

Class 13

working memory and cognitive control

29th September 2022

Thursday

Is Working Memory a Place or a State?

- Working memory is often conceptualized as the mind's active workspace
- “Working memory” might not, in fact, describe a separate *place* for memories to be moved; rather, it might describe an active *state* for memories otherwise resident in LTM but not accessible to conscious reflection and manipulation until they are activated

Delayed Nonmatch-to-Sample Task



Monkey moves sample object for reward.



Screen obscures monkey's view during delay.



Monkey must choose novel nonmatch object for next reward.

Courtesy of David Yu, Mortimer Mishkin, and Janita Turchi, Laboratory of Neuropsychology, NIMH/NIH/DHHS.

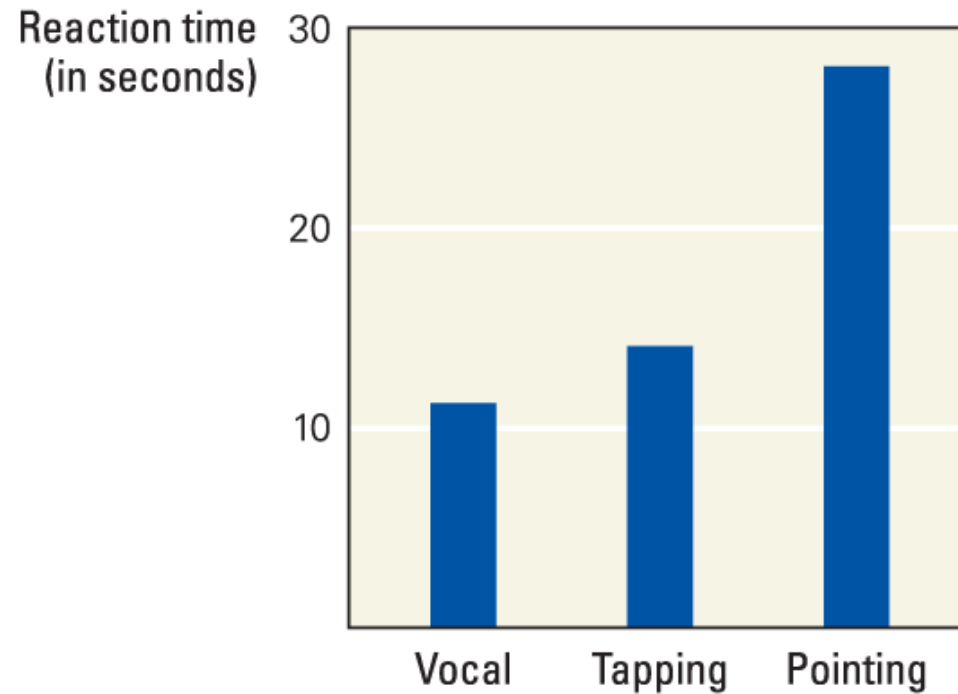
The **delayed nonmatch-to-sample (DNMS) task** is another test of visual working memory that involves remembering some object seen at the trial's start

A Dual-Task Experiment

A

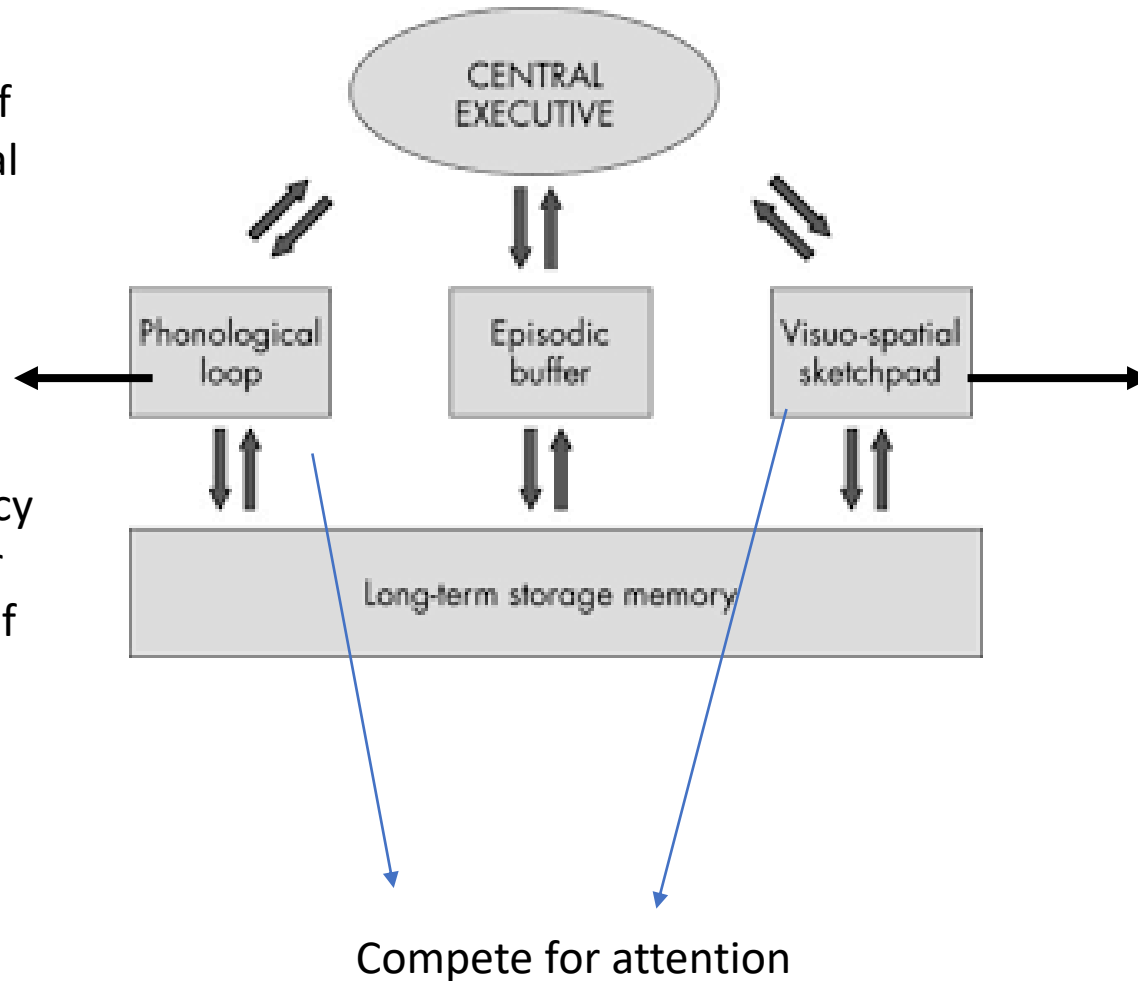


B



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- Without rehearsal, most people retain about 2 seconds' worth of information in their phonological memory
- Internal, unspoken speech used during rehearsal is vital to the phonological loop and verbal working memory
- **Word-length effect:** the tendency for a person to remember fewer words from a list as the length of the words increases

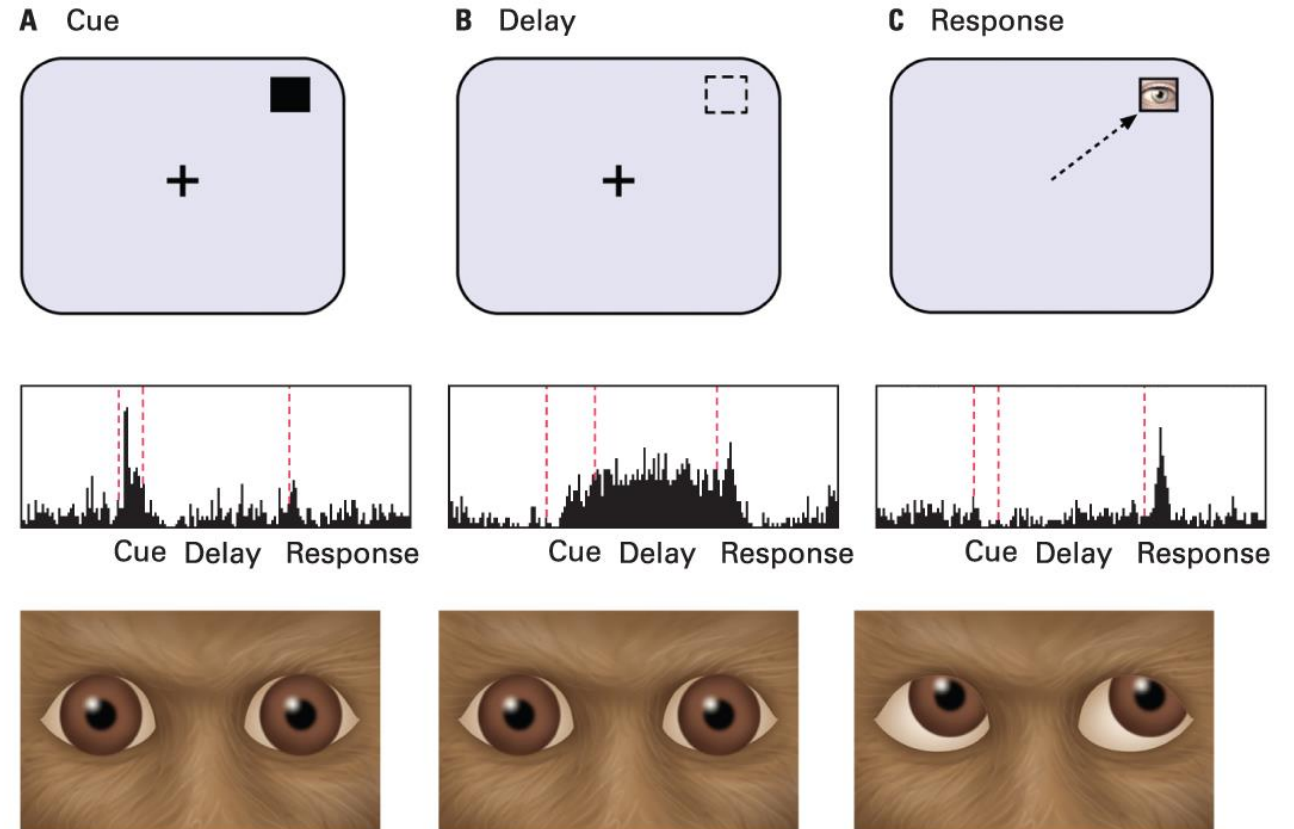


- The visuospatial sketchpad is a mental workspace for storing and manipulating visual and spatial information
- Limited capacity similar to the phonological loop, but these capacities are independent of one another
- Dual-task experiments provide evidence for the independence of these two memory buffers

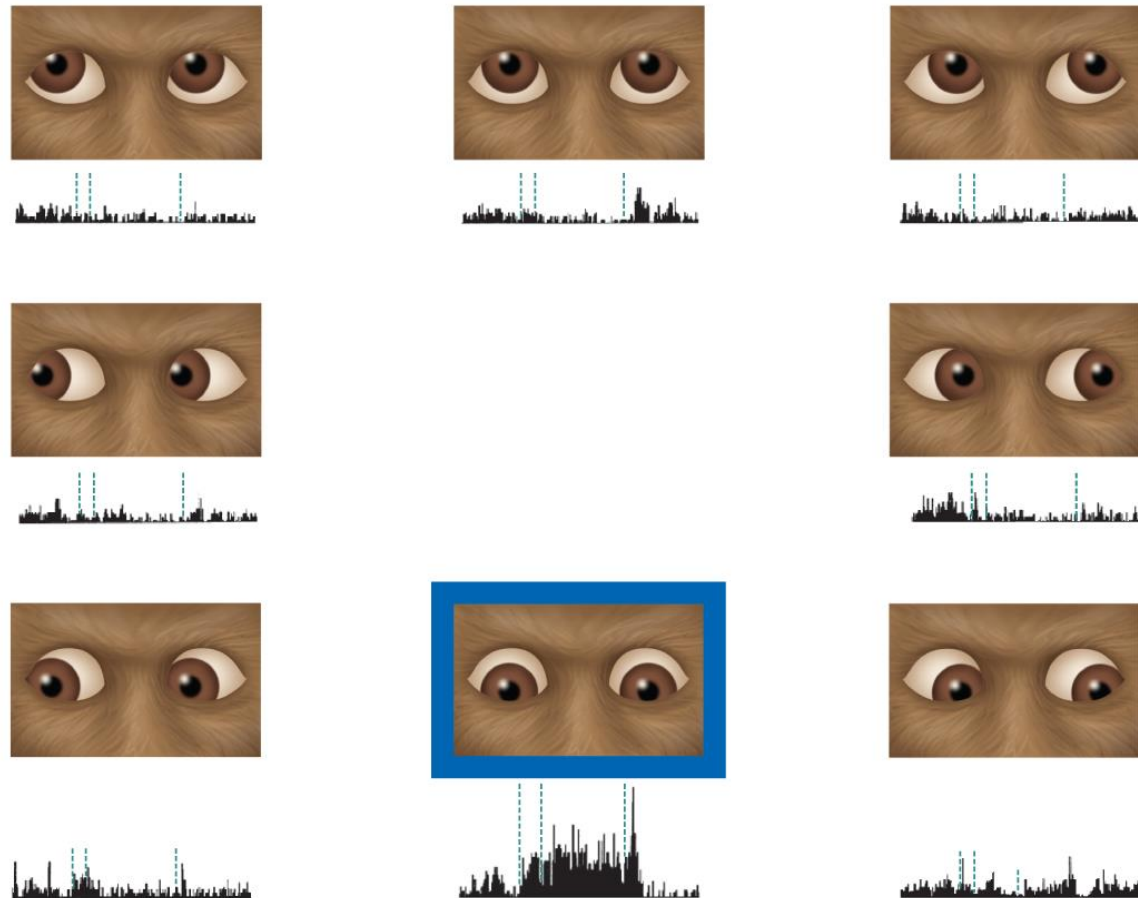
- How does the brain maintain information active over time?

Frontal Brain Activity During Working-Memory Tasks

- Researchers in the early 1970s began to record prefrontal-cortex neural activity during working-memory tasks



Response of One Prefrontal Cortex Neuron During the Delayed-Response Eye-Gaze Task



Quiz 5

Cognitive Control

- *Cognitive control*, also known as *executive control* or *executive function*: the manipulation of working memory that allows for the exercise of various aspects of higher-order cognition, including reasoning, task flexibility, problem solving, and planning
- Researchers have found evidence of cognitive control in many behaviors, including:

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

N-back task

3-back task

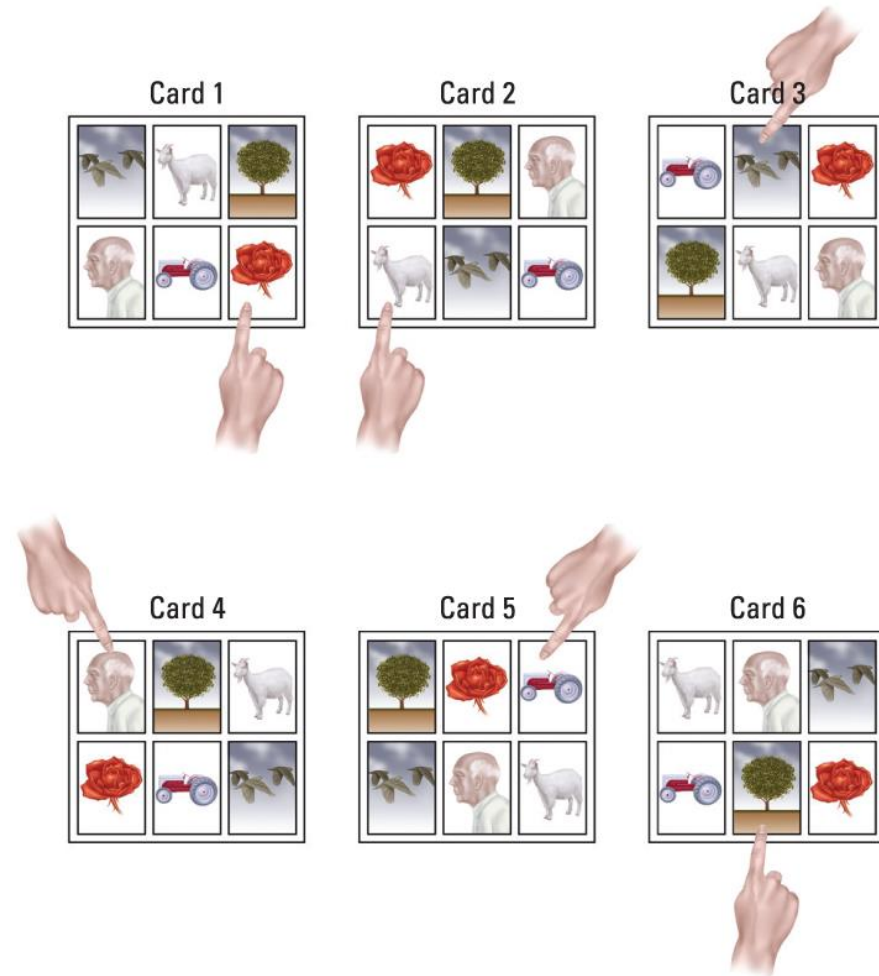
4 6 5 8 7 3 9 1 6 7 0 3 5 2 7 5 1 4 8 7 8 9 5 4 7

Real- life example?

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

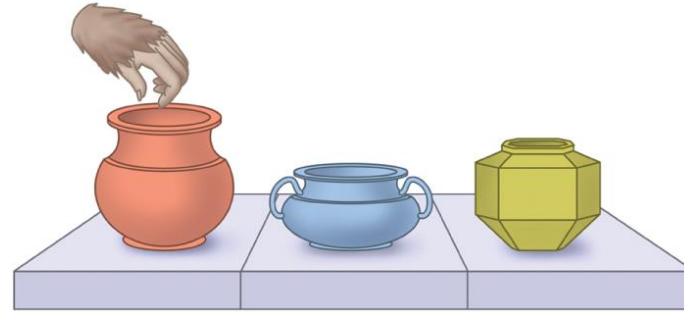
Controlled Updating of Short-Term Memory Buffers

- Self-ordered tasks that ask people to keep track of their previous responses are another tool that can be used to assess the central executive's manipulation of working memory.

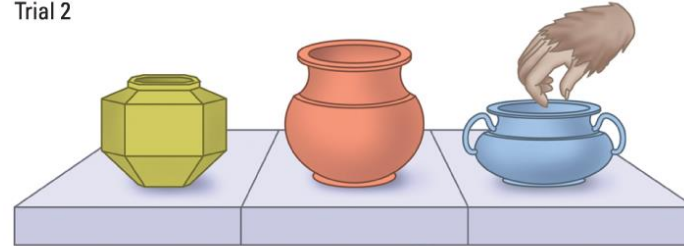


A Self-Ordered Memory Task for Monkeys

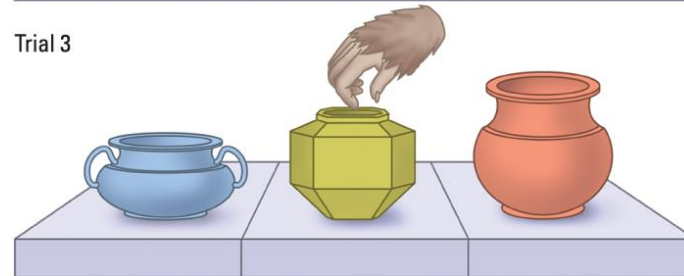
Trial 1



Trial 2



Trial 3

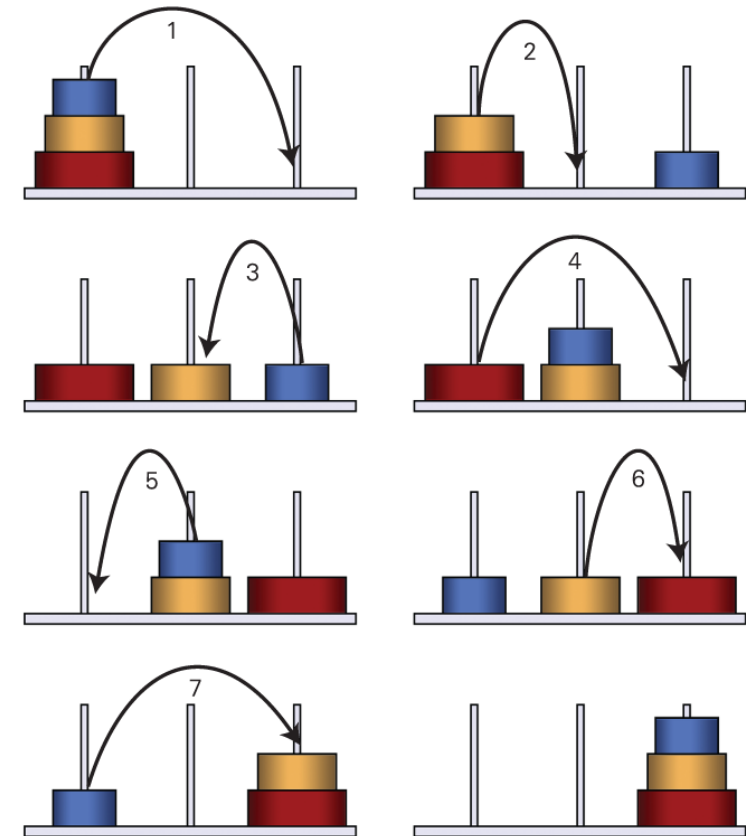


Tower of Hanoi

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 at least three things at all times
 - What subgoals have been accomplished
 - What subgoals remain
 - What subgoal is the next to be addressed



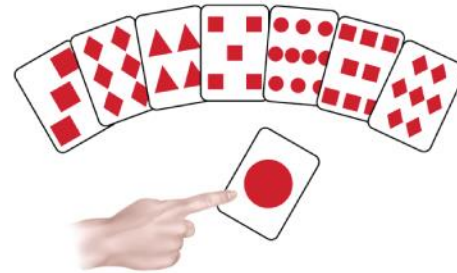
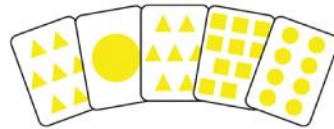
Task Switching

- 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
- A commonly used procedure for studying task switching in the laboratory is the Wisconsin Card Sorting Test

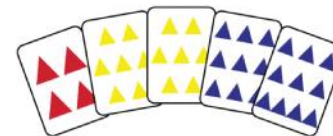
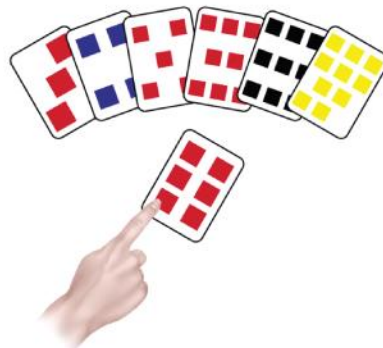
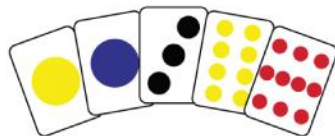
The Wisconsin Card Sorting Test

(online exp)

A First sort by color



B Then sort by shape



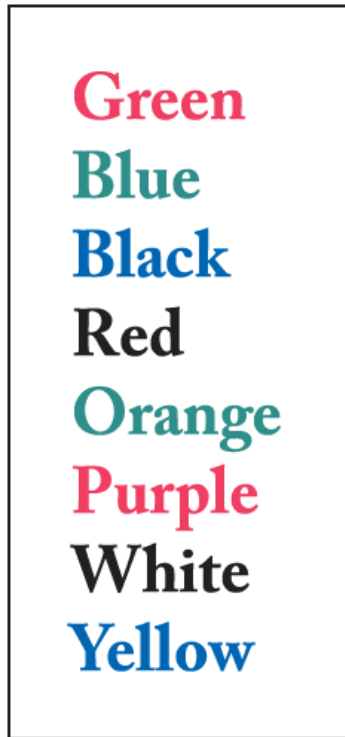
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Real life E.g.?

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

red
yellow
green
blue
red
blue
yellow
green
blue
red

Real life E.g.?

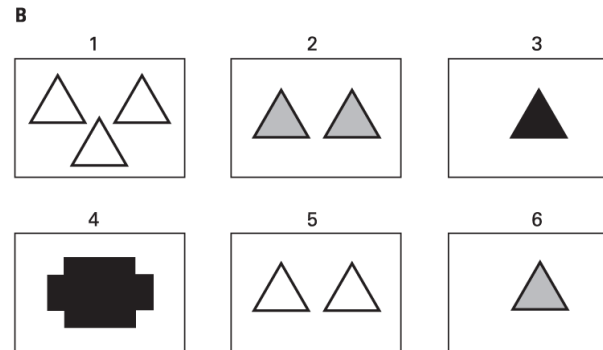
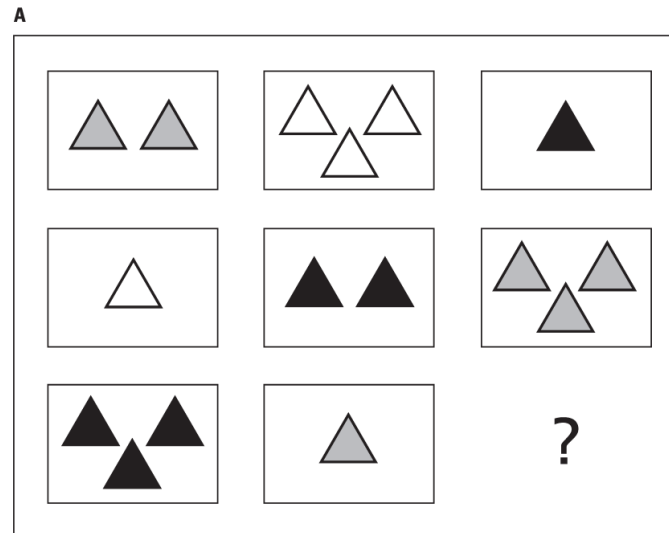
For more online experiments

- <https://www.psychtoolkit.org/c/3.4.2/library>

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

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

Raven Progressive Matrix Test of Nonverbal Intelligence



Are Working Memory and Cognitive Control the Keys to Intelligence?

- Evidence of a relationship between working memory and intelligence does not depend only on verbal intelligence
- being able to juggle many rules in one's head is correlated with scoring high on nonverbal tests of intelligence
- Results suggest that general intelligence appears to be associated with a strong working memory, especially in terms of the control and manipulation of larger numbers of rules, concepts, goals, and ideas

Intelligence, defined as the capacity for learning, reasoning, and understanding, is a familiar enough term, but the concept is often poorly understood. Intelligent people are frequently described as “quick,” but a growing body of research suggests that intelligence has less to do with the brain's processing speed and more to do with executive control of working memory.

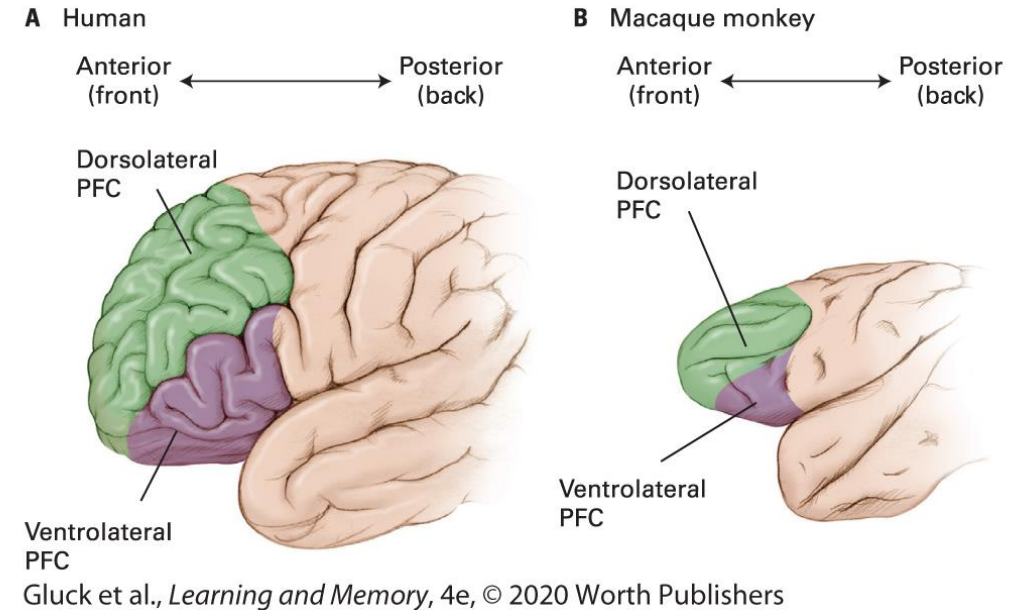
Multi-tasking can drain your working memory

- 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



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



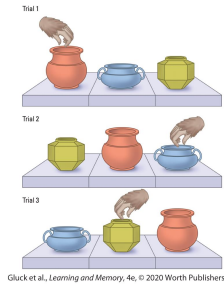
How are the frontal lobes organized?
How does working memory actually work?

Deficits in Working Memory Following Frontal-Lobe Damage

- People with damage to the frontal lobes show deficits on all of the working-memory and cognitive-control tasks described in the previous section
 - short-term memory
 - Planning, organizing,
 - Response Inhibition
 - task switching
- Patients with frontal-lobe damage have no problem learning an initial sorting rule, but later show **perseveration**, which means they fail to learn a new rule and, instead, persist in using an old rule despite repeated feedback indicating that the old rule is no longer correct
- **Dysexecutive syndrome:** a disrupted ability to think and plan
- Frontal lobe damage can be caused by tumors, surgery, strokes, or blunt-force trauma
 - Professional (and even some high school) football players who routinely headbutt other players and experience rapid deceleration also show a pattern of frontal-lobe damage and associated cognitive problems



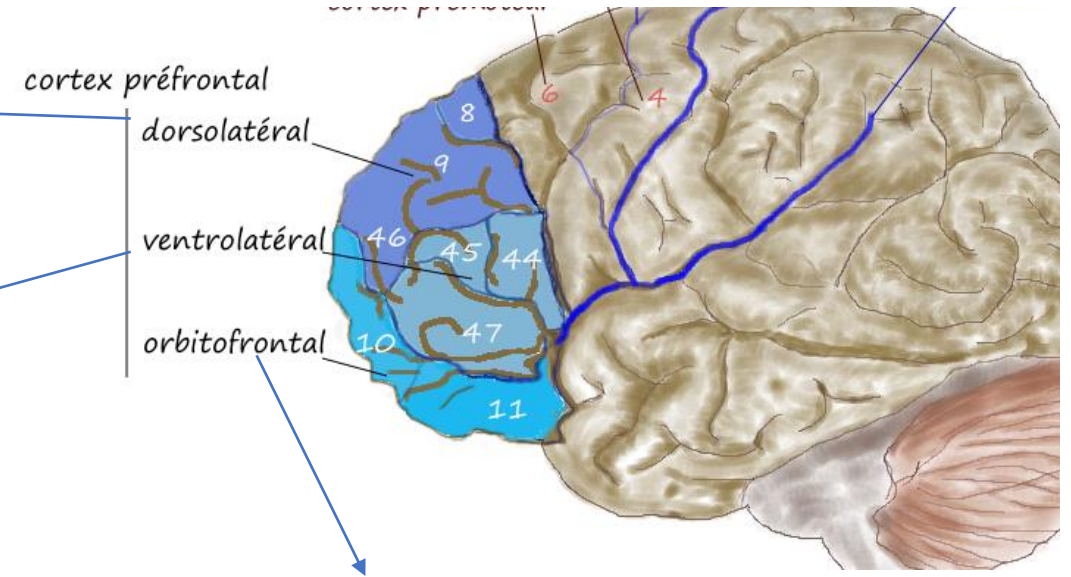
Divisions of the Prefrontal Cortex



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

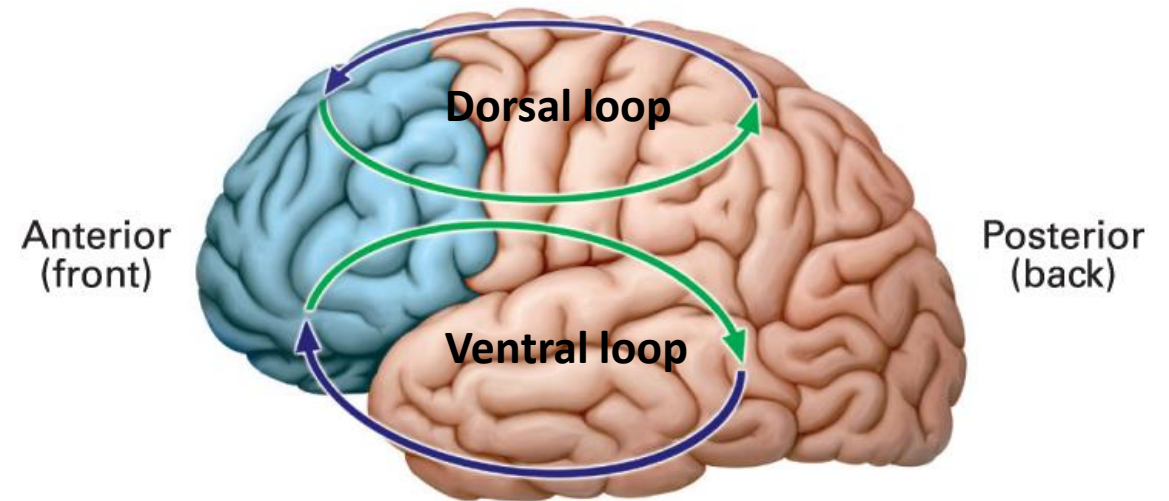


Decision making, prediction, reward evaluation, etc.

- 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

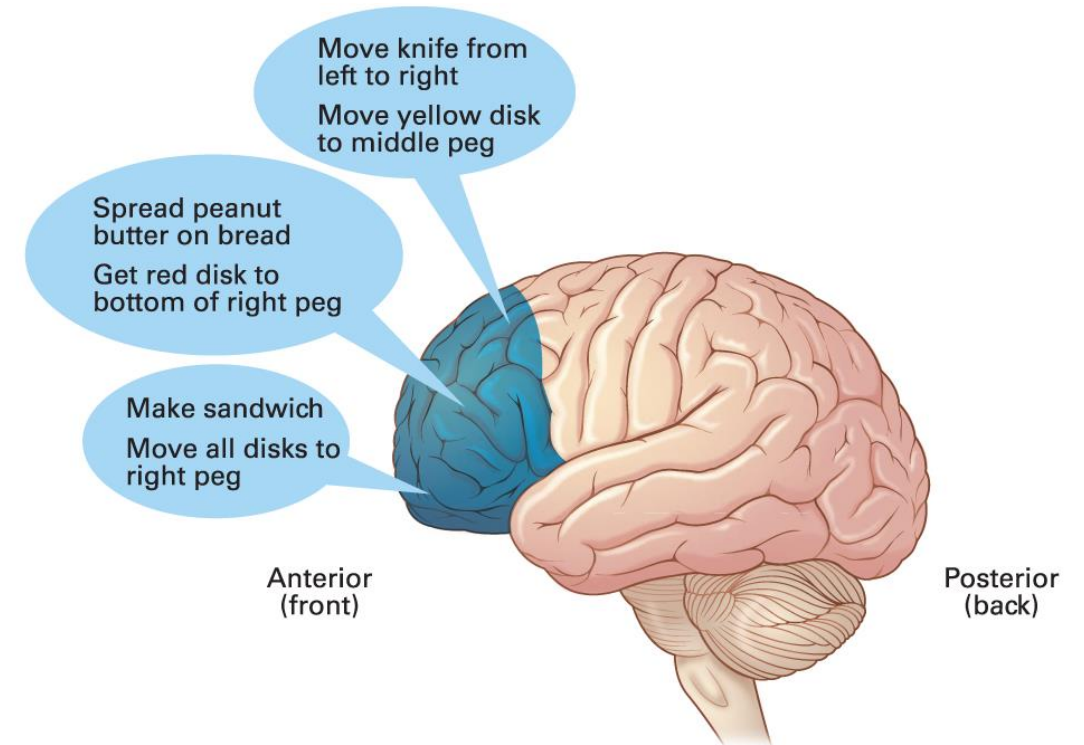
- Increasing evidence suggests that the frontal-cortex activations reflect not the *storage* of information in working memory but rather the executive *processes* that are needed to maintain the representations of memory items in posterior areas of cortex, where they are permanently stored
- Computational modeling and lesion data alike have argued that both working memory and long-term memory (LTM) representations are stored in the same posterior cortical regions involved in the initial perception, encoding, and long-term storage of memories
- 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)



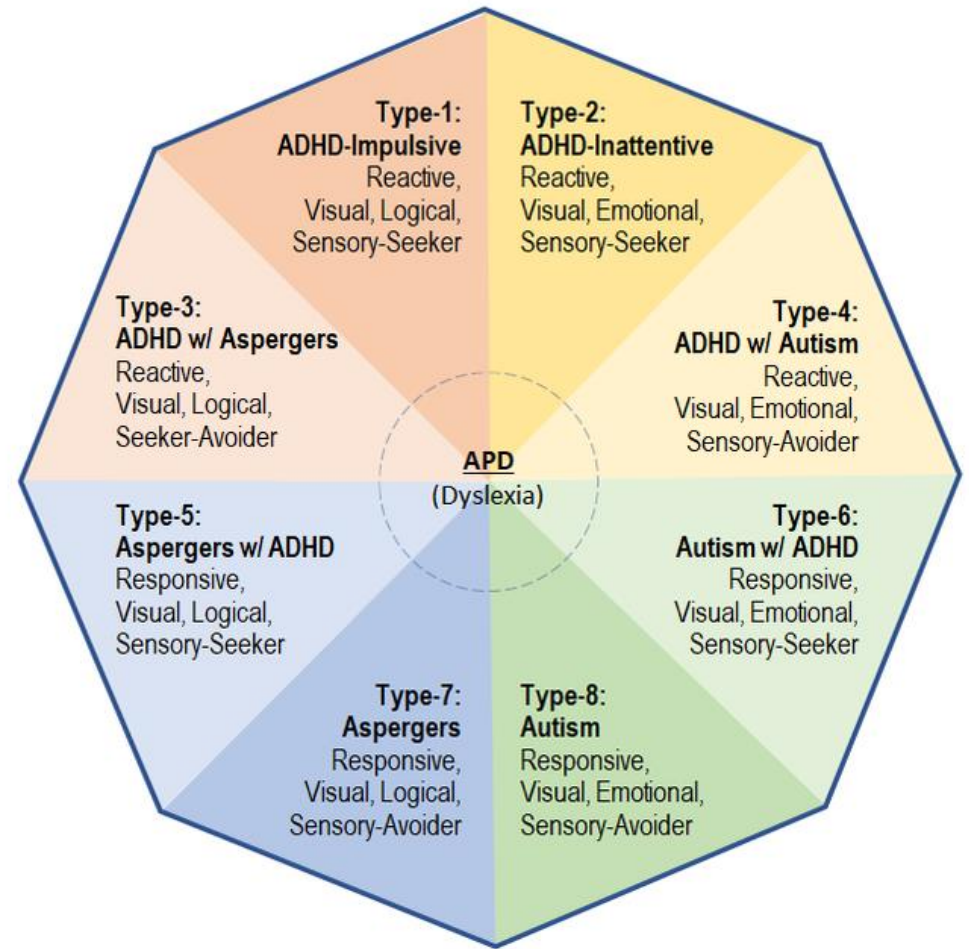
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- Identify the region of the prefrontal cortex whose activity is most critical for each of the following tasks.
 1. Deciding who should sit where around a dinner table set for eight to avoid seating ex-spouses and feuding ex-business partners next to each other
 2. Rehearsing the speech you will make at your farewell
 3. Remembering where you parked and deciding which way to walk to your parking spot as you exit the department store at the mall

Attention-Deficit/Hyperactivity Disorder (ADHD)

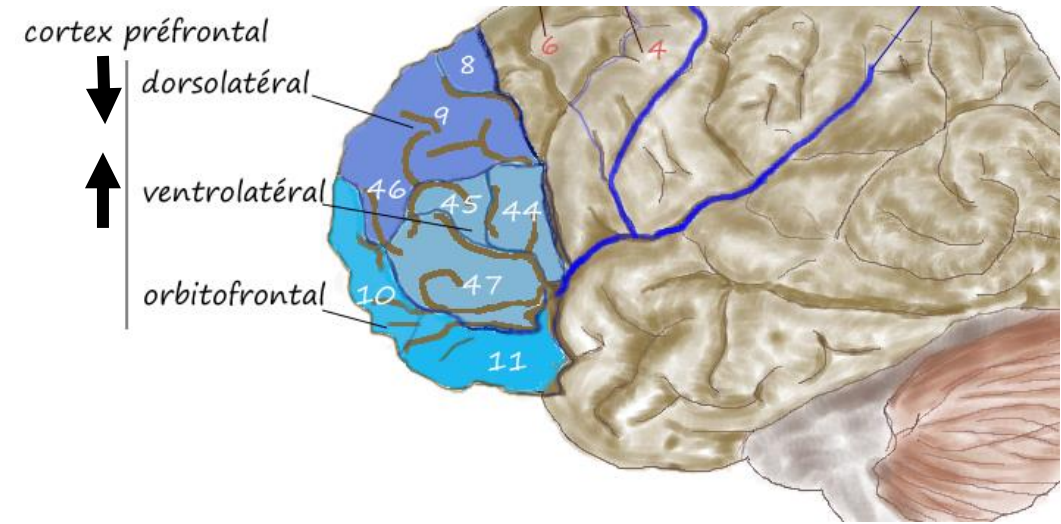
- About 5% of children are diagnosed with ADHD
- Children and adults with this disorder have great difficulty with cognitive-control processes such as planning, organizing their time, keeping attention focused on a task, and inhibiting responses to distracting stimuli
- children with ADHD shows that they have a smaller right prefrontal cortex, the region associated with spatial attention and working memory
- Drugs that increase dopamine activity are prescribed – to compensate for poor prefrontal activity

Eight Sensory Profiles of the ADHD & Autism Spectrum

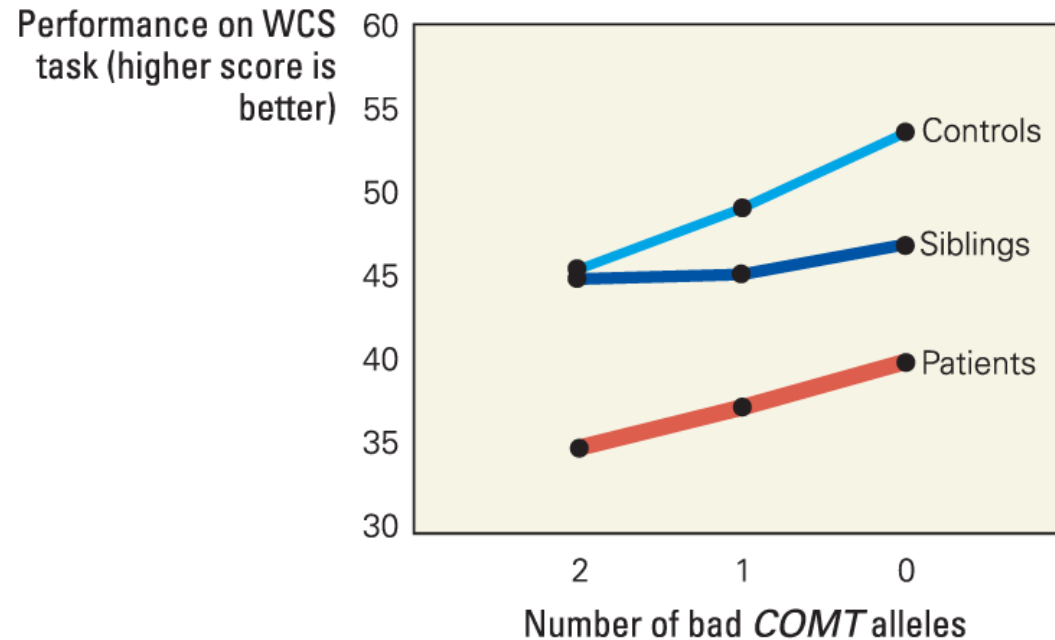


The Prefrontal Cortex in Schizophrenia

- People diagnosed with schizophrenia display disturbances in both cognition and memory, especially in working memory and executive control
 - Almost normal performance on phonological or visuospatial memory tasks (vIPFC)
 - Impaired at visuospatial working- memory tasks when these tasks involve the manipulation or updating of information in working memory (dIPFC)



Effect of Gene Mutation on Frontal-Lobe Function in Schizophrenia



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Genetic research into the causes of schizophrenia has shown that mutation in the *COMT* gene affects dopamine metabolism in the frontal lobes

COMT is one of several enzymes that are critical for degrading dopamine and other neuromodulators

- 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.

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

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

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](#)

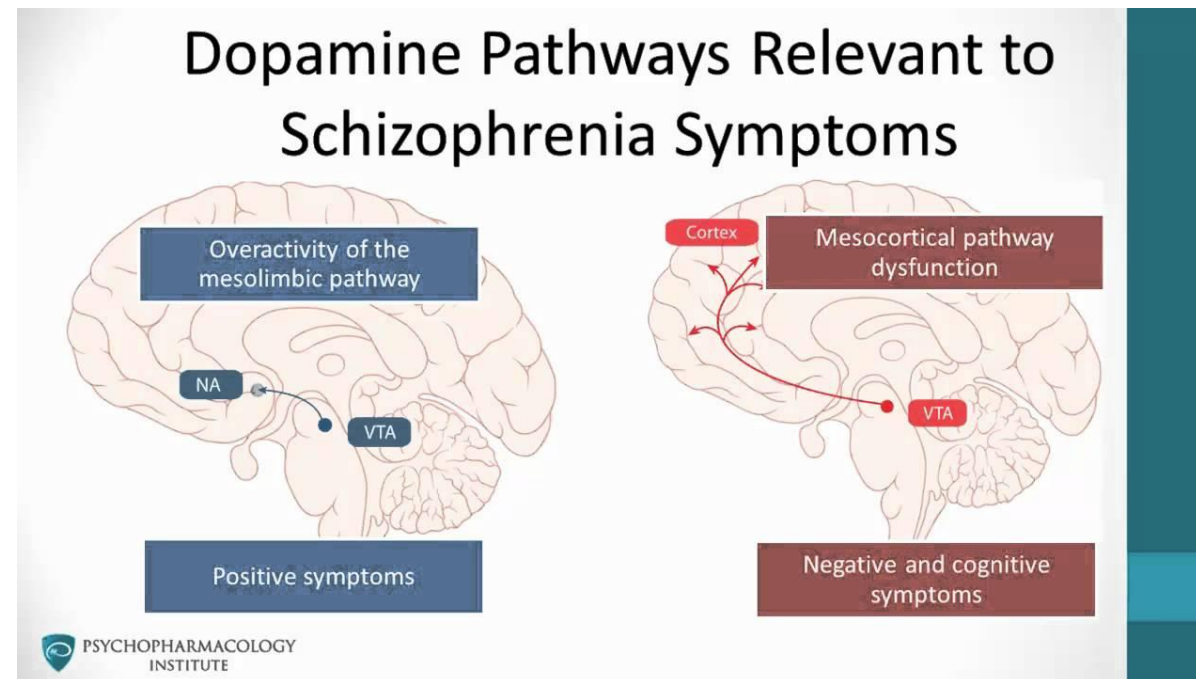
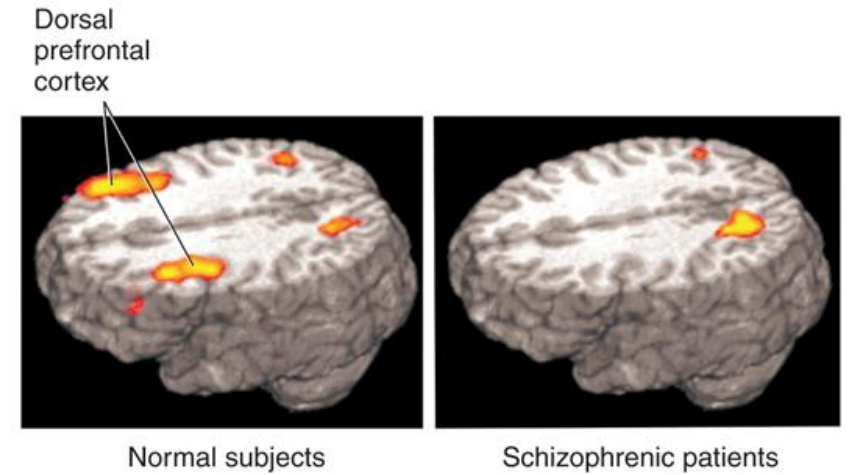
[Psychiatric Interviews for Teaching: Psychosis](#)

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

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

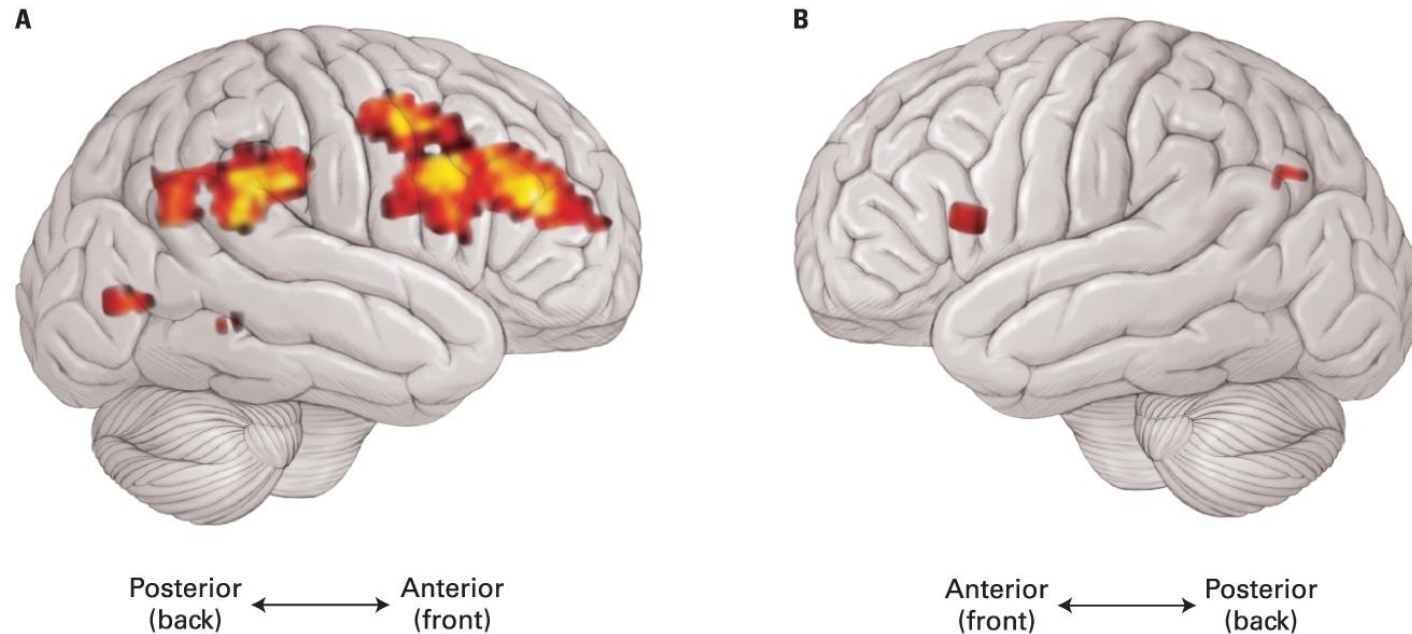
Hypofrontality in Schizophrenia

- 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

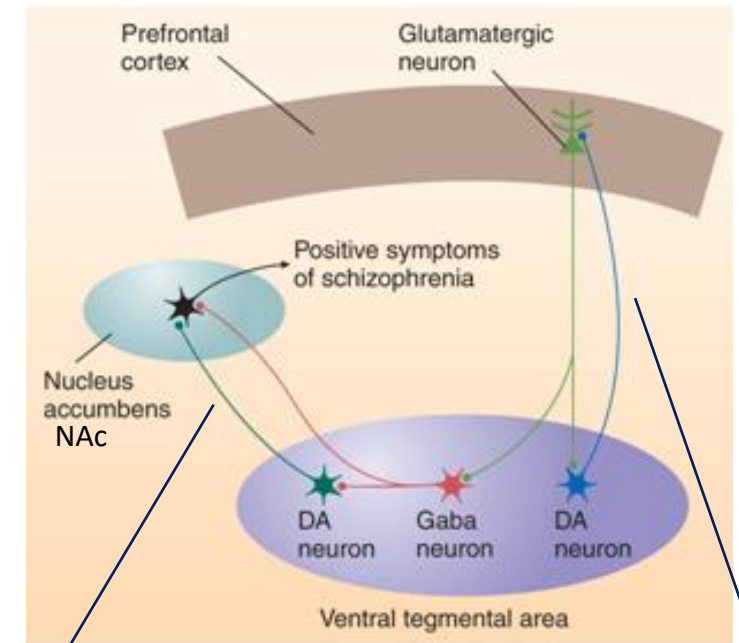
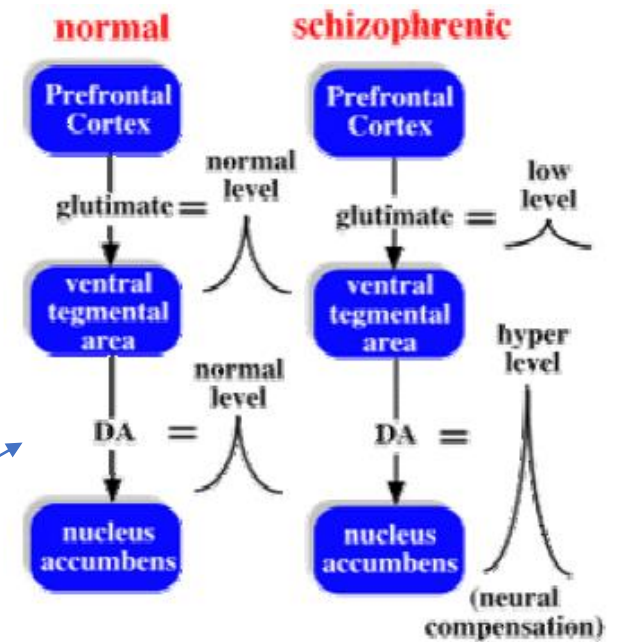
- Increased prefrontal activation is thought to reflect inefficient function in the prefrontal areas, such that the increased activity is necessary to support a given level of performance



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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