Executive Functions

Dr. Lavinia Carmen Uscătescu

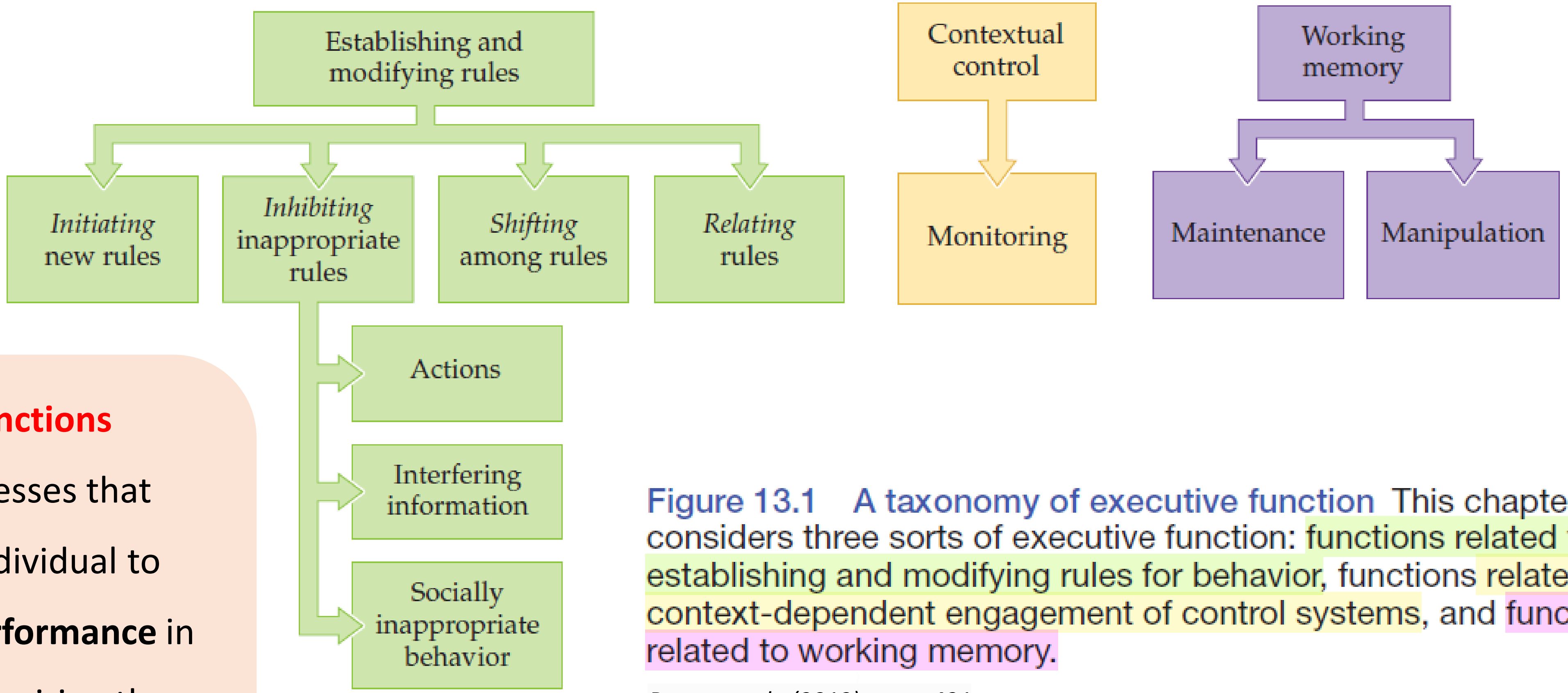
May 27th , 2024

Outline

1. Conceptual clarifications

2. Assessment

Conceptual clarifications



executive functions

control processes that enable an individual to **optimize performance** in situations requiring the operation and **coordination** of several more basic cognitive processes

Figure 13.1 A taxonomy of executive function This chapter considers three sorts of executive function: functions related to establishing and modifying rules for behavior, functions related to context-dependent engagement of control systems, and functions related to working memory.

Purves et al., (2012), page 431

Figure 13.4 The case of Phineas Gage *In 1848, Phineas Gage was a foreman on the team constructing a new railway in Vermont. While he was tamping down some blasting powder in a hole in the rock, the powder unexpectedly exploded, driving the tamping iron (a metal rod about 2 meters in length and 3 centimeters in diameter)* ***through his left cheek and out the top of his skull.***

(Top) *This* ***modern reconstruction*** *based on the damage to Gage's skull illustrates that the most likely path of the rod was* ***through the middle of the frontal lobes****, leading to significant* ***damage to the orbitofrontal and medial prefrontal cortex****. (from Damasio et al. 1994)*

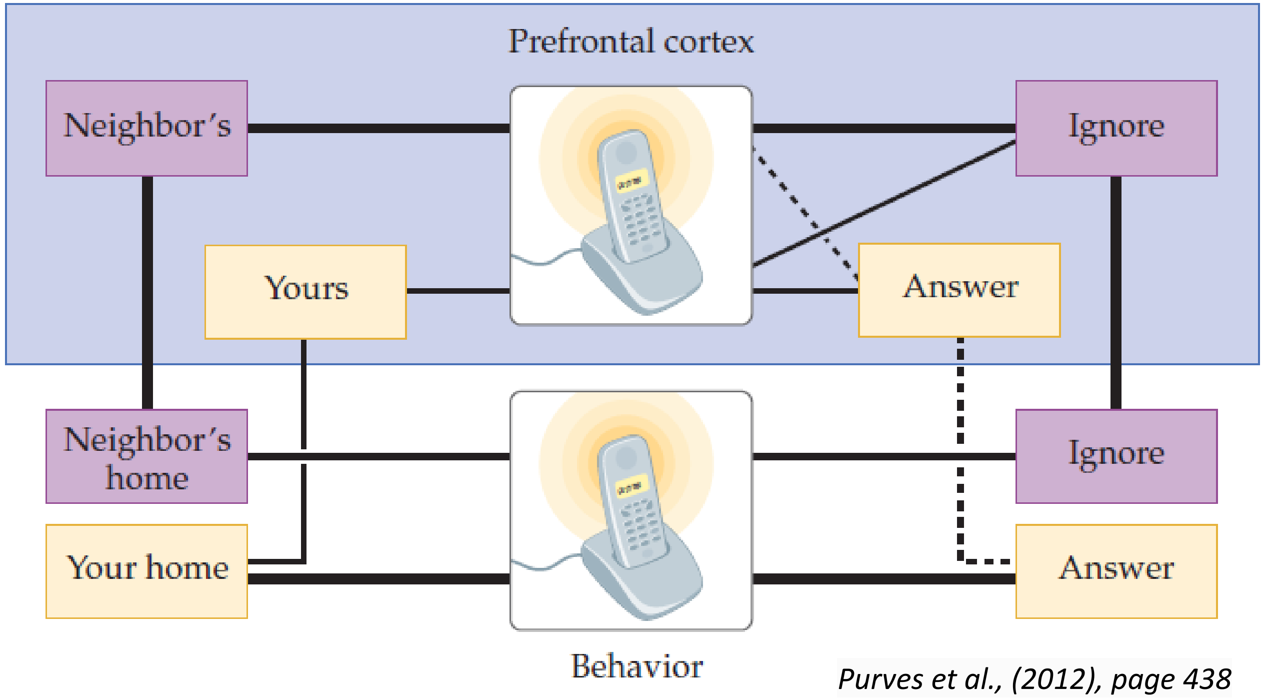
(Bottom) *The traditional narrative about Phineas Gage reports that this damage had* ***dramatic effects on his personality****; for instance, he* ***changed from being responsible and conscientious to being profane, reckless, and impulsive****. Recent research suggests that this narrative is exaggerated. For example, Gage was hardly itinerant and unproductive; after the accident, he traveled independently to South America and remained employed there for several years. This photograph of Gage after his accident was recently discovered. (from Wilgus and Wilgus 2009)*

Purves et al., (2012), page 437

the concepts of *"rules"* & *"control"* are central to executive functions

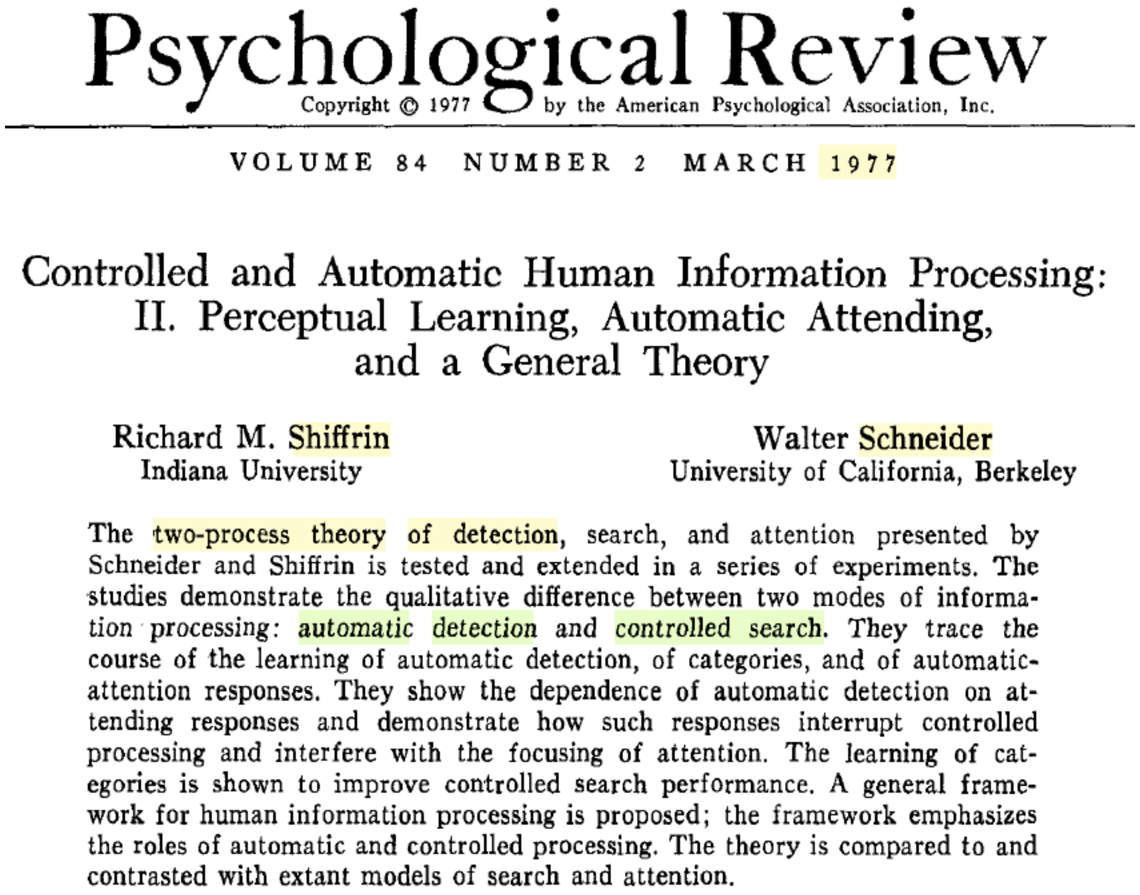
Figure 13.5 A conceptual framework for executive functions

*In the framework advanced by Miller and Cohen, control processes in the **prefrontal cortex** inhibit or strengthen rules for behavior to fit the current context. Thus, when a person hears a phone ringing, there is a strong tendency (indicated here by the thick connecting lines) to answer it, especially at home. However, this behavior is inappropriate in other contexts, such as at a neighbor's house. The **prefrontal cortex** is postulated to model the current context and possible actions, so that the **necessary action can be potentiated** (thick lines) **and undesirable actions can be inhibited** (dashed lines). In this conception, the prefrontal cortex allows information to flow along some paths but not others to facilitate effective behavior. (after Miller and Cohen 2001.)*



Purves et al., (2012), page 438

the distinction between *"automatic"* & *"controlled"* behavior is central to executive functions



Psychological Review

VOLUME 84 NUMBER 2 MARCH 1977

Controlled and Automatic Human Information Processing: II. Perceptual Learning, Automatic Attending, and a General Theory

Richard M. Shiffrin
Indiana University

Walter Schneider
University of California, Berkeley

The two-process theory of detection, search, and attention presented by Schneider and Shiffrin is tested and extended in a series of experiments. The studies demonstrate the qualitative difference between two modes of information processing: automatic detection and controlled search. They trace the course of the learning of automatic detection, of categories, and of automatic-attention responses. They show the dependence of automatic detection on attending responses and demonstrate how such responses interrupt controlled processing and interfere with the focusing of attention. The learning of categories is shown to improve controlled search performance. A general framework for human information processing is proposed; the framework emphasizes the roles of automatic and controlled processing. The theory is compared to and contrasted with extant models of search and attention.

https://psycnet.apa.org/record/1977-20305-001

e.g., driving on a **familiar** route, we rely on **automatic behaviors** ("on autopilot") vs. if traffic is diverted through an **unfamiliar** route, we would need to override the automatic behavior and exert **online control**.

Baddeley's model of working memory (extension of Baddeley and Hitch (1974))

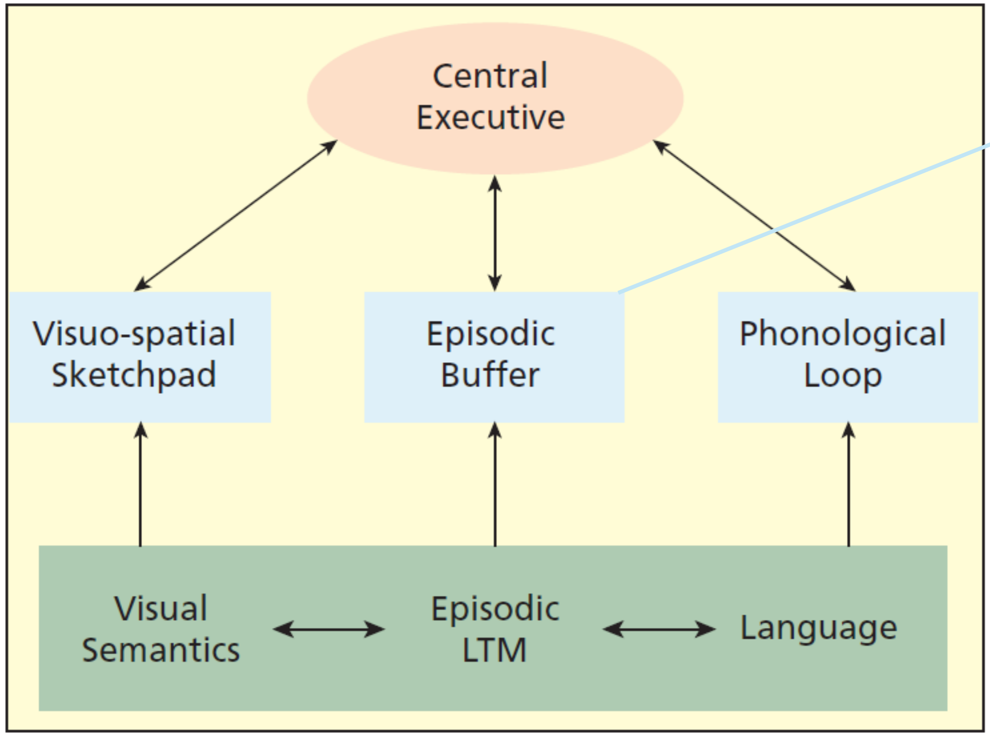


FIGURE 11.1: ***Baddeley****'s (2000) model of* ***working memory*** *was revised to incorporate three kinds of* ***short-term systems*** *(blue) that interface with* ***long-term memory*** *(green).*

Ward, (2020), p. 267

maintaining *and* ***manipulating*** *information from* ***episodic long-term memory***

Alan Baddeley

"The ***episodic buffer*** *is assumed to be capable of* ***storing information*** *in a* ***multi-dimensional*** *code. It thus provides a* ***temporary interface*** *between the* ***slave systems*** *(the phonological loop and the visuospatial sketchpad) and* ***LTM****. It is assumed to be* ***controlled by the central executive****, which is responsible for* ***binding information from a number of sources into coherent episodes****. Such episodes are assumed to be* ***retrievable consciously****. The buffer serves as a modelling space that* ***is separate from LTM****, but which forms an* ***important stage in long term episodic learning****."*

Graham Hitch

Baddeley, A. D., & Hitch, G. (1974). Working Memory. Psychology of Learning and Motivation, 47–89. https://doi.org/10.1016/s0079-7421(08)60452-1

Baddeley, A. (2000). The episodic buffer: a new component of working memory? Trends in Cognitive Sciences, 4(11), 417–423. https://doi.org/10.1016/s1364-6613(00)01538-2

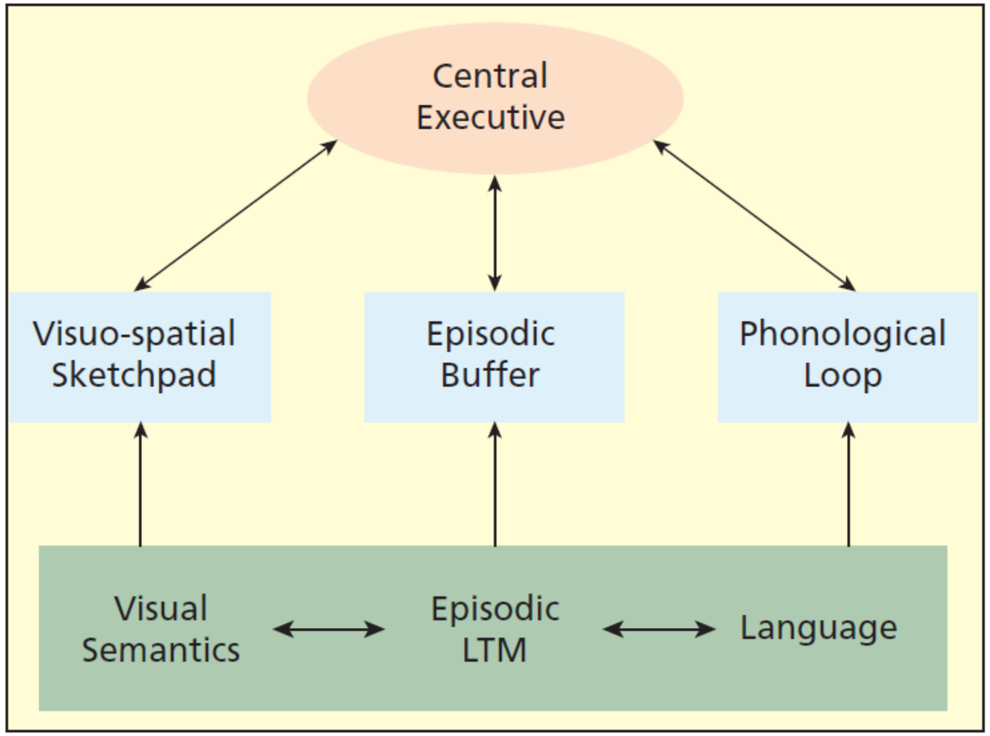
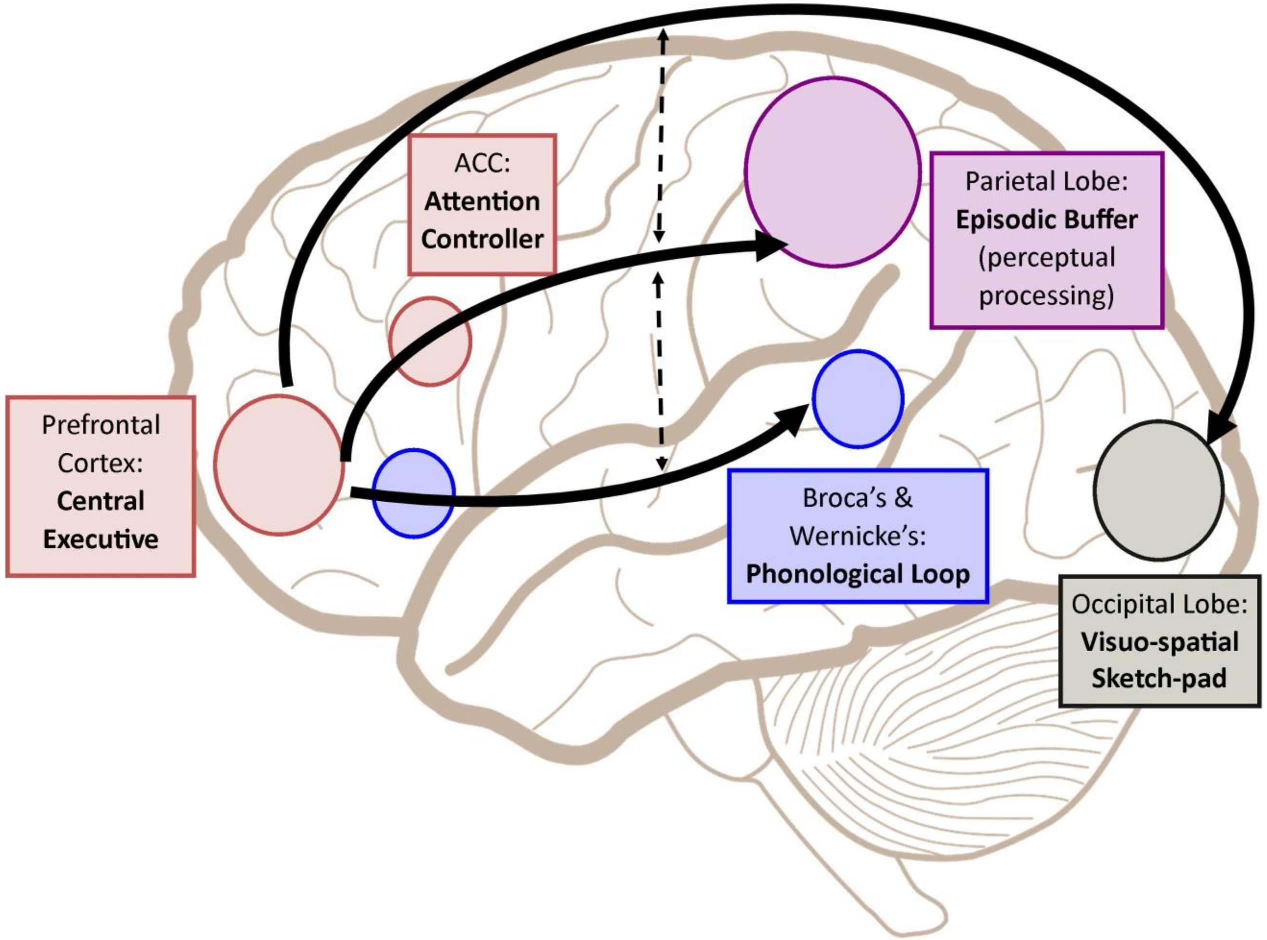
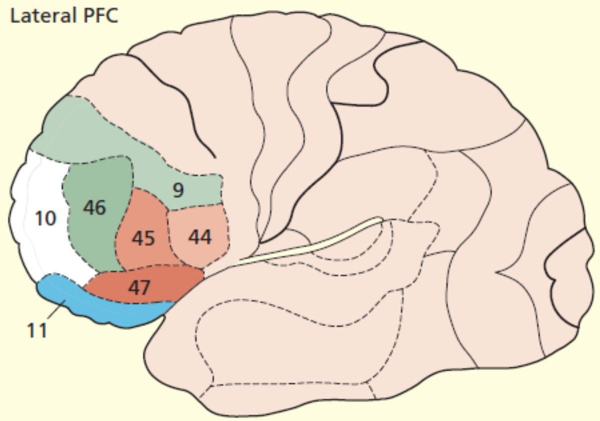


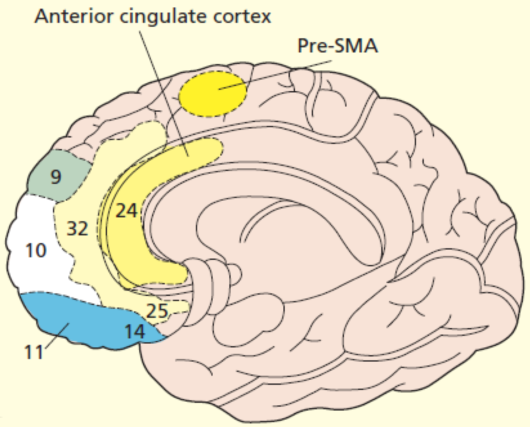
FIGURE 11.1: ***Baddeley****'s (2000) model of* ***working memory*** *was revised to incorporate three kinds of* ***short-term systems*** *(blue) that interface with* ***long-term memory*** *(green).*

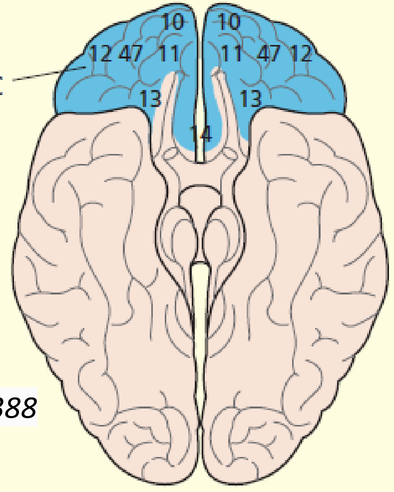
Ward, (2020), p. 267



Chai et al., (2018)
https://www.frontiersin.org/journals/psychology/articles/10.3389/fpsyg.2018.00401/full

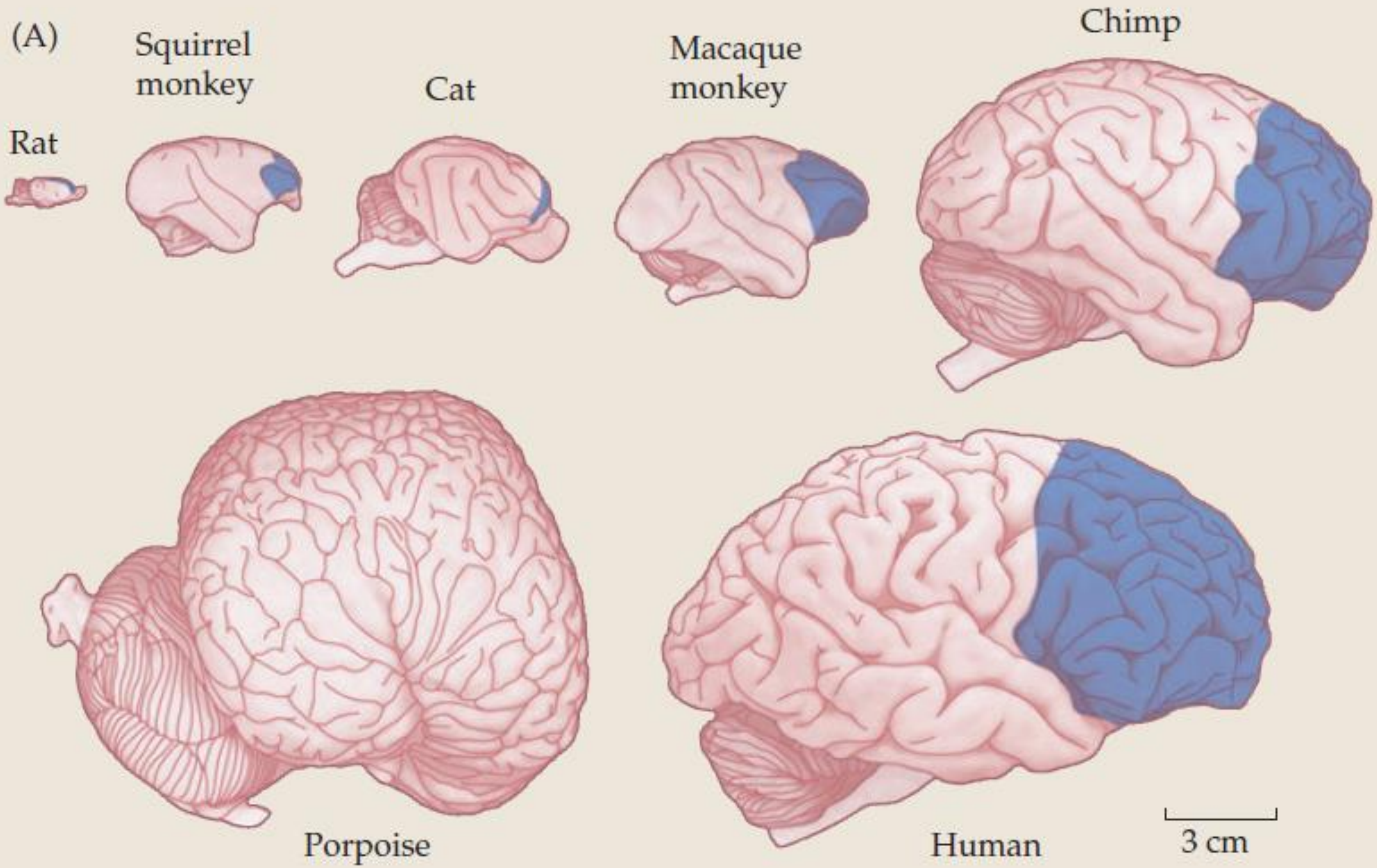






Ward, (2020), page 388

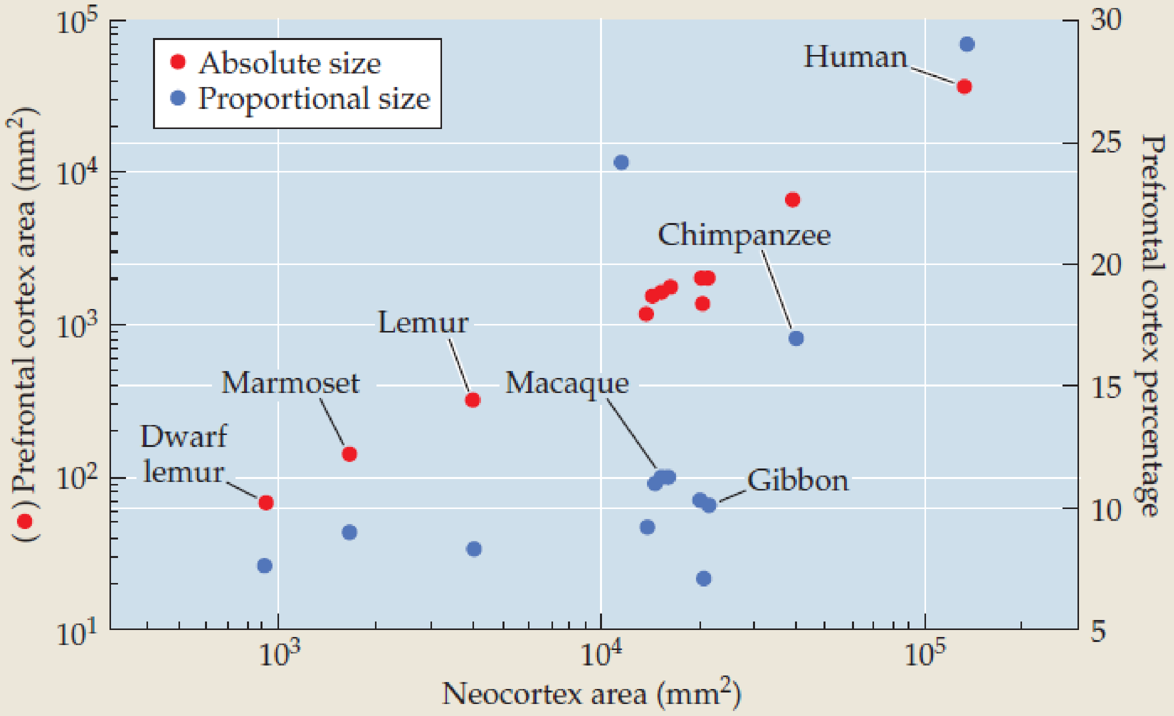
Brodmann's areas	*Other names*	*Possible functions (left hemisphere)*	*Possible functions (right hemisphere)*
44, 45, 47	Ventro-lateral prefrontal cortex (VLPFC); Areas 44 + 45 on left also called Broca's area.	Retrieval and maintenance of semantic and/or linguistic information	Retrieval and maintenance of visual and/or spatial information
9, 46	Dorso-lateral prefrontal cortex (DLPFC)	Selecting a possible range of responses and suppressing inappropriate ones; manipulating the contents of working memory.	Monitoring and checking of information held in mind, particularly in conditions of uncertainty; vigilance and sustained Attention.
10	Anterior prefrontal cortex; frontal pole; rostral prefrontal Cortex.	Multi-tasking; maintaining future intentions / goals whilst currently performing other tasks or sub-goals. The medial portion has been implicated in "theory of mind".	
24 (dorsal) 32 (dorsal	Anterior cingulate cortex (dorsal) Pre-supplementary motor area (Pre-SMA)	Monitoring in situations of response conflict and error detection.	
11, 12, 13, 14	Orbito-frontal cortex	Executive processing of emotional stimuli (e.g., evaluating rewards and risks).	



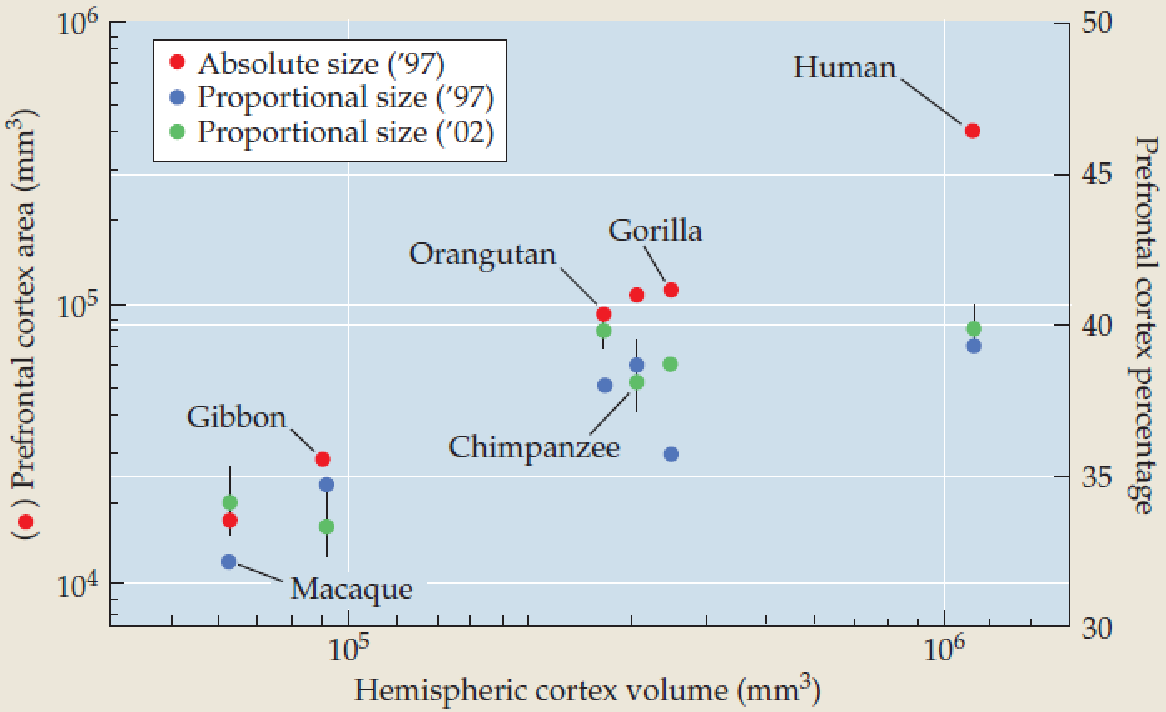
(A) Comparative anatomy of the prefrontal cortex. *Not only is absolute brain size greater in primates compared to other mammals, but there is also a disproportionate increase in the size of the prefrontal cortex (blue). The porpoise brain is provided for size comparison; its prefrontal cortex is not indicated, because there are no clear homologies between the prefrontal cortices of primates and cetaceans.*

Purves et al., (2012), page 432

(B) Prefrontal cortex scaling according to Brodmann (1912)



(C) Frontal lobe scaling according to Semendeferi et al. (1997, 2002)



***(B) The prefrontal cortex** is particularly well developed in **primates**. Largely because of Brodmann's work, it was thought that the **proportional size** of the prefrontal cortex was greater in humans than in other great apes.*

(after Brodmann 1912)

***(C)** More recent studies indicate that the **frontal lobes and the prefrontal cortex** occupy about the **same proportion of overall brain volume** in great apes and humans.*

(after Semendeferi et al. 1997, 2002)

Purves et al., (2012), page 433

Assessment

Working memory: the **Self-Ordered Pointing Task**

Welcome to the Self-Ordered Pointing Task!

Here are six pictures. On each screen you will see the same pictures, but they will be rearranged in different positions. Your job is to click on a different picture on each screen. Once you select a picture, do not select that same picture on the following screens.

For example, imagine you selected the gorilla in the middle of the first row. Go ahead and click on the gorilla now.

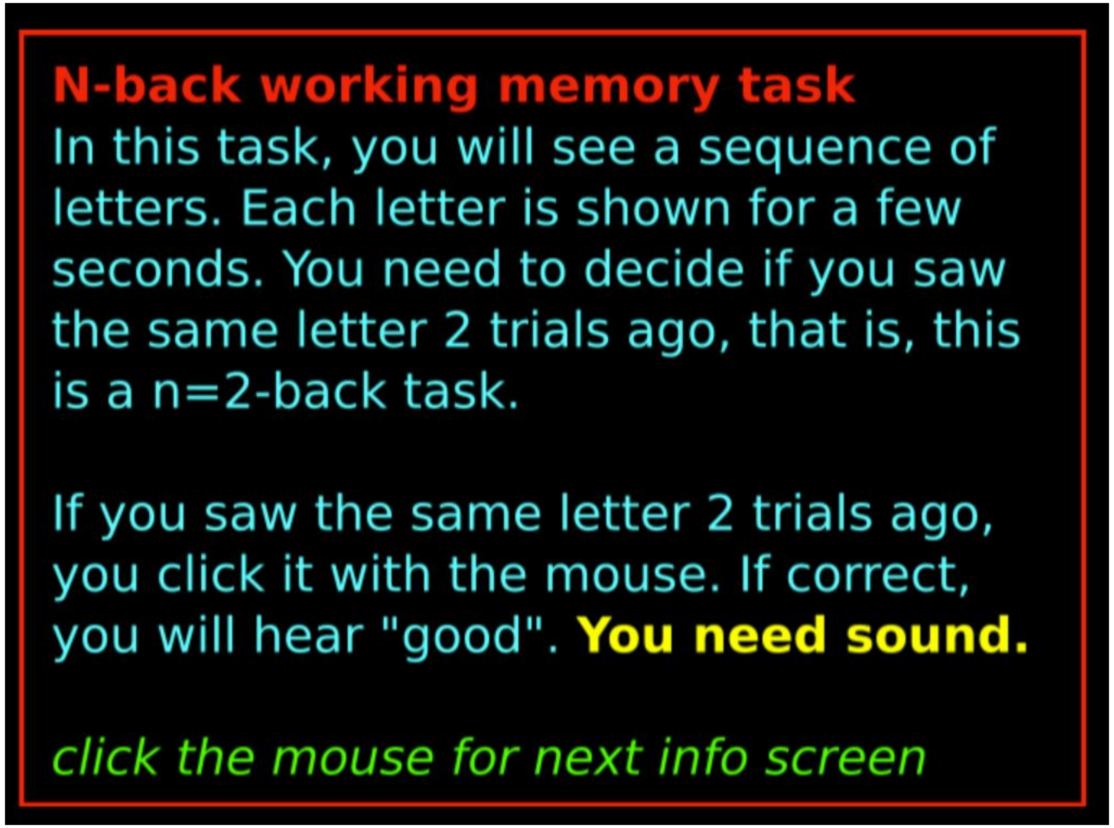
https://www.millisecond.com/download/library/sopt

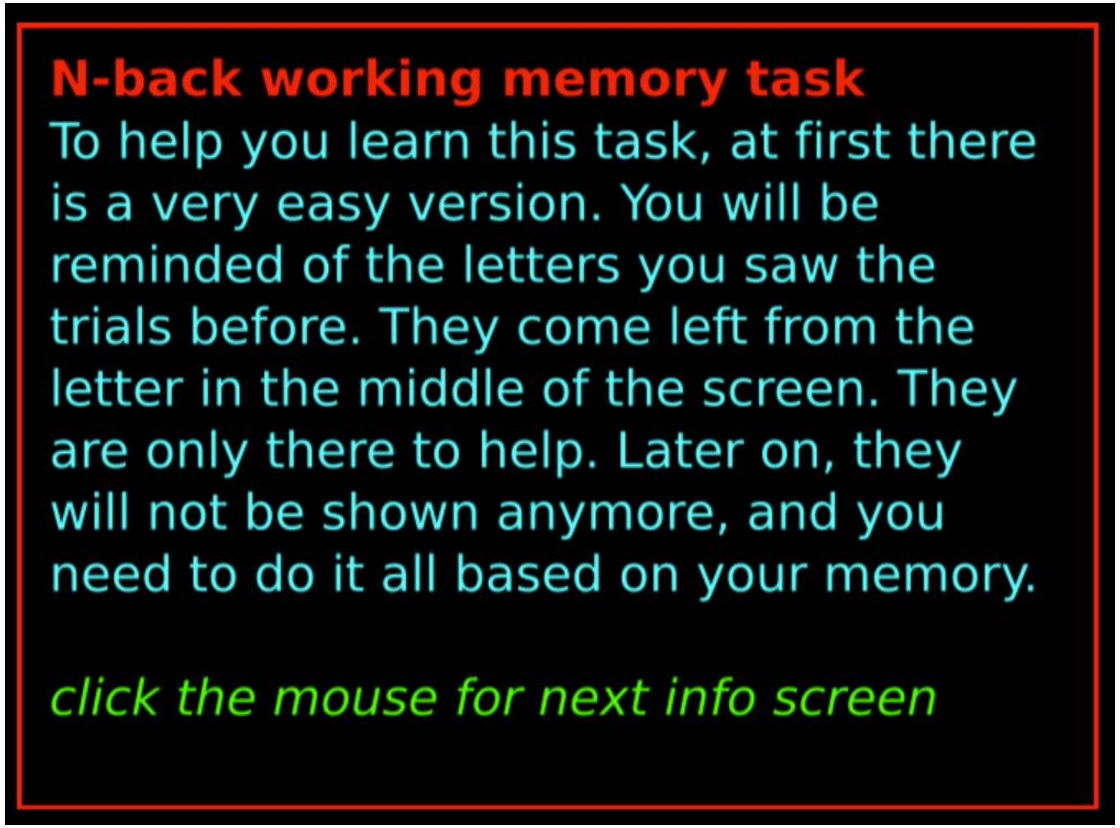
one must maintain and update an online record of chosen items

self-ordered pointing task

a task in which participants must point to a new object on each trial and thus **maintain a working memory** for previously selected items

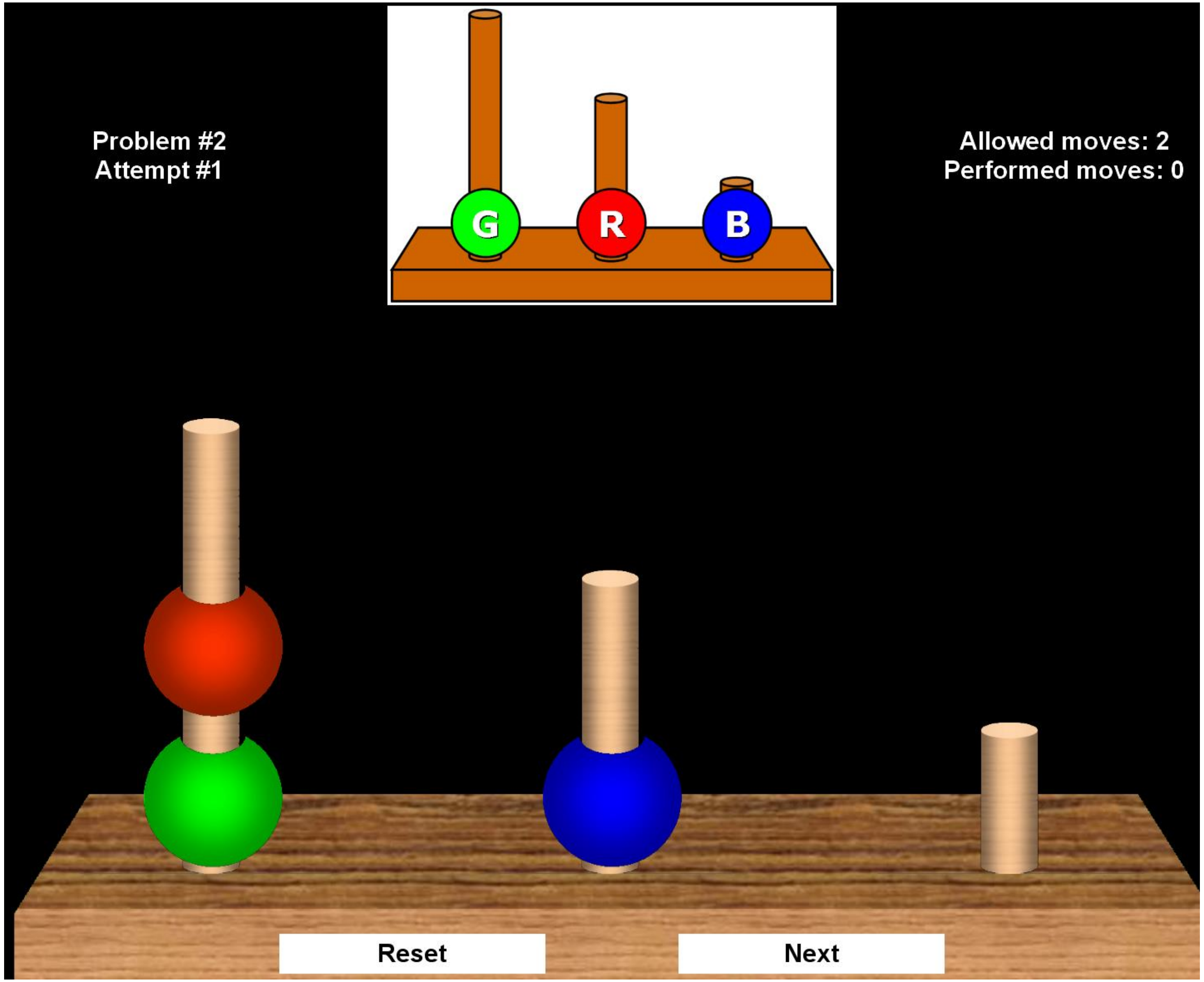
Working memory: the **N-back task**





https://www.psytoolkit.org/experiment-library/touch_nback2.html

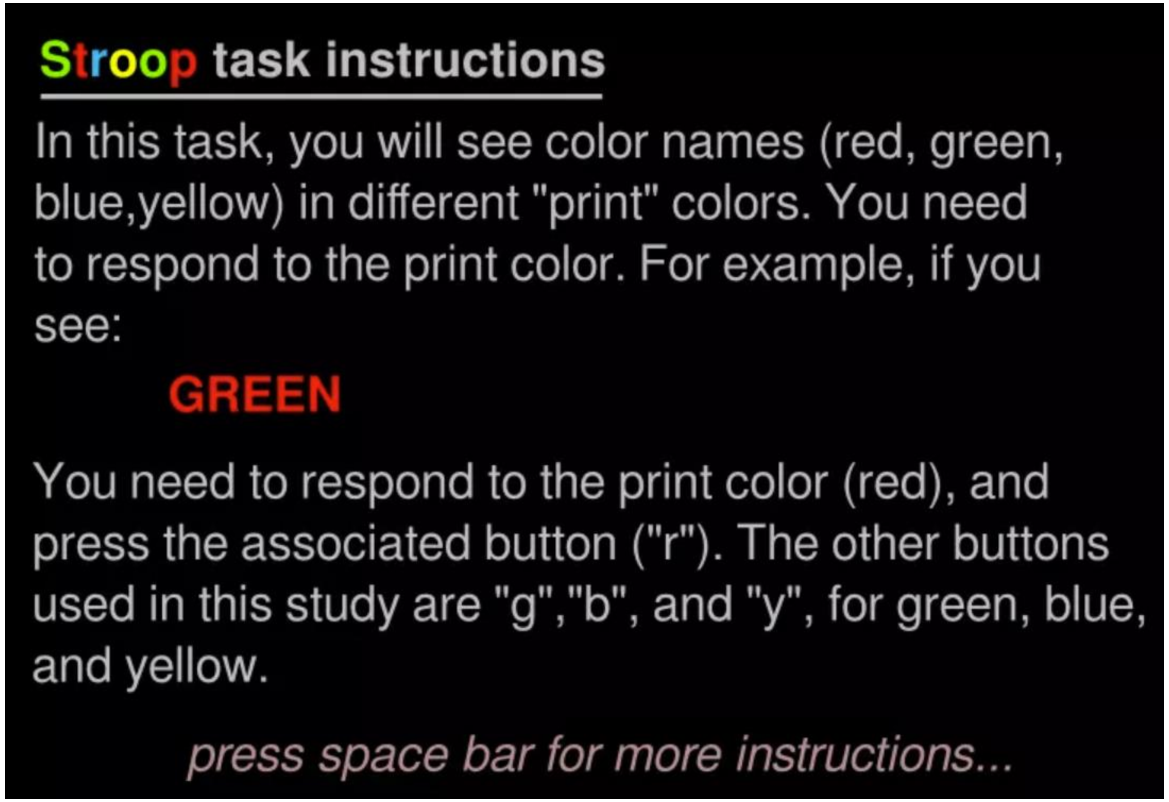
Task-setting & **problem-solving**: the **"Tower of London"**



https://www.millisecond.com/download/library/toweroflondon

one must mentally determine the fewest number of moves required to transform one arrangement of colored elements to a different arrangement

Inhibition of potent or habitual response: the **Stroop test**



Stroop task instructions

In this task, you will see color names (red, green, blue,yellow) in different "print" colors. You need to respond to the print color. For example, if you see:

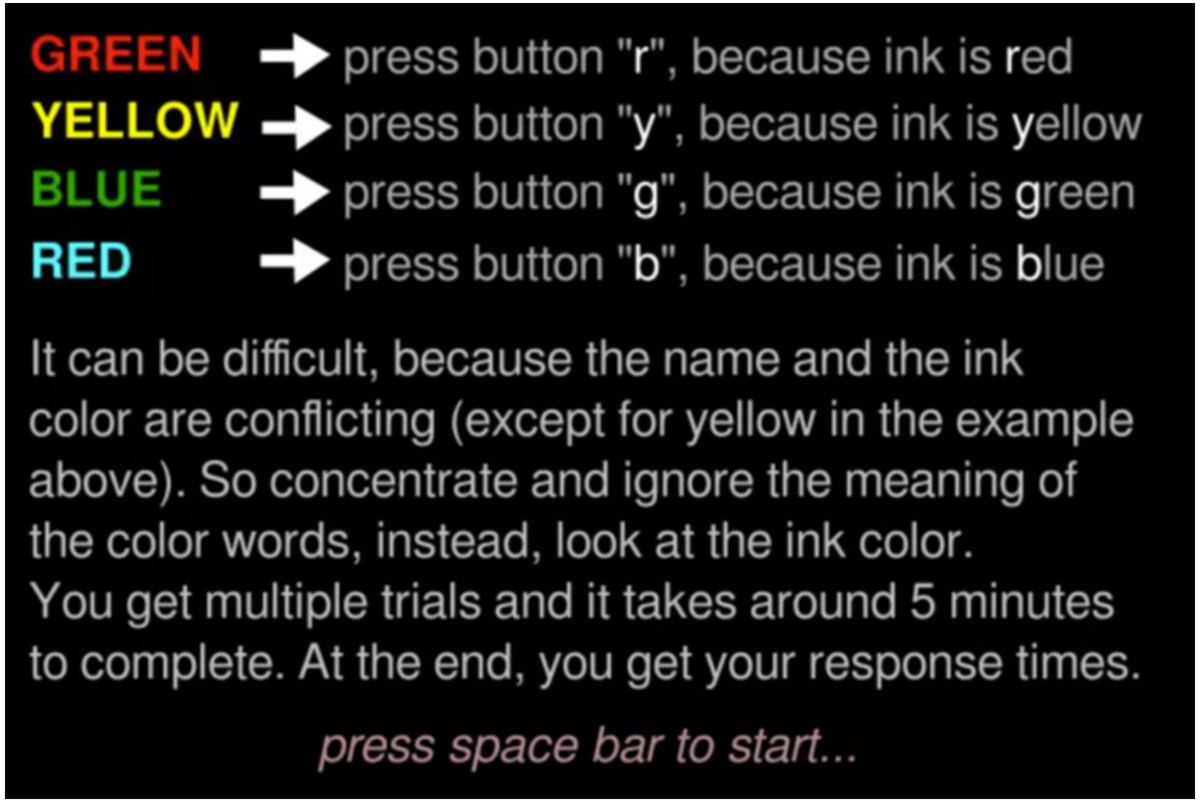
GREEN

You need to respond to the print color (red), and press the associated button ("r"). The other buttons used in this study are "g","b", and "y", for green, blue, and yellow.

press space bar for more instructions...

https://www.psytoolkit.org/experiment-library/stroop.html

one must name the color of the ink and ignore reading the word (which also happens to be a color name)



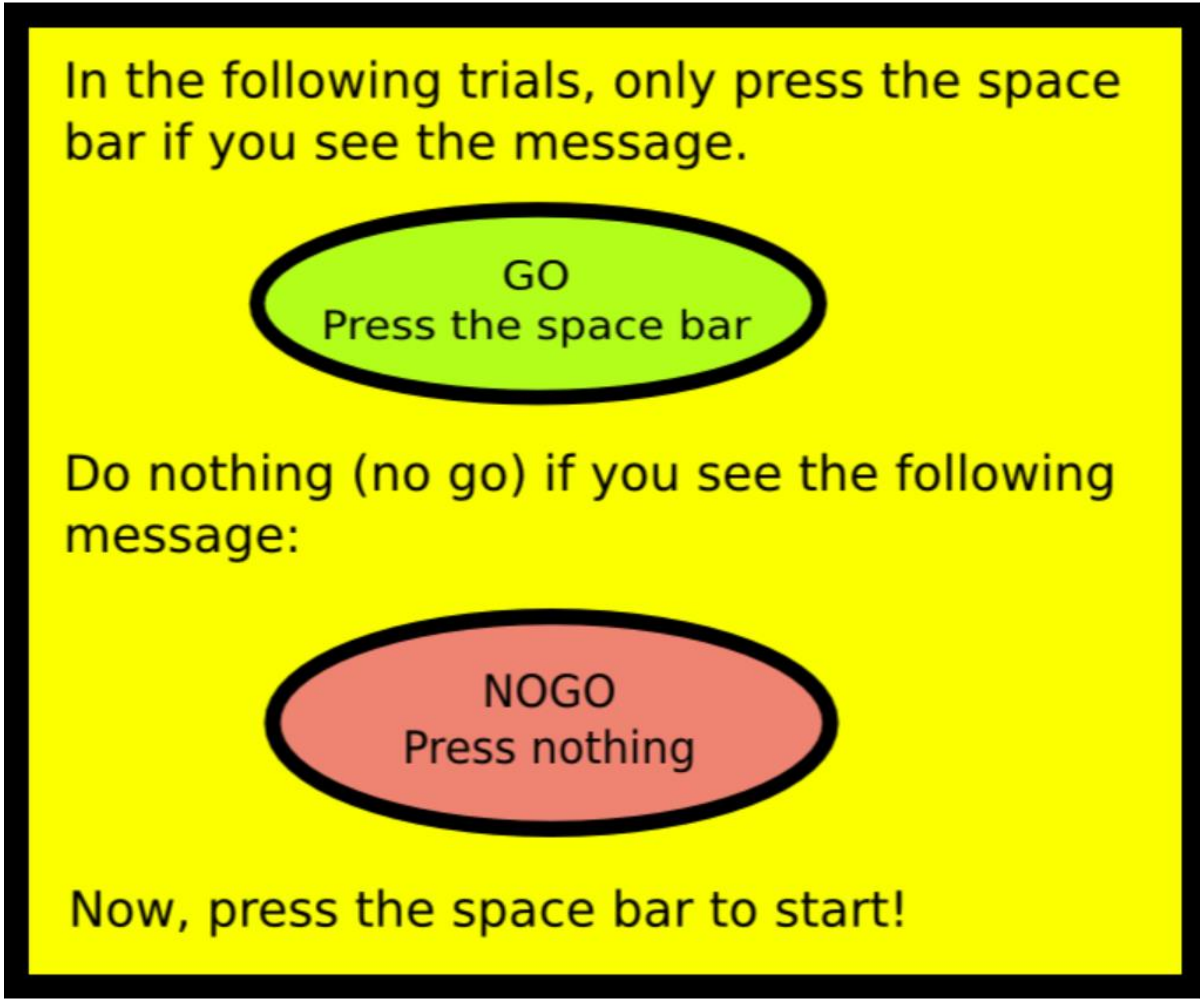
GREEN → press button "r", because ink is red
YELLOW → press button "y", because ink is yellow
BLUE → press button "g", because ink is green
RED → press button "b", because ink is blue

It can be difficult, because the name and the ink color are conflicting (except for yellow in the example above). So concentrate and ignore the meaning of the color words, instead, look at the ink color. You get multiple trials and it takes around 5 minutes to complete. At the end, you get your response times.

press space bar to start...

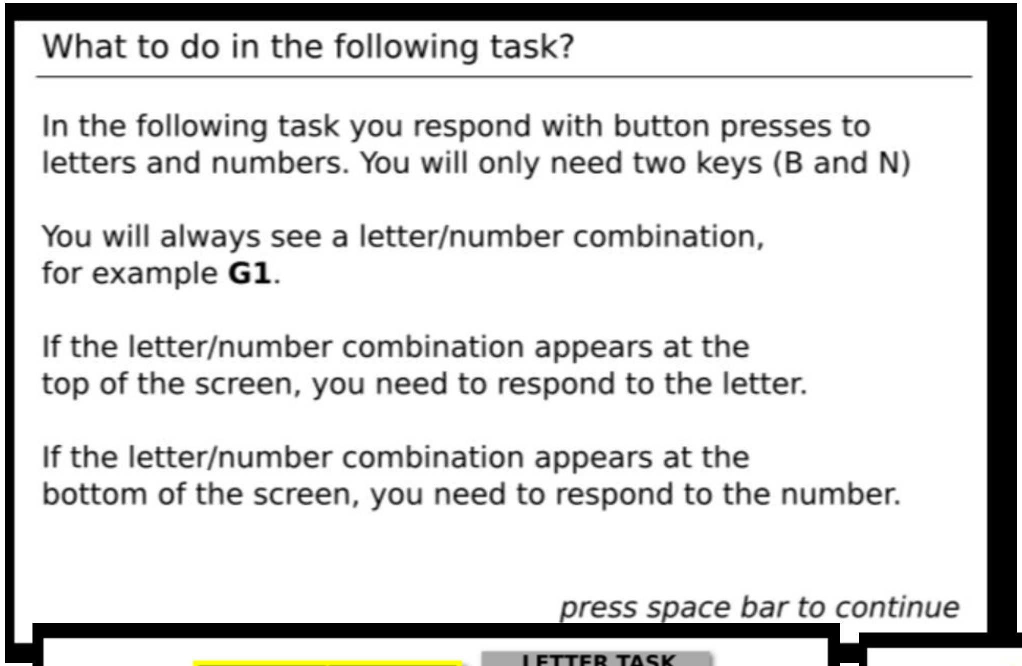
The standard explanation is that reading of words occurs automatically and this generates a salient incorrect response that competes with the less-automatic task of naming colors (MacLeod & MacDonald, 2000).

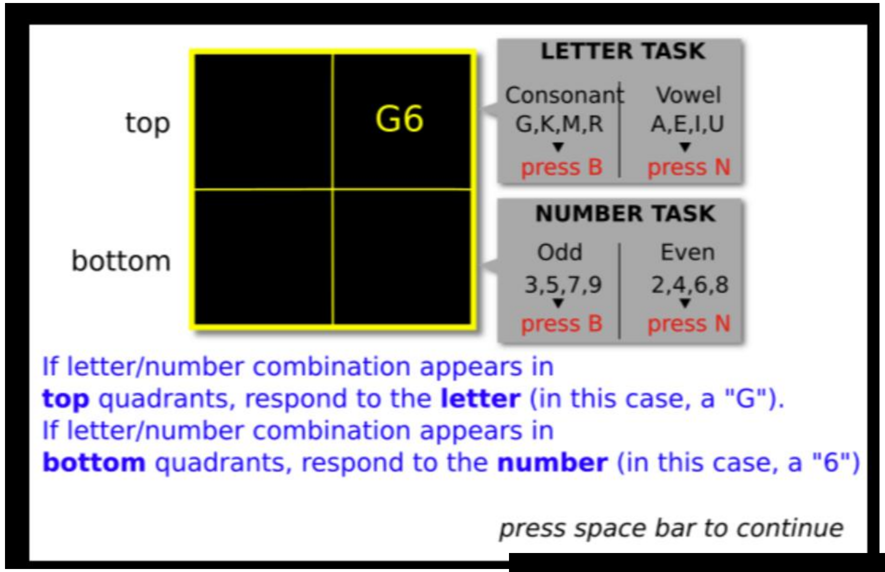
Inhibition of potent or habitual response: the **Go/No-go task**

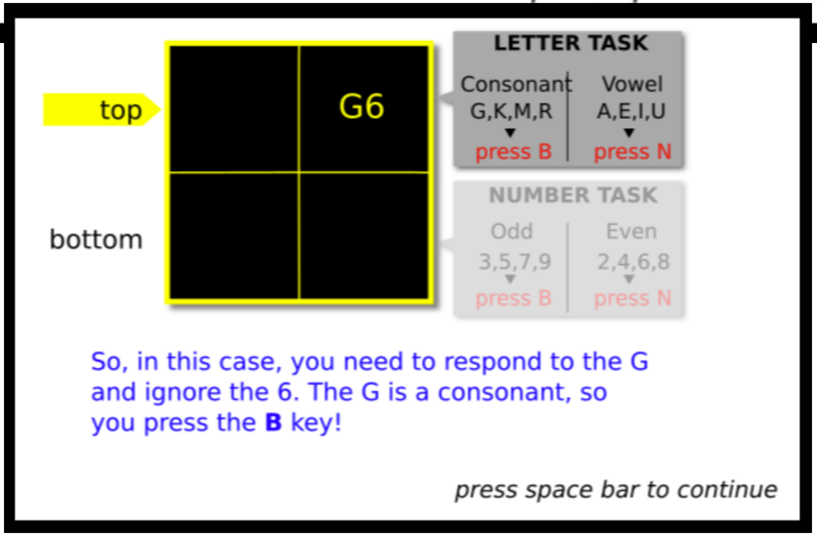


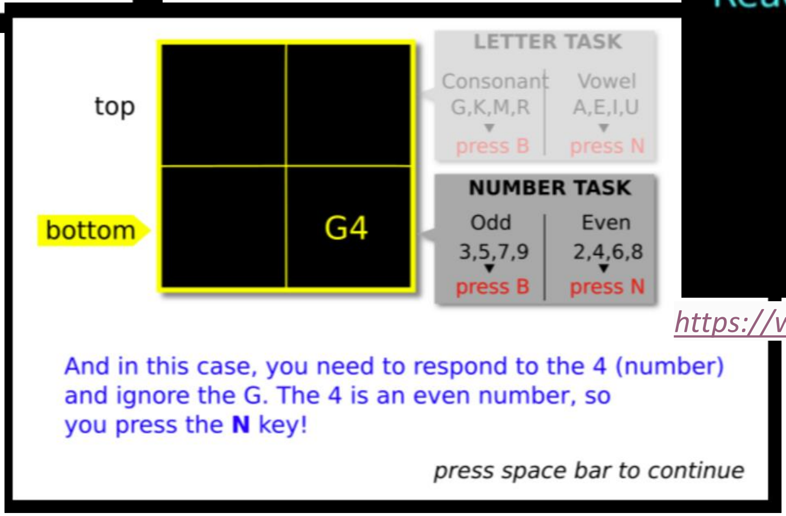
https://www.psytoolkit.org/experiment-library/go-no-go.html

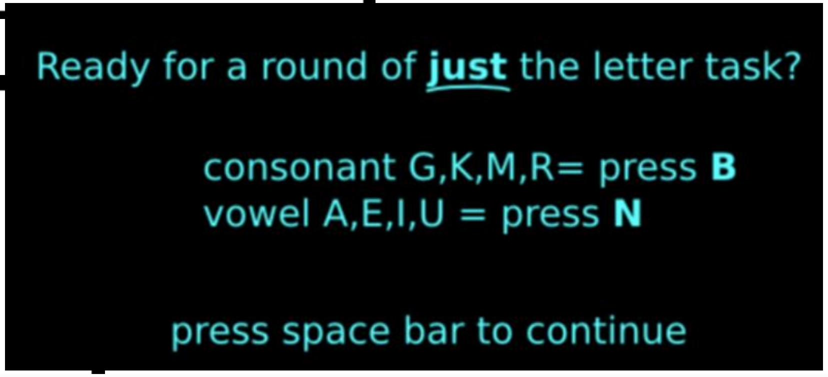
Task-switching: based on Roger & Monsell (1995)











https://www.psytoolkit.org/experiment-library/taskswitching.html

Rogers, R. D., & Monsell, S. (1995). Costs of a predictible switch between simple cognitive tasks. Journal of Experimental Psychology: General, 124(2), 207–231. https://doi.org/10.1037/0096-3445.124.2.207

Task-switching: the Wisconsin card Sorting Test

https://www.millisecond.com/download/library/cardsort

task-switching

discarding a previous **schema** and establishing a **new one**

switch cost

a **slowing of response time** due to discarding a previous schema and setting up a new one

perseveration

an **inability to interrupt** a task or to shift from one strategy or procedure to another

https://www.youtube.com/watch?v=RV1JjOXzA5U