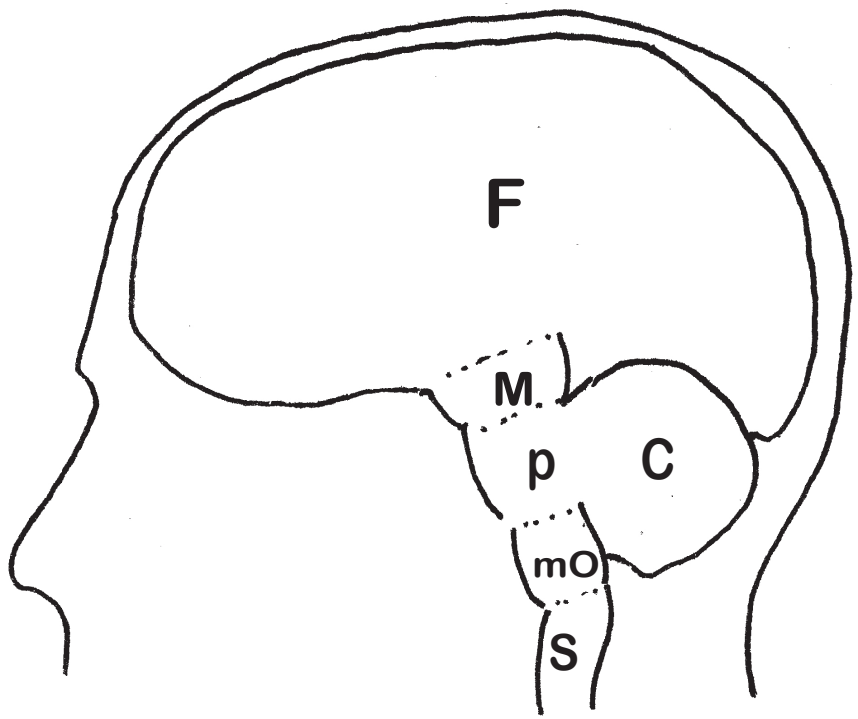
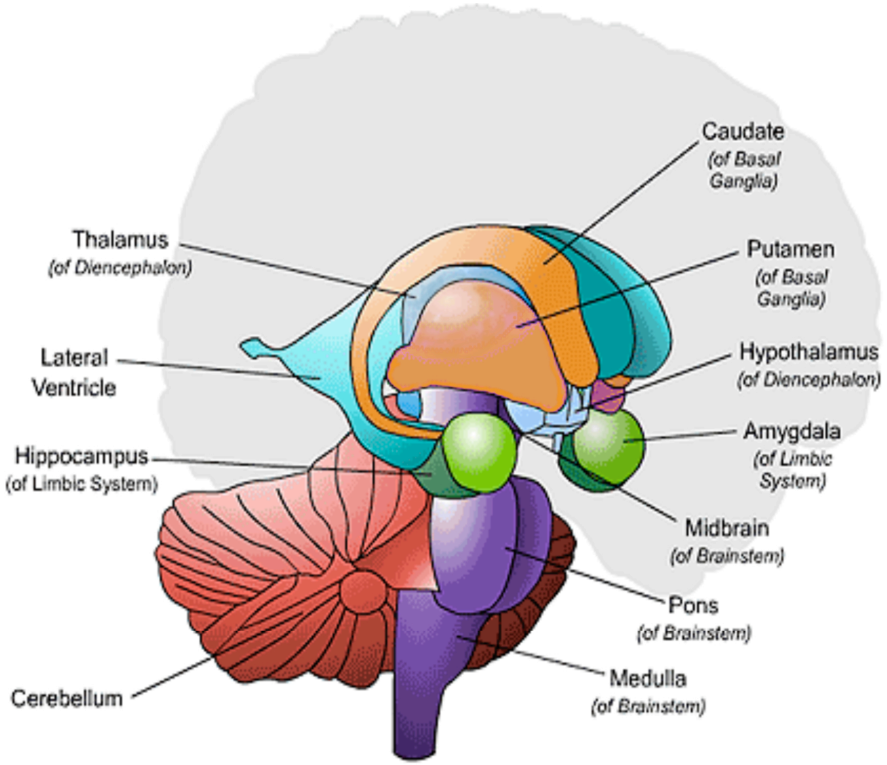
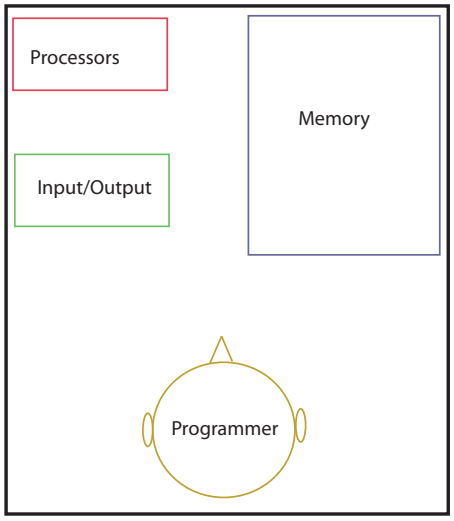
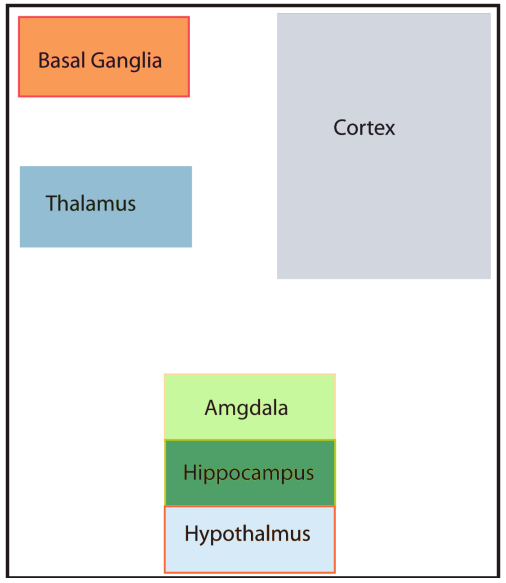
Computation & the Brain:
A short Introduction



The part of the brain that governs
What we think of as complex,
goal-directed behavior is the
FOREBRAIN (F)
That sits on top of phylogenetically
earlier structures that have more basic
functions.







A convenient way to think about the different parts of the FOREBRAIN is to compare them to standard programming functions in conventional computing

Programming in the brain can be broken down into:

The **Amygdala**: rate importance of external Demands

The **Hippocampus**: modify an existing program.

The **Hypothalmus**: score the program in terms of its value to its host.

A patient with amygdala damage draws figures to depict different emotions

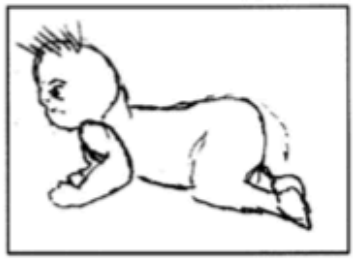
HAPPY

SAD

SURPRISED

DISGUSTED

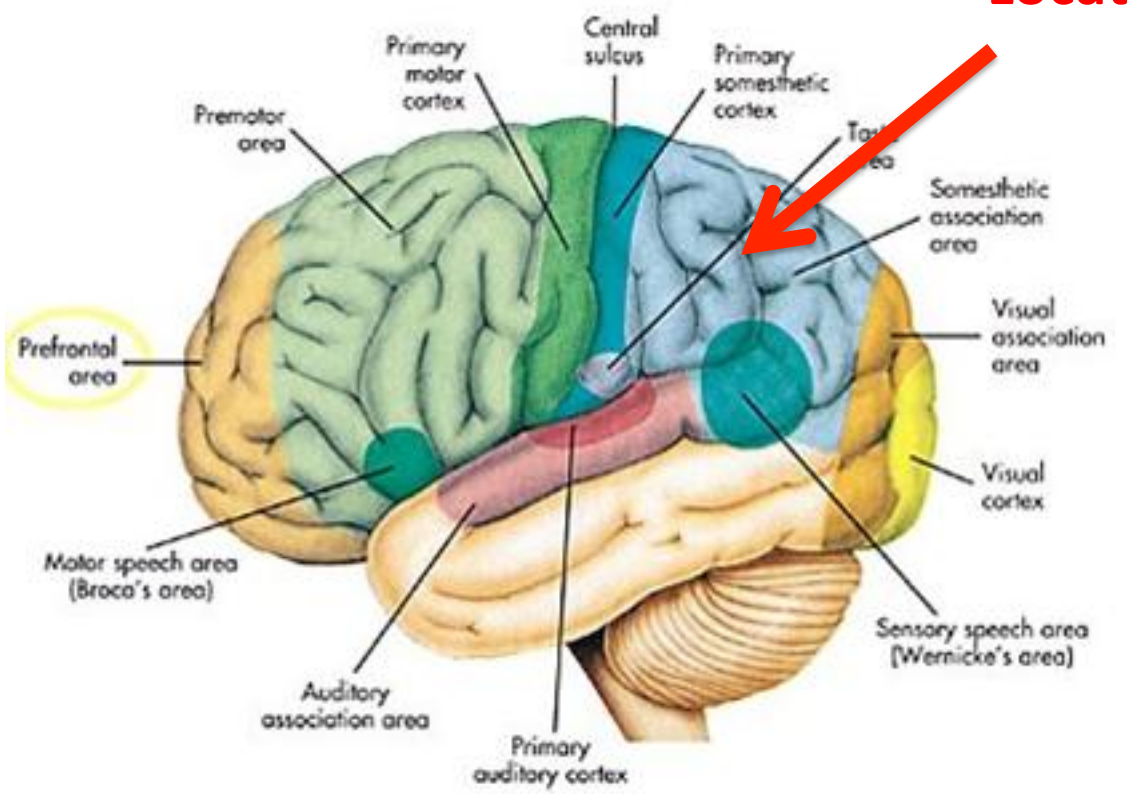
ANGRY



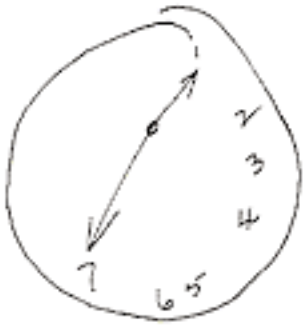
AFRAID


Cells
Axons

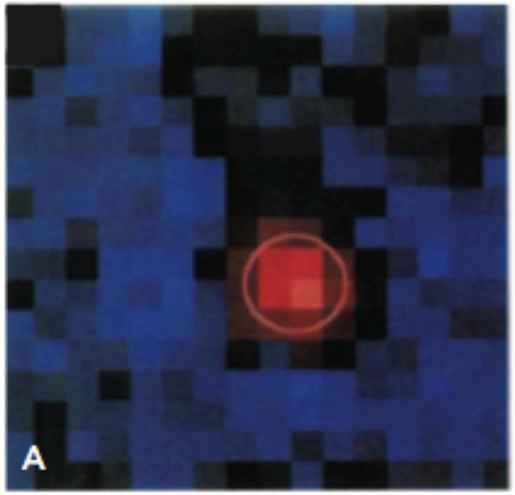
Locations


Primary motor cortex
Central sulcus
Primary somesthetic cortex
Premotor area
Somesthetic association area
Visual association area
Prefrontal area
Visual cortex
Motor speech area (Broca's area)
Sensory speech area (Wernicke's area)
Auditory association area
Primary auditory cortex

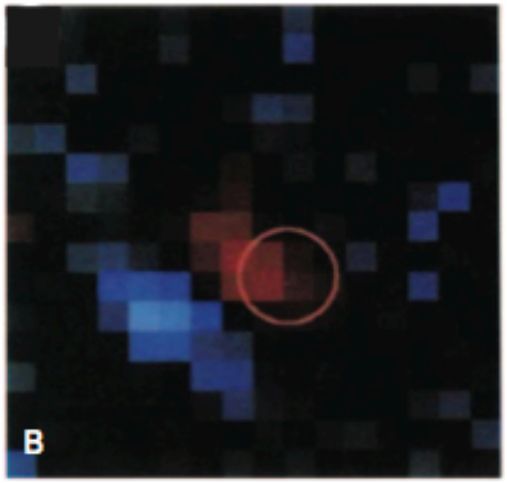

12
1
2
3
4
5
6
7
8
9
10
11

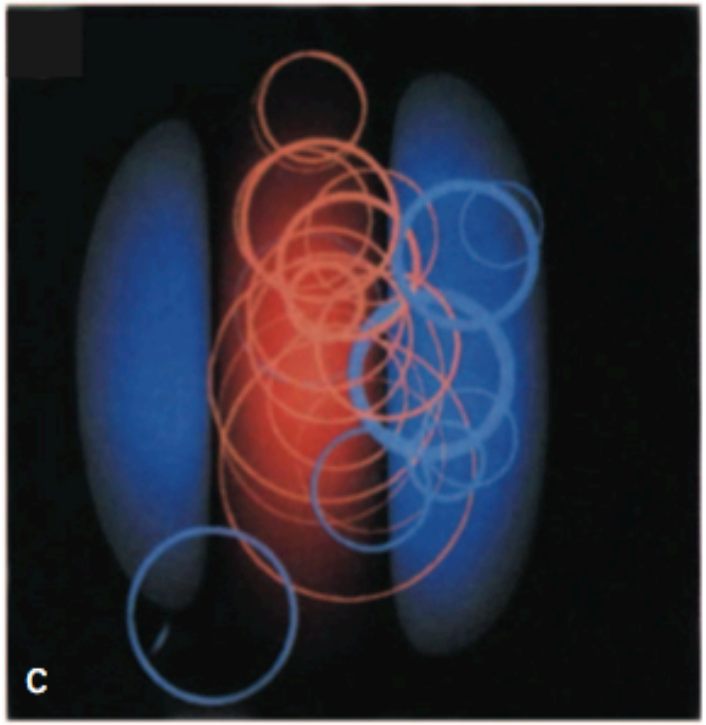


Thalamus
(LGN)



Visual Cortex
(V1)

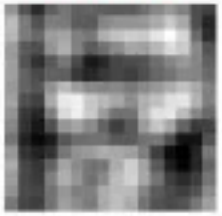




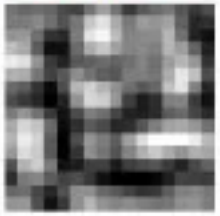
Summary data: LGN Cells
Overlaid on one V1 cell
Receptive field (RF)

image_0182.pgm

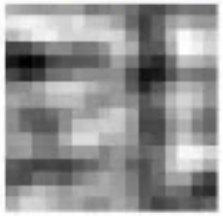
1 spikes



1 spikes



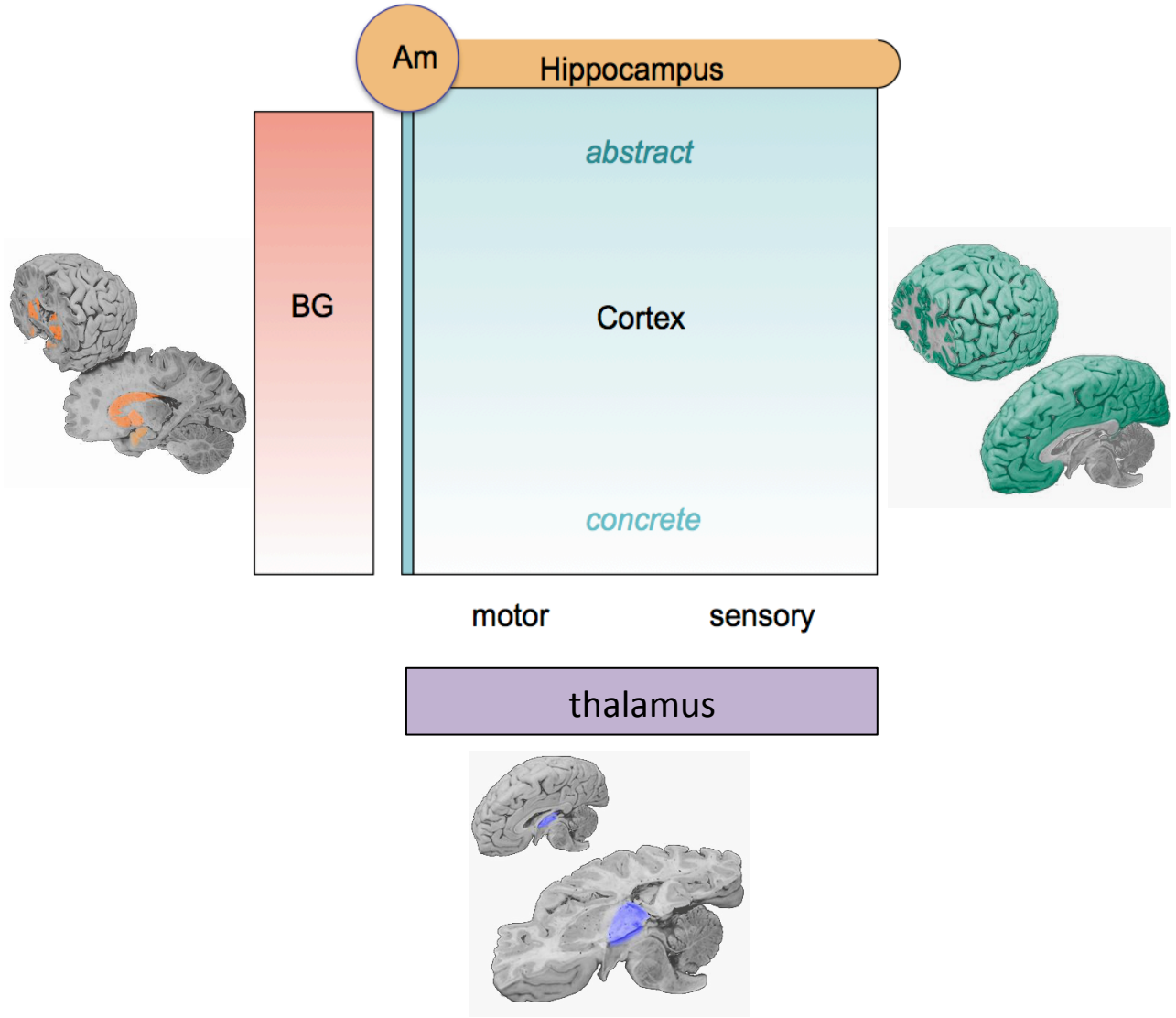
1 spikes



Description	Abstract Function	Example Function
EVALUATION	Strategic decisions	Evaluate current task suite. Hungry? What are the nourishment options?
SCHEDULER	Multi-task management	Regulate different sandwich making programs. Jelly jar lid off now?
PROGRAMS	Solve a single task	Spread peanut butter on bread. Peanut butter is viscous and spreads easily.
ROUTINES	Individual fixations used to guide posture changes	Find location of bread slice. Vision locates the bread loaf.
DATA ABSTRACTION	World sensory data coded to emphasize intrinsic organization	Compact codes for sensori-motor signals: Activate codes for color and texture of bread.

Table 1.2. In order to manage complexity, the brain also has to resort to different levels of computational abstraction. While the ultimate abstraction has not been precisely determined we can describe tentative organization based on the tasks that the brain has to direct.

Brain programs: the outer loop

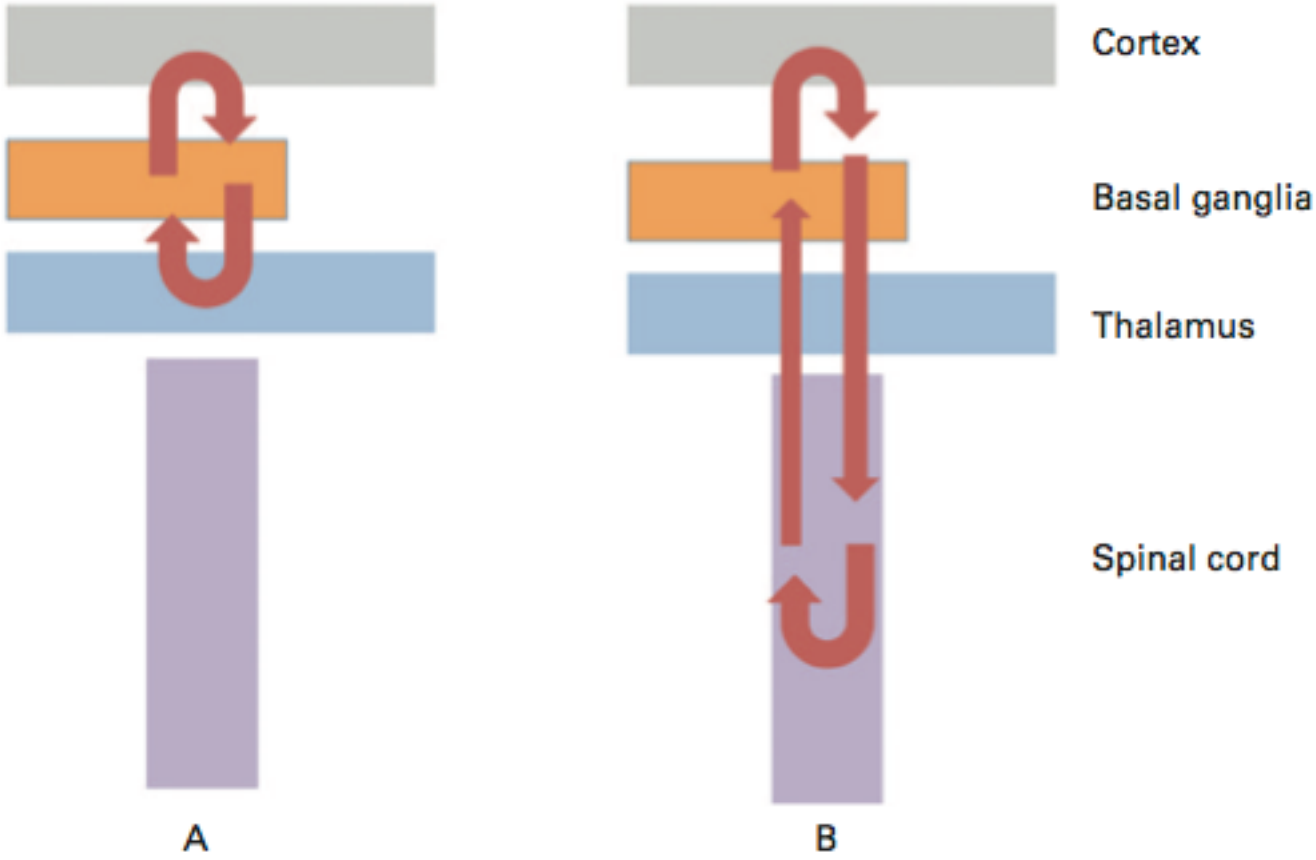


The basic outer loop governing behavior takes 200-300 milliseconds.

During that time the **Cortex** is put into a state that interconnects all the features needed for That instant and triggers an action carried out by the **Thalamus**. Next, the **Basal Ganglia** puts the Cortex into a subsequent state and the process continues until done or interrupted.

Eye fixations are in lock step with this activity and can be used to diagnose exactly what behavior is being focused on.

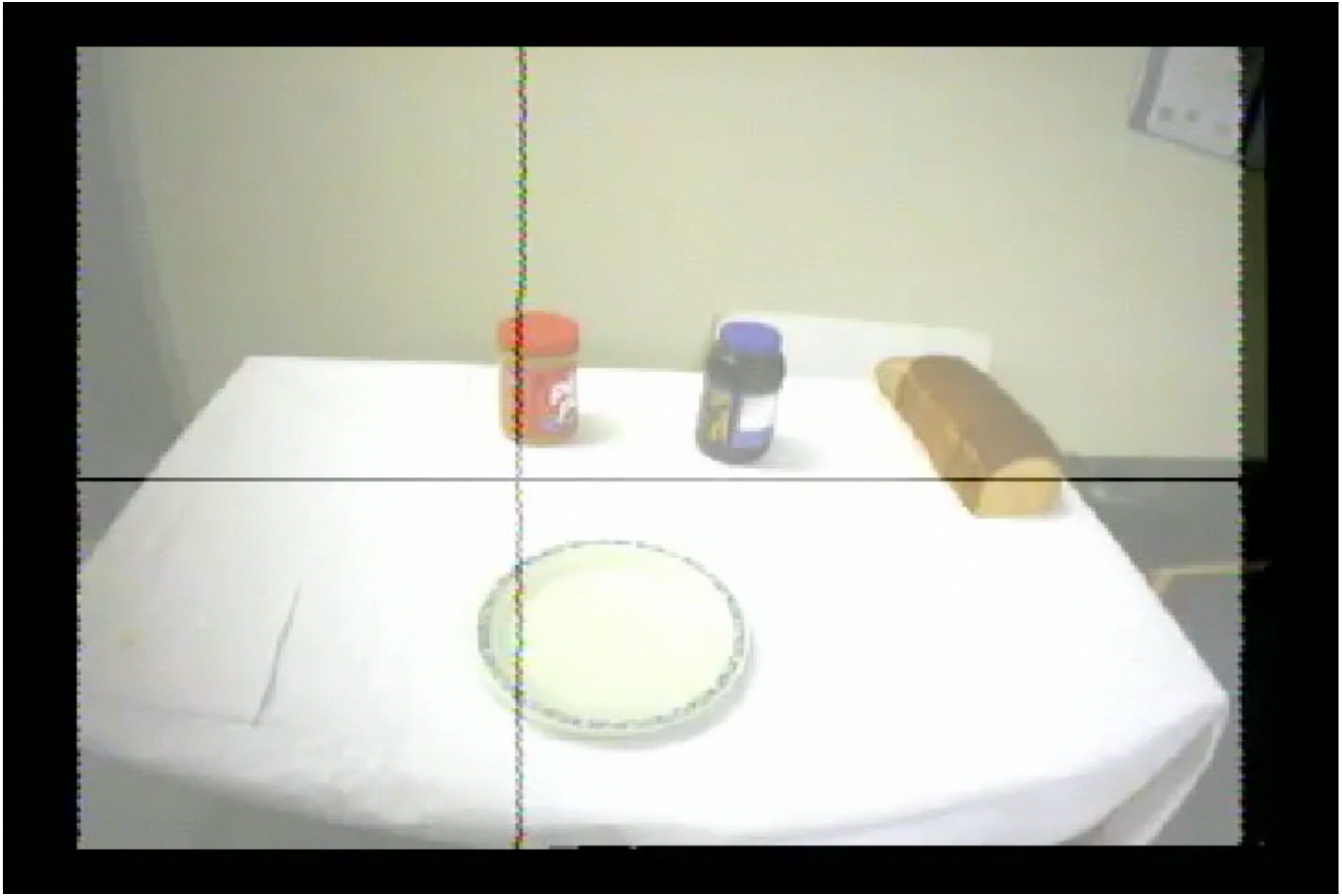
(Remember the peanut butter and jelly video)



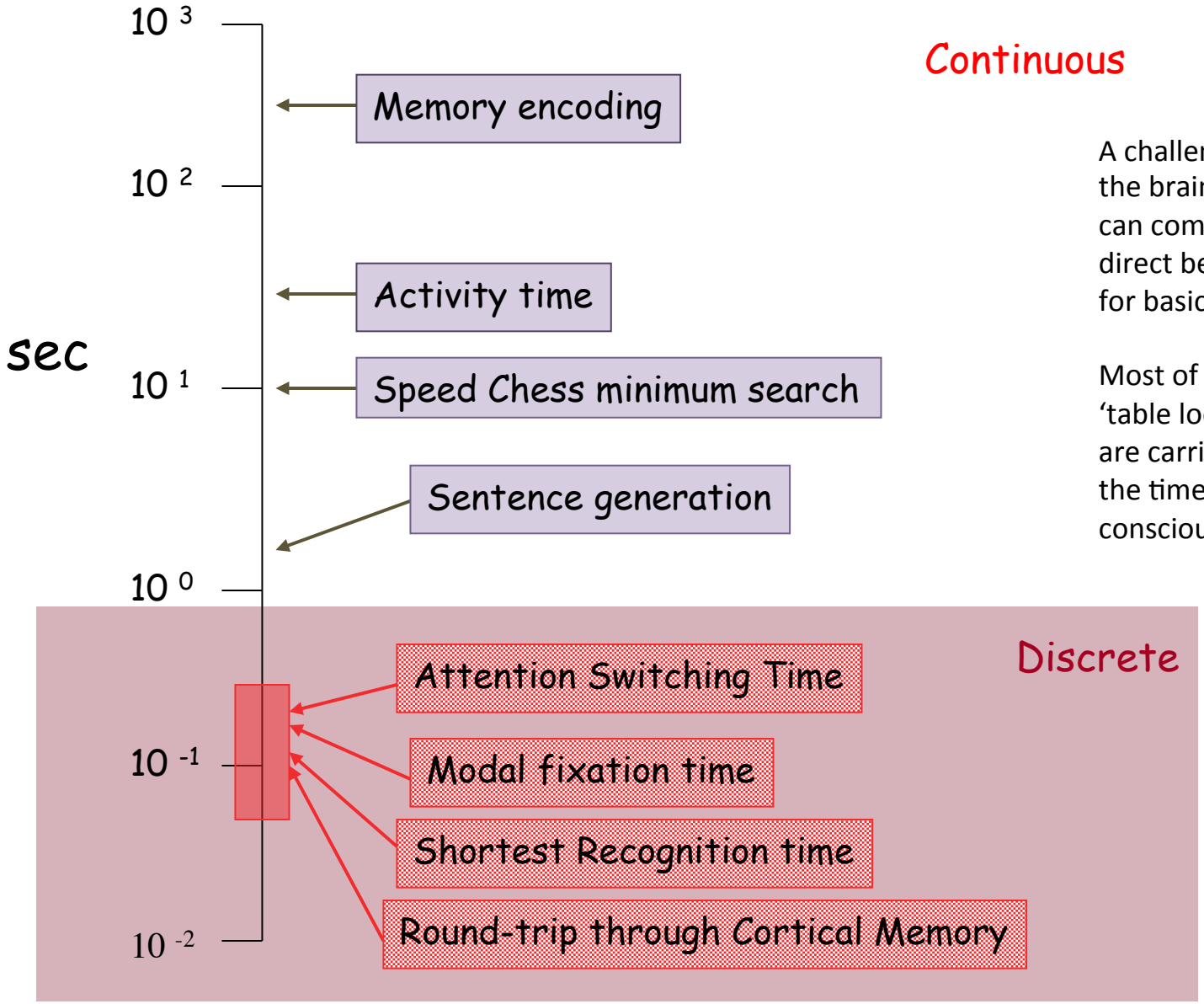
Thinking

Acting


D:095 H:338 V:163 FC:62443



Timescales



A challenge for understanding the brain is to explain how it can compute fast enough to direct behavior (see next slide for basic neural data).

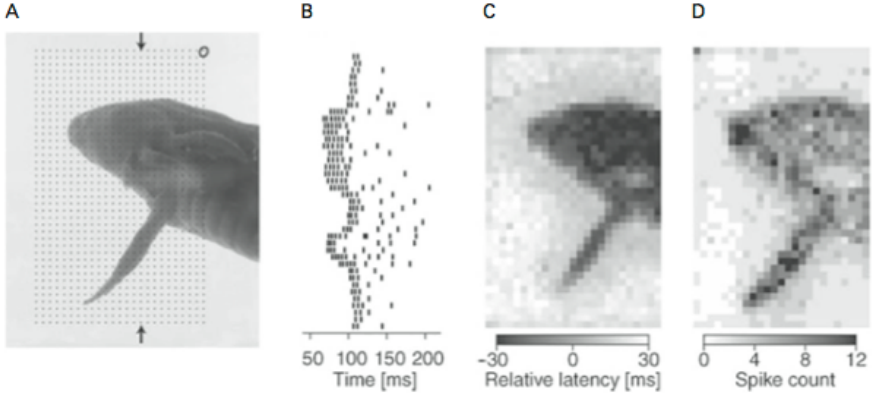
Most of the basic 'table lookup' operations are carried out below the time needed for conscious awareness

Computation with slow circuitry

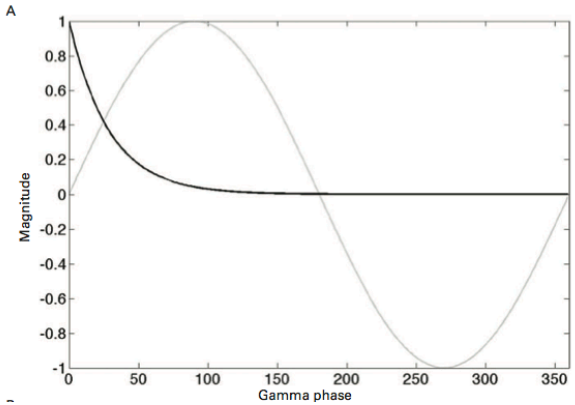
Feature	**Value**
Number of neurons	10^{11}
Ave. no. connections per neuron	10^{4}
Total connections	10^{15}
Speed of communication	10 meters/sec
Average signaling rate	10 voltage spikes/sec
Sum of all axonal lengths	10^{6} km

How do spikes distinguish between abstraction levels? One answer: Frequencies

Coding with delays

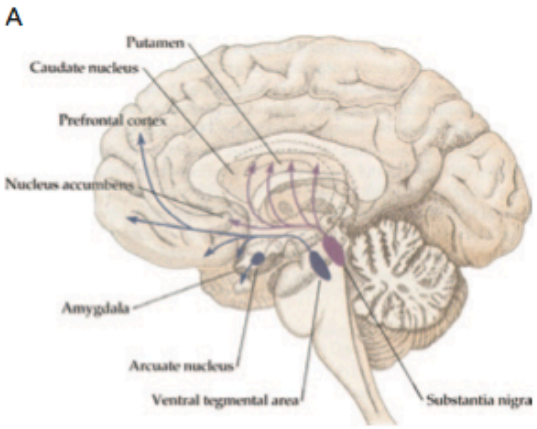


Phase coding in frequencies

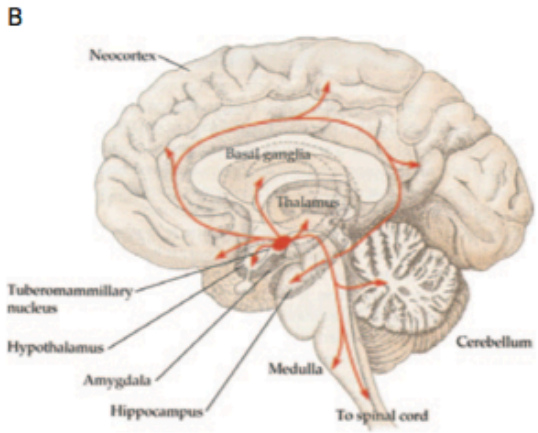


Frequency	Range (Hertz)		Evidence
θ	4 - 7	Task clock	Lots
α	8 - 12	??	
β	13 - 39	Sub-task clock	Some
γ	40 - 90	Algorithm clock	Some

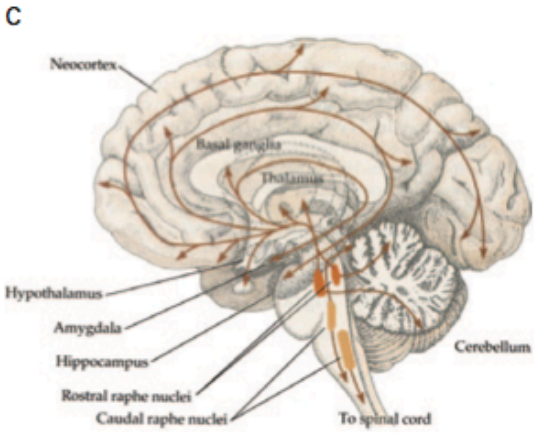
Neurotransmitters



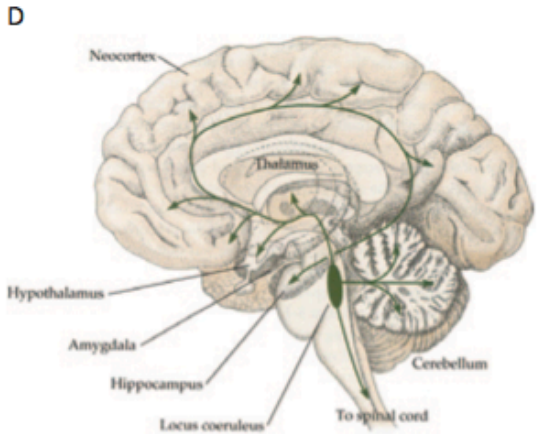
Dopamine:
Secondary reward, movement generation



Histamine:
Energy metabolism



Serotonin:
Sleep-wake cycle, cognitive performace, aggression



Norepinephrine:
Attention, arousal, circadian rhythms

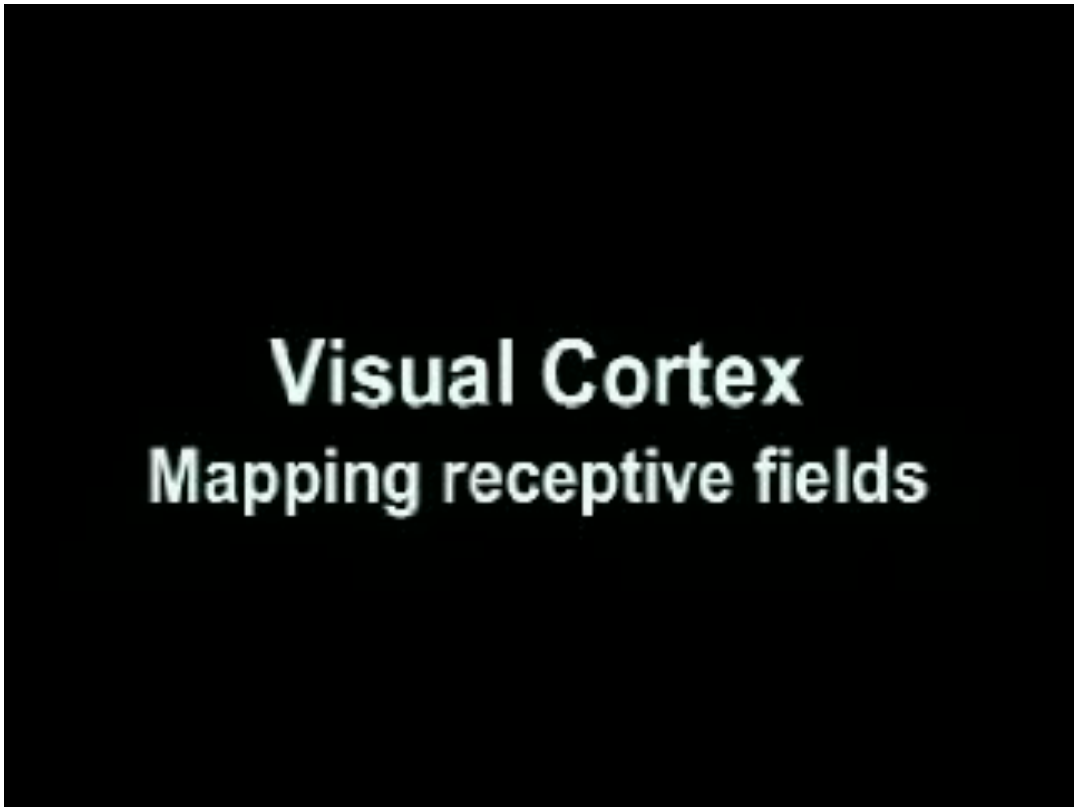
Besides neural 'programs,' the forebrain uses chemical molecules called NEUROTRANSMITTERS that can modulate neural responses to shape behavior.
The most important four are:

Dopamine: rate programs in terms of utility

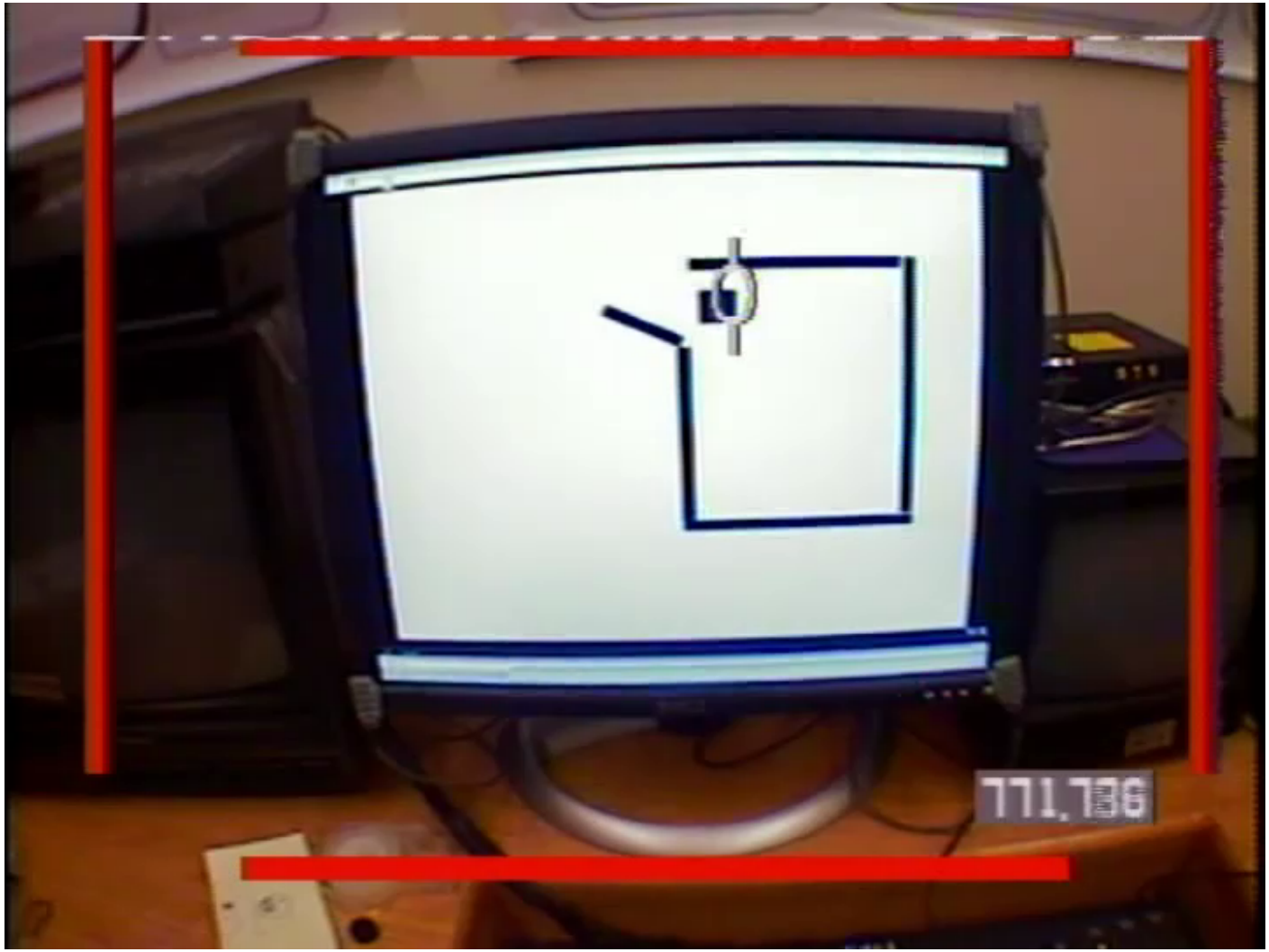
Serotonin: rate programs in terms of risk

Norepinephrine: Prepare the body's response level based on external factors

Histamine: Prepare the body's response level based on internal factors


Visual Cortex
Mapping receptive fields

In describing moving tokens, a subject animates abstract tokens and interpolates human relationships



Abstract reasoning can be difficult

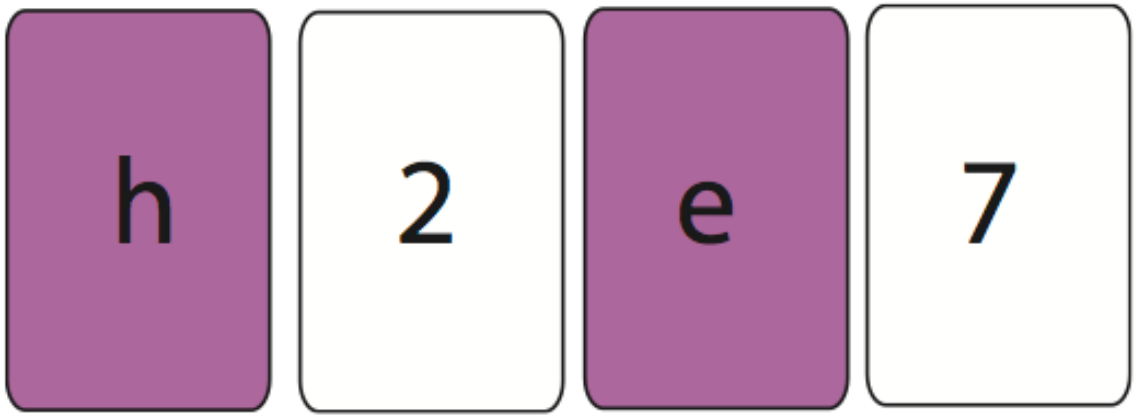


Figure 1.6
Cards have letters on one side and numbers on the other. Which two should you turn over to check whether every even-numbered card has a consonant on the other side?