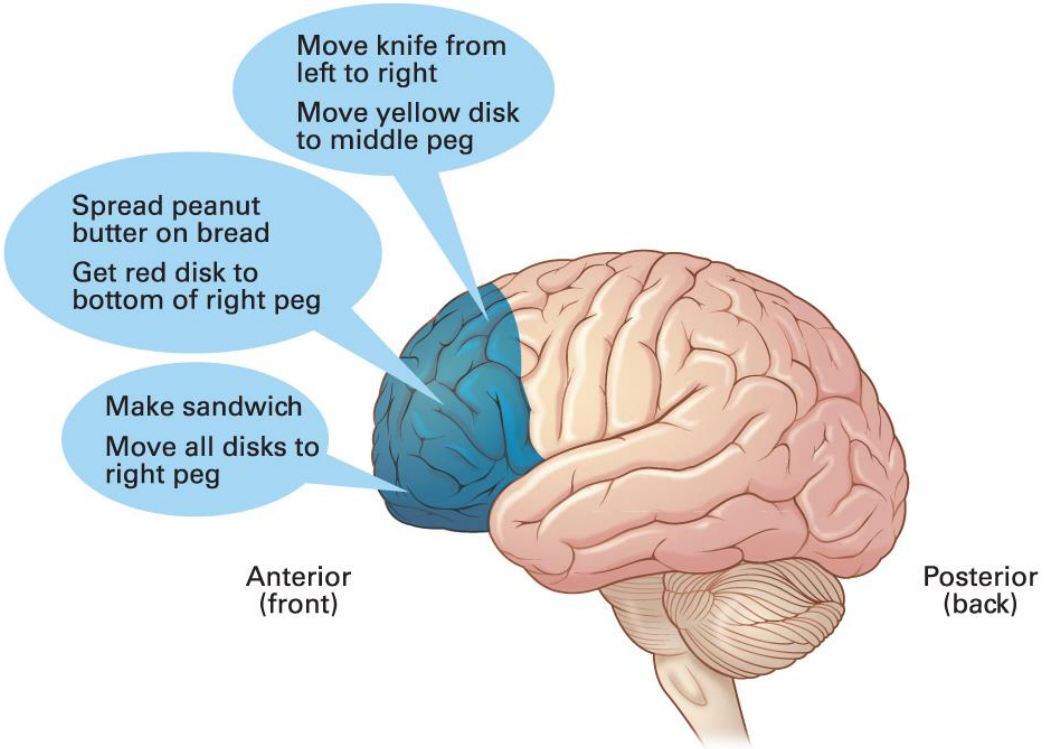
Goal Abstraction and Frontal-Lobe Organization

- The gradient of abstraction from general plans and goals to more specific action plans follows a physical gradient beginning at the front of the frontal lobes and moving back - flow of control goes from the most anterior regions (big picture goal) toward the back of the frontal lobes (specific subgoals)



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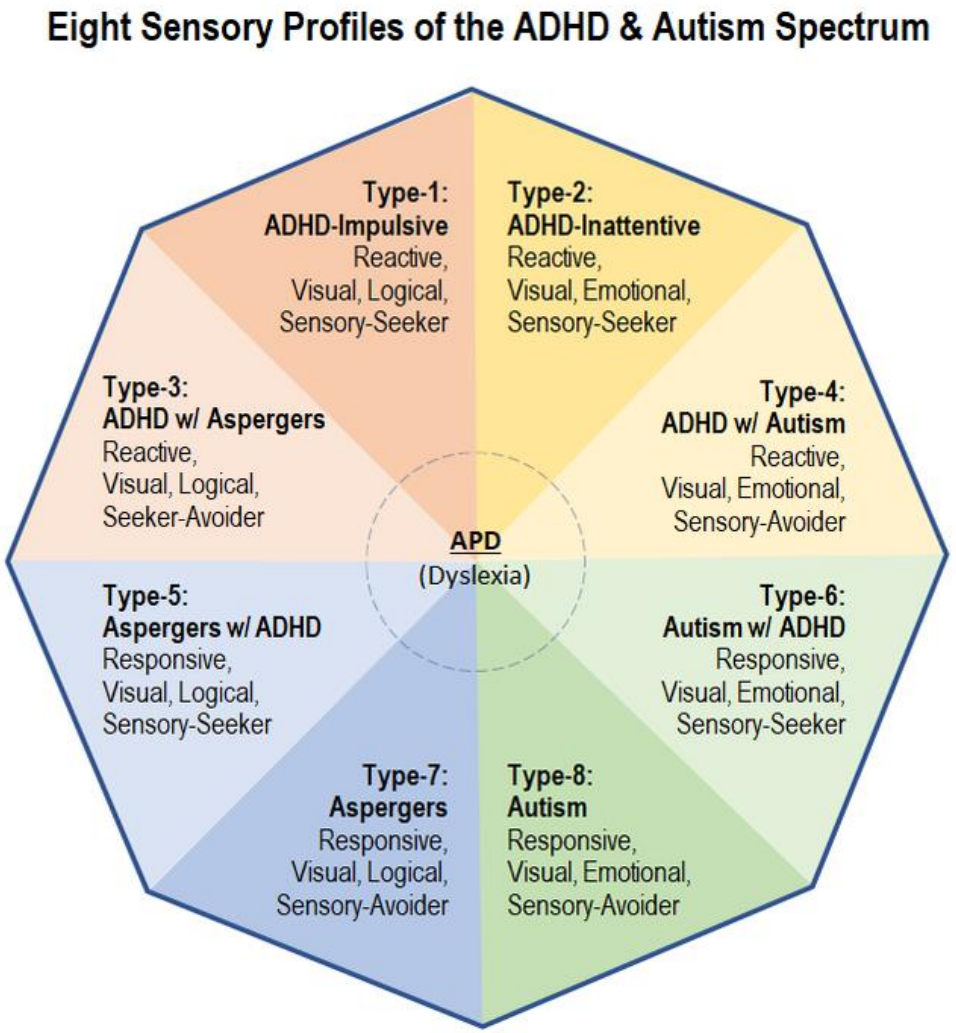
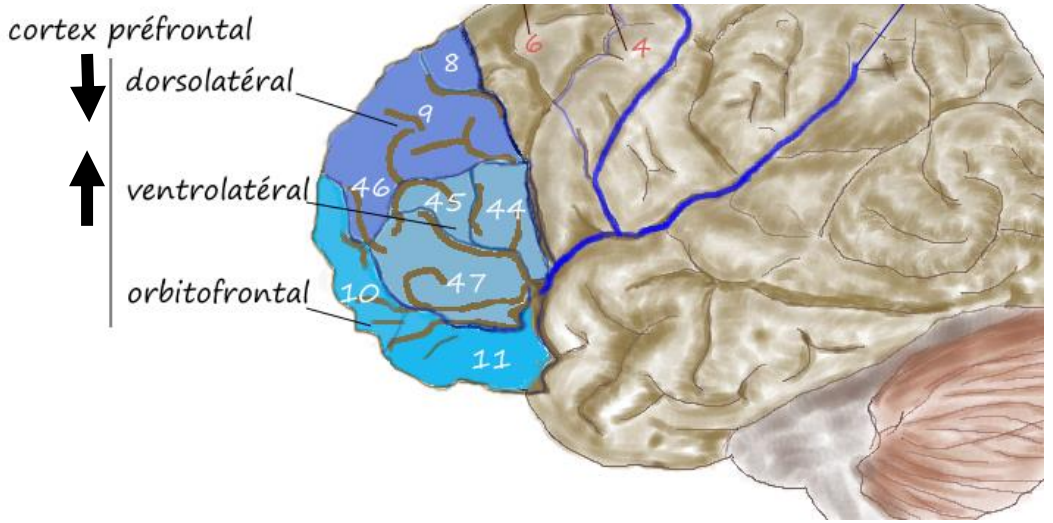
Attention-Deficit/Hyperactivity Disorder (ADHD)

- difficulty with cognitive-control processes such as planning, organizing their time, keeping attention focused on a task, and inhibiting responses to distracting stimuli
- Studies show children with ADHD have a small right prefrontal cortex, the region associated with spatial attention and working memory
  - poor prefrontal activity
  - Drugs to increase dopamine are prescribed – to compensate



The Prefrontal Cortex in Schizophrenia

- disturbances in working memory and executive control
  - Almost normal performance on phonological or visuospatial memory tasks (vlPFC)
  - Impaired at visuospatial working- memory tasks when these tasks involve the manipulation or updating of information in working memory (dlPFC)



- Extra info on schizophrenia begins (not in the syllabus)

What might cause schizophrenia?

- Other factors that may play a role in schizophrenia susceptibility–
  - paternal age
  - maternal stress or malnutrition
  - prenatal infections (viral infections in mother)
  - urban birth or residing in an urban setting – higher rate of viral infections
  - childhood adversity
  - Substance abuse

Positive symptoms

Due to excessive dopaminergic activity – as seen in substance abuse

- ***Delusions.*** Delusions of being controlled (e.g., "Aliens are making me steal"), delusions of persecution (e.g.,"My mother is poisoning me"), or delusions of grandeur (e.g., "Narendra Modi admires my drawings").
- ***Hallucinations.*** Imaginary voices making critical comments or telling patients what to do.
- ***Inappropriate affect.*** Reacting with an inappropriate emotional response to positive or negative events.
- ***Disorganized speech or thought.*** Illogical thinking, peculiar associations among ideas, belief in supernatural forces.
- ***Odd behavior.*** Talking in rhymes, difficulty performing everyday tasks.

Negative symptoms

- *Affective flattening.* Diminished emotional expression
- *Avolition.* Reduction or absence of motivation.
- *Catatonia.* Remaining motionless, often in awkward positions for long periods.
- poverty of speech
- inability to experience pleasure (anhedonia)
- social withdrawal

Due to degeneration or impaired development. Common in brain damage disorders, especially to frontal lobes

Cognitive symptoms

- difficulty sustaining attention
- low *psychomotor speed* (for example, in movements that include a cognitive element, such as reaction time, connecting numbers or letters in sequence, or alternating numbers and letters),
- deficits in learning and memory,
- poor abstract thinking, and poor problem solving

The frequent recurrence of any two of these symptoms for 1 month is currently sufficient for the diagnosis of schizophrenia—provided that one of the symptoms is delusions, hallucinations, or disorganized speech.

- Depression, anxiety, substance abuse, and smoking are also very common in schizophrenia.

- The symptoms of schizophrenia typically appear gradually, over a period of several years.
  1. first clinical symptoms of schizophrenia tend to be symptoms of depression,
  2. followed by social withdrawal (negative symptoms) and
  3. cognitive difficulties (cognitive symptoms),
  4. positive symptoms

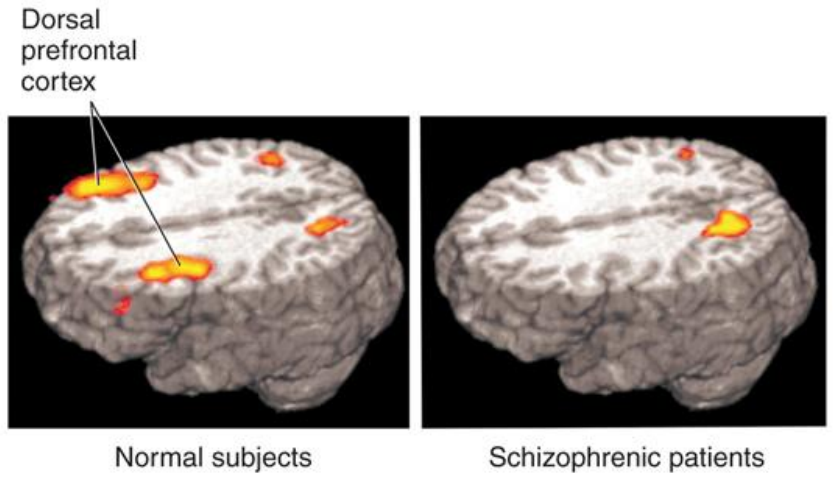
Interview: Catatonic Schizophrenic

Psychiatric Interviews for Teaching: Psychosis

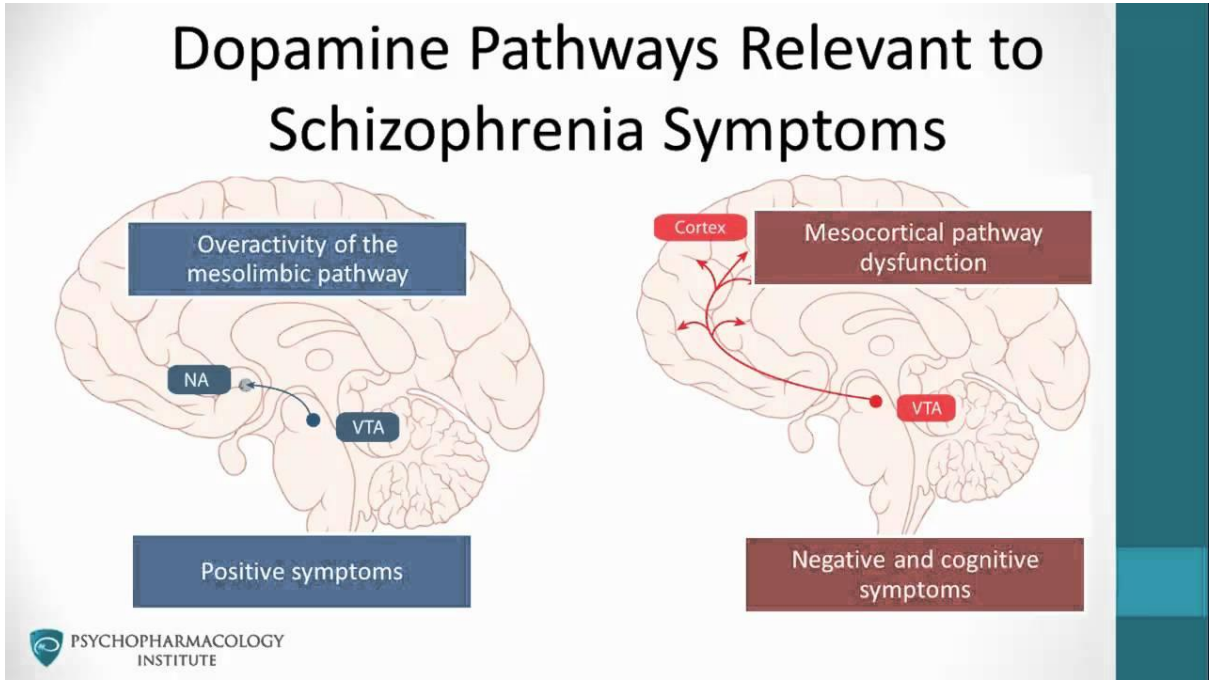
https://www.youtube.com/watch?v=iGH7hGkkMrU&ab_channel=NorthwesternMedicine

http://schizophrenia.com/diag.php#

Hypofrontality in Schizophrenia

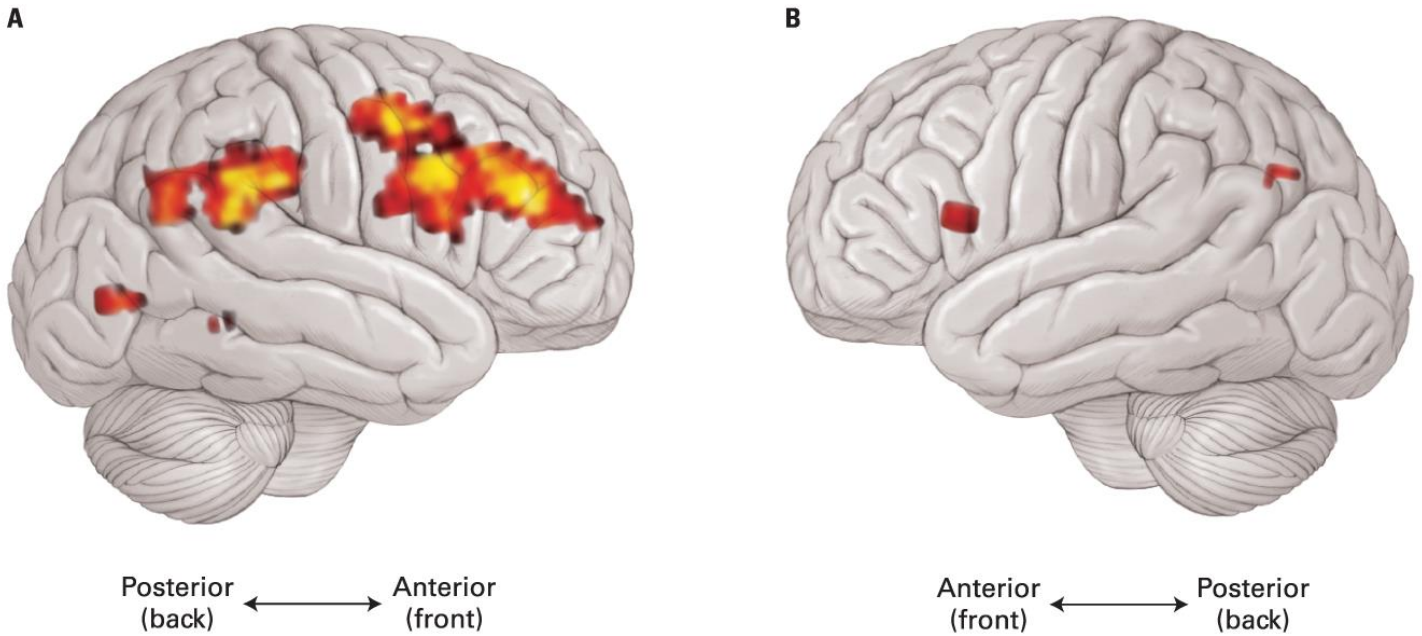


- Hypofrontality – structural changes in frontal lobe
  - fewer number of glutamate and dopamine receptors in the PFC
  - may be driven by prenatal environment (maternal viral infections)
  - may alter the brain development leading to smaller frontal regions and decreased activity during adolescence.



Dopamine and the Genetics of Schizophrenia

- Increased prefrontal activation is thought to reflect inefficient function in the prefrontal areas, such that the increased activity is necessary to support a given level of performance



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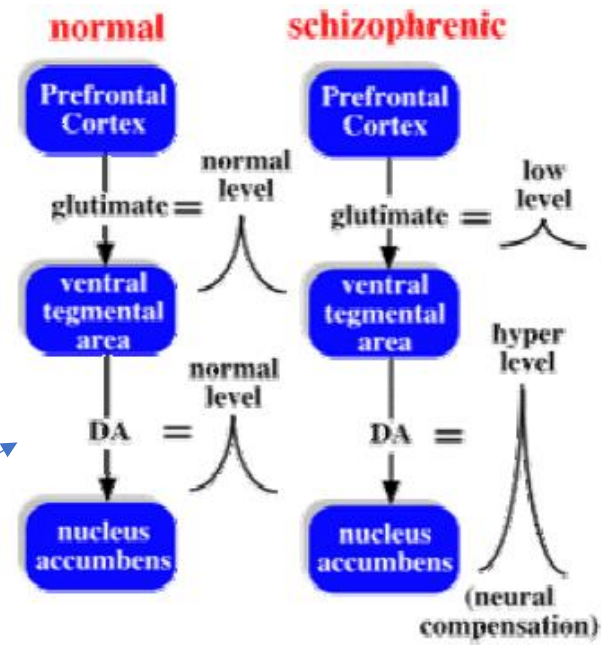
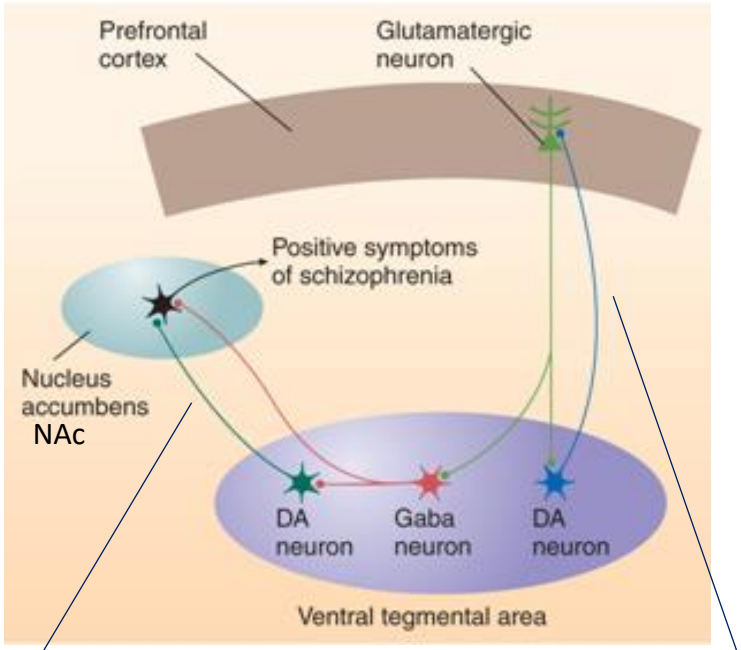
The schizophrenia network in the brain

- The prefrontal cortex (PFC) and excitatory (glutamatergic) and inhibitory (GABAergic) connections to the VTA
- Normally, at resting state, basal or spontaneous release of a neurotransmitter occurs constantly in the nervous system, independent of any environmental stimuli.
- Hypofrontality reduces the basal release of glutamate from the PFC to the VTA. This leads to lower basal release of dopamine in the VTA which in turn cause dopamine receptors in the VTA to become supersensitive, so they over react to environmental stimuli (neural compensation)
- Hypofrontality also lessens the inhibition from PFC to VTA, leading to hyperactivity in dopaminergic neurons from VTA to Nac.
- Thus overall, there is excess of dopamine released from VTA to NAc – resulting in positive symptoms (similar to those seen in substance abuse)
- The dopamine increase in NAc affects other brain areas it is connected to, especially amygdala, resulting in exaggerated positive symptoms (neutral faces look angry, delusions, etc.)
- Dopaminergic neurons also project back to the PFC – but due to hypofrontality (fewer dopamine receptors) the dopamine effect is low - the cause of negative and cognitive symptoms





Mesolimbic pathway

Mesocortical pathway