Cognitive Neuroscience

Preliminaries

What to do if I'm sick?

- Stay home if you might be contagious or if you feel badly
  - Can always ask a doctor if you're not sure if you are contagious
- OK to watch lectures/classes via Zoom live feed
- NOT OK to record

My course schedule is wrong

› Unfortunately, I have no control over this, but here's who can help you: team5.uvaeka.arts@au.dk

Cognitive Neuroscience

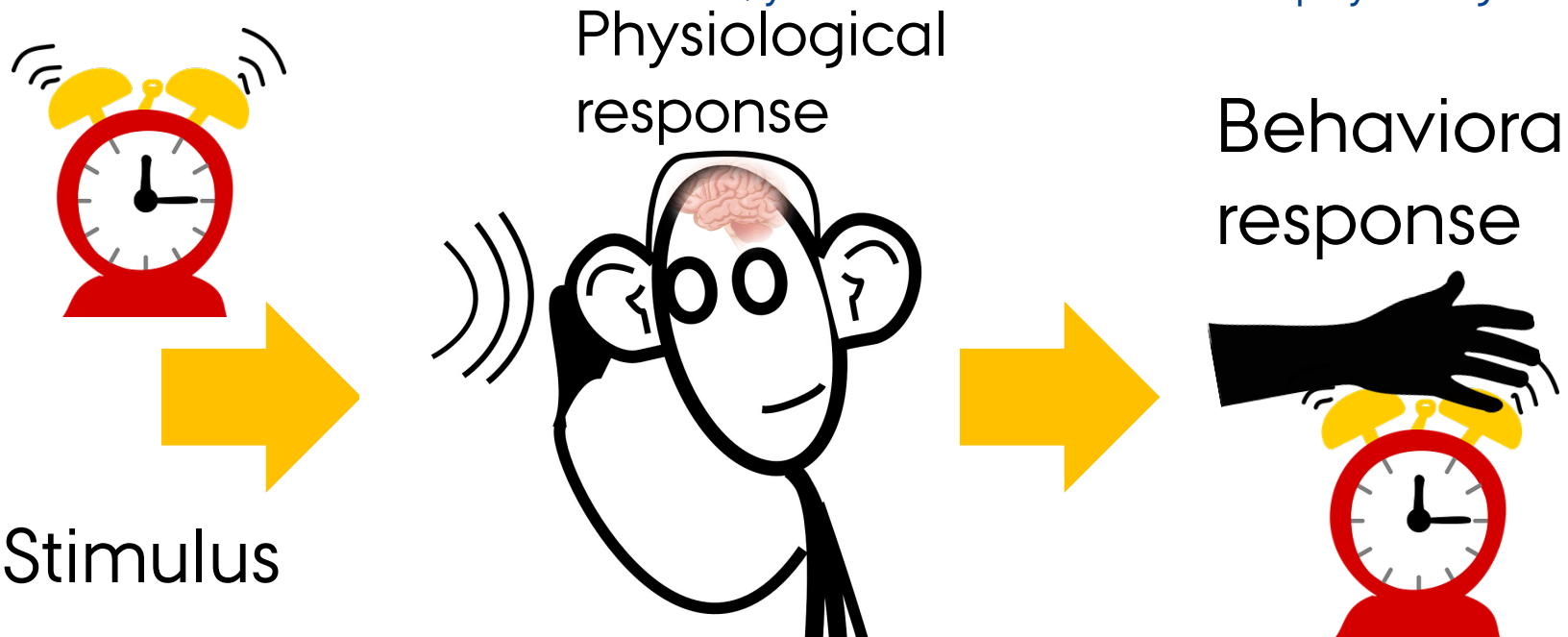
Cognitive neuroscience

- What's the difference?
- The study of how cognition is realized in the brain, including findings in the study of most complex thought processes
- Exciting field! Limited tools…

Levels of analysis

Levels of analysis = A topic can be studied many different ways

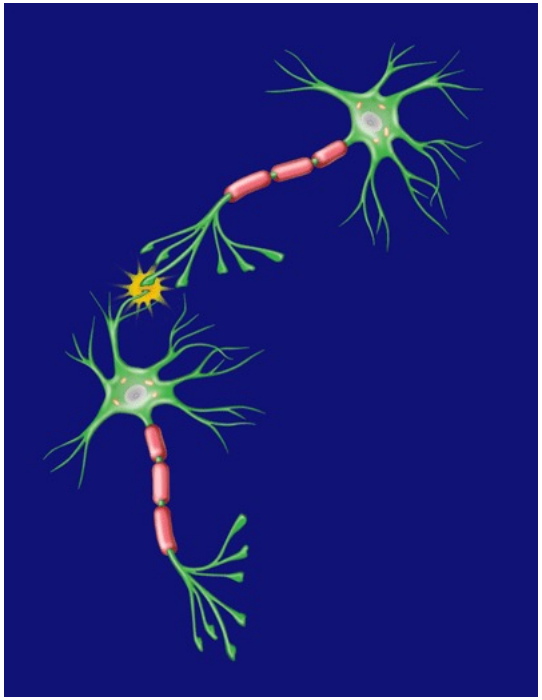
To understand how the mind works, you need behavioral *and* physiological data

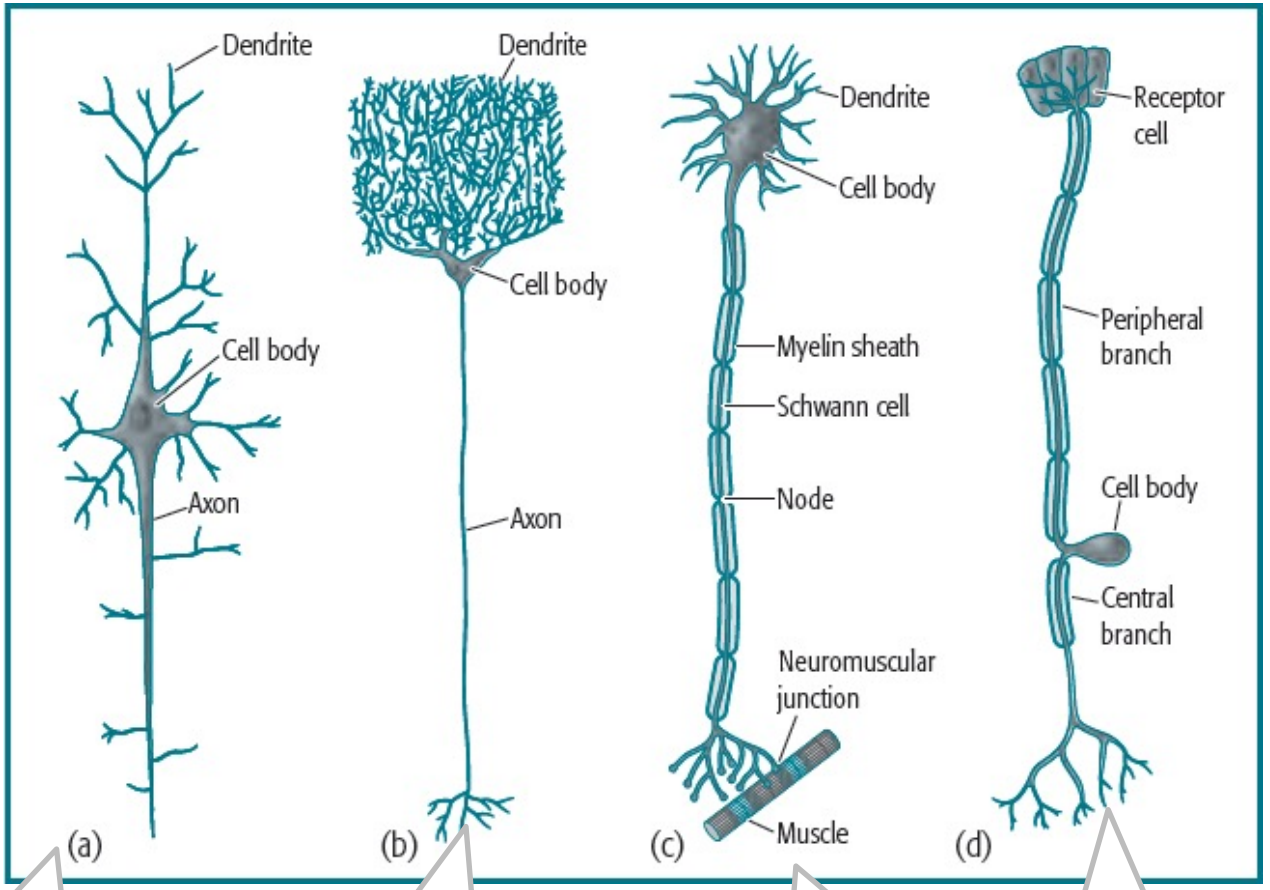


The communicative neurons

- More information processing…
- A cell that accumulates and transmits electrochemical activity in the nervous system
- There are approximately 100 billion neurons in the human brain, which are simultaneously active to process information

What is a neuron?





Pyramidal

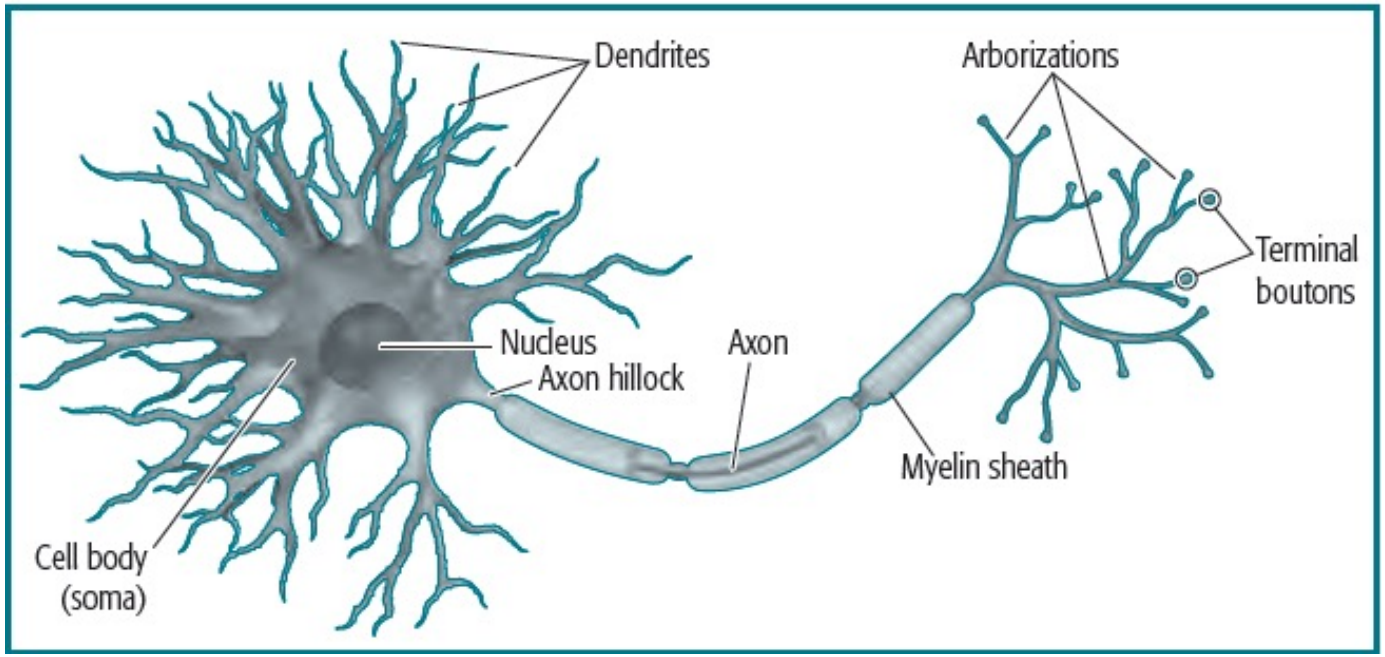
Purkinje, cerebellar

Motor neuron

Sensory neuron

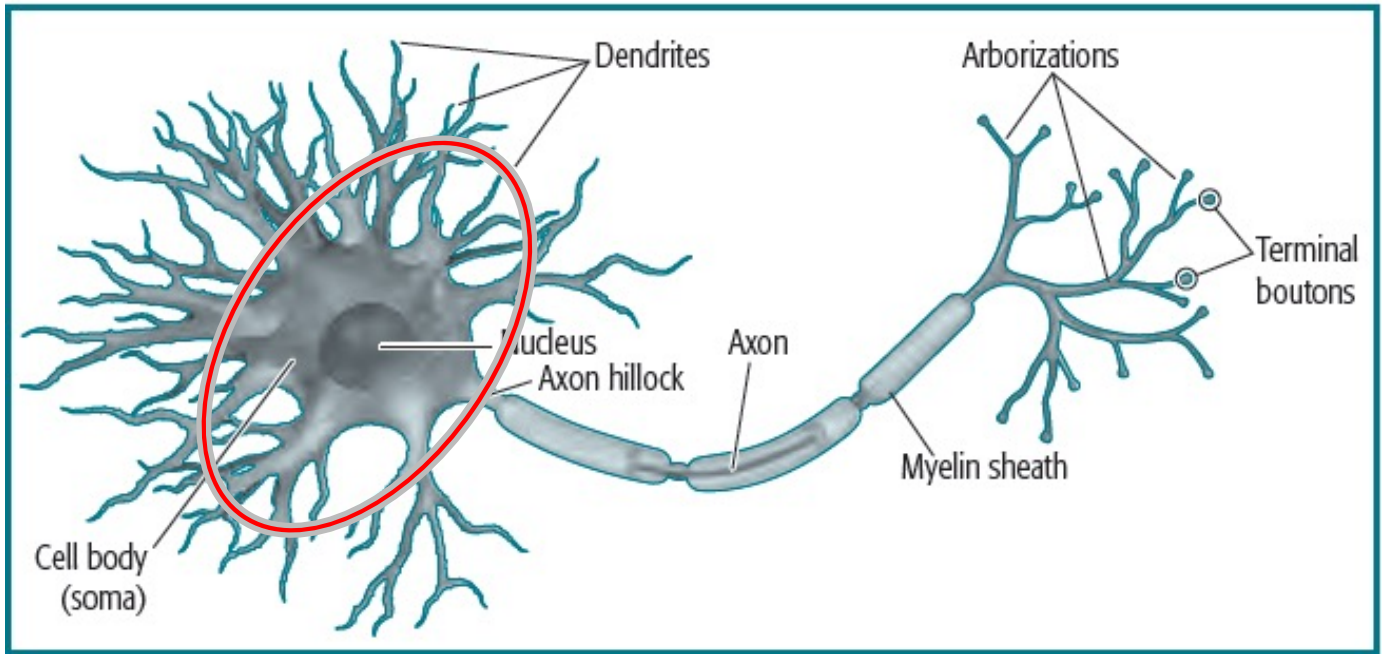
The communicative neurons

› Neurons come in a wide variety of shapes and sizes
› A schematic representation of a typical neuron:



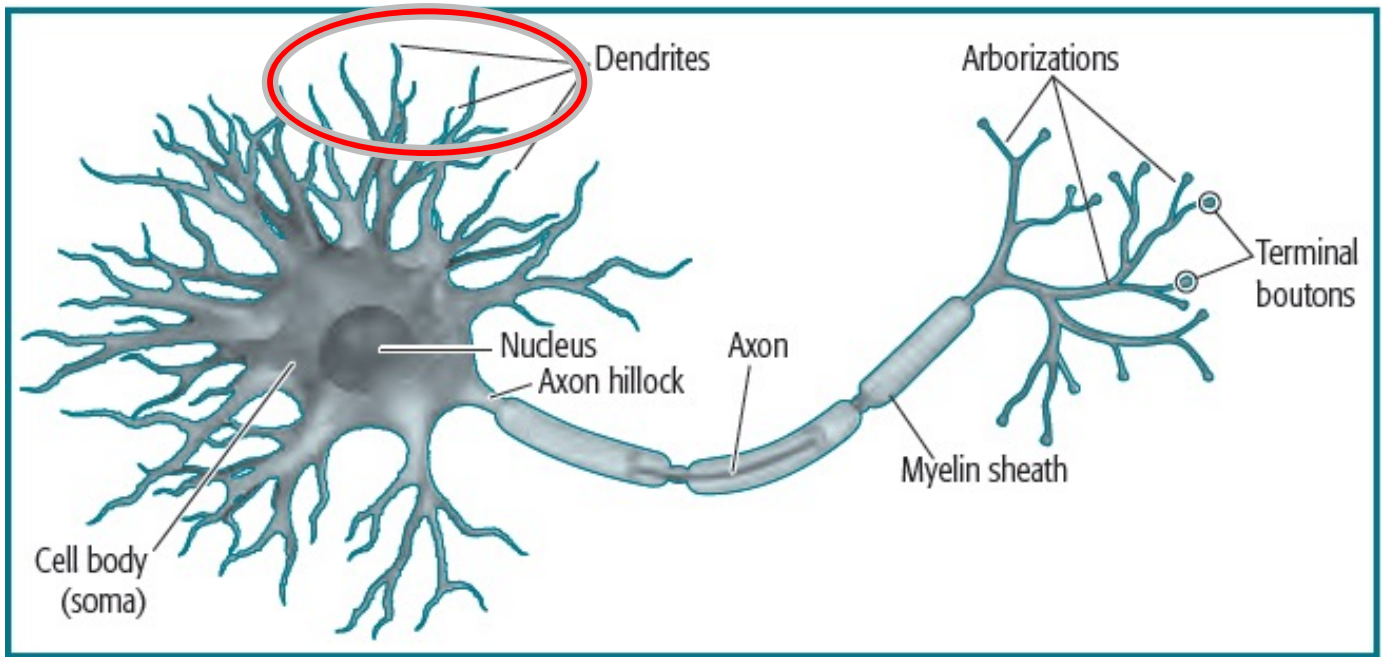
The communicative neurons

› Soma: Main (cell) body of the neuron
› Typically 5 to 100 micrometers (μm) in diameter



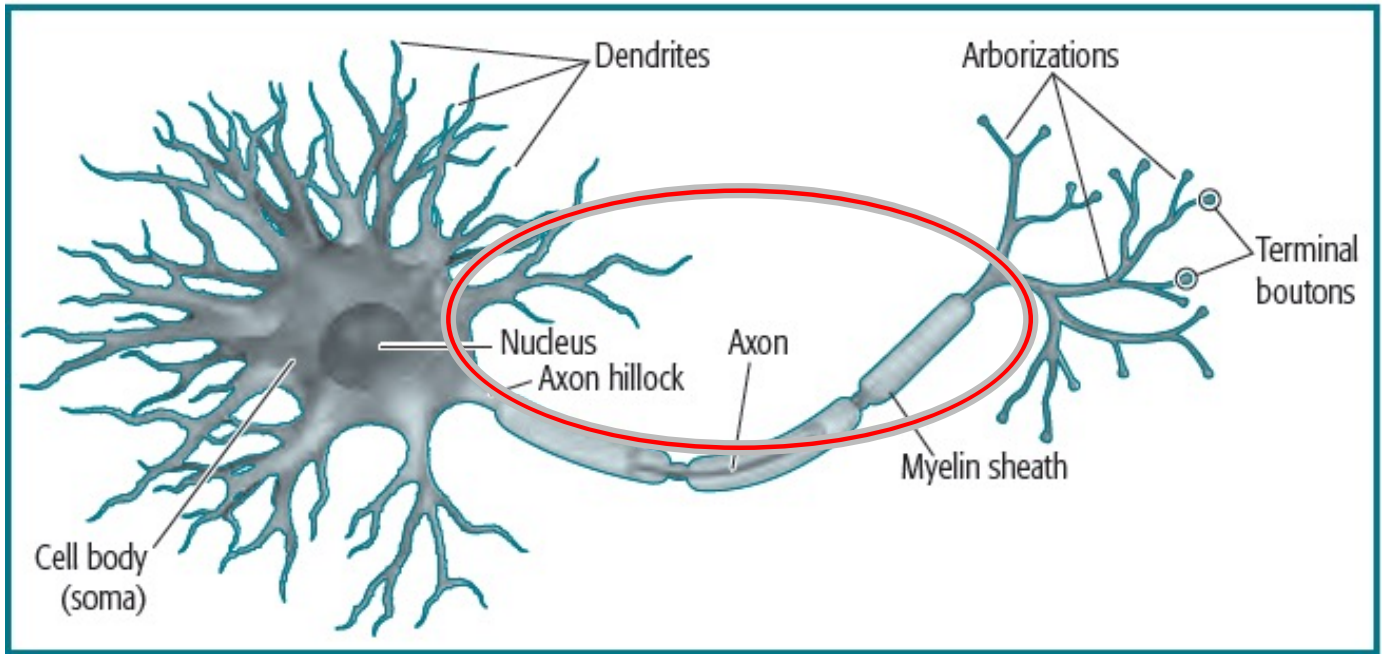
The communicative neurons

- Dendrites: Branch-like processes extending from the cell soma
  - Receiving information from terminal boutons of adjecent neurons



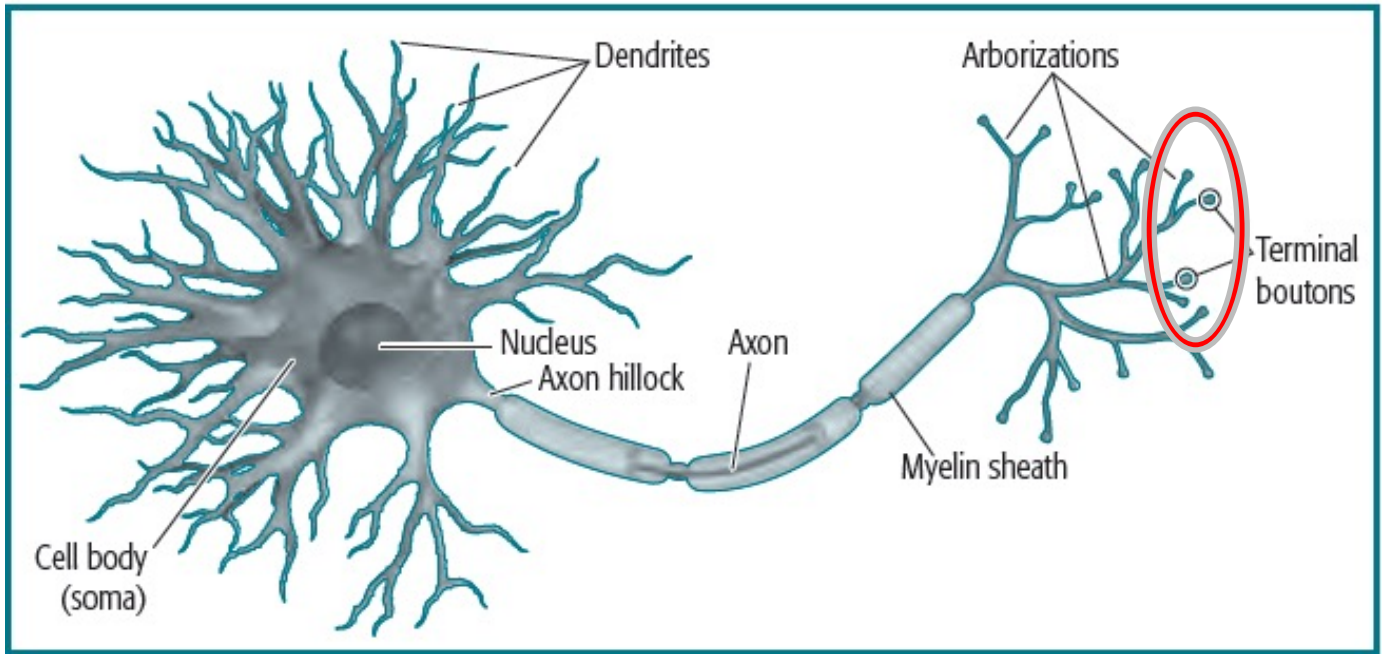
The communicative neurons

- Axon: Long, thin tube extending from soma (from millimeters to a meter long!)
- Provides the paths for communication



The communicative neurons

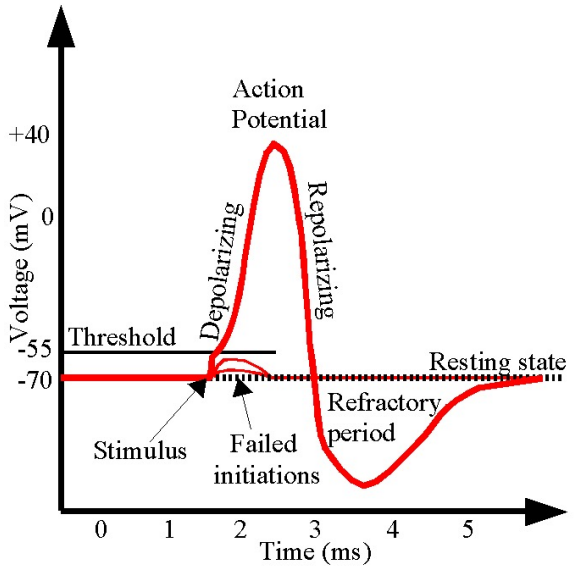
- Terminal boutons: Ball-like structures at the ends of axon branches
  - contain neurotransmitters
  - Form synapses with other neurons



Neurons and Information Processing

RESTING POTENTIAL

- The constant charge of the neuron at rest
- Sometimes call "resting state"



Neurons and Information Processing

POLARIZATION (ELECTRIC POTENTIAL)

- Excitatory synapses
  - Increase the likelihood of a cell firing
- Inhibitory synapses
  - Decrease the likelihood of a cell firing

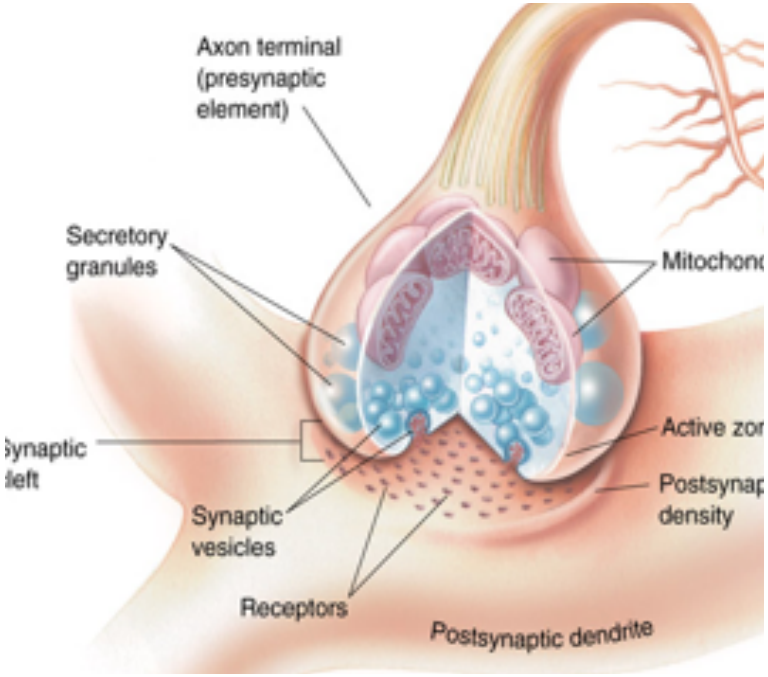
Neurons and Information Processing

ACTION POTENTIAL

- Brief electrical impulse by which electrical information is transmitted along the neuron's axon
- When an action potential reaches the terminal bouton, the bouton secretes a chemical substance called a neurotransmitter.

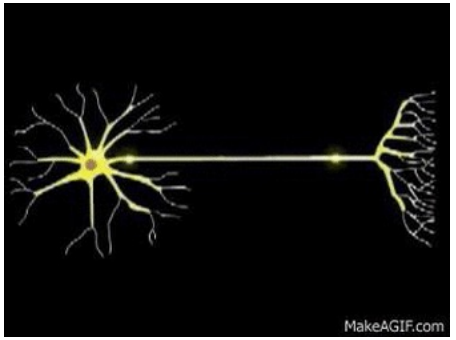
The synapses

- Near-contact gap between two neurons (boutons of one and dendrites of another)
  - The connection point
- Synaptic transmission here is chemical
- An action potential causes the presynaptic neuron to release a neurotransmitter

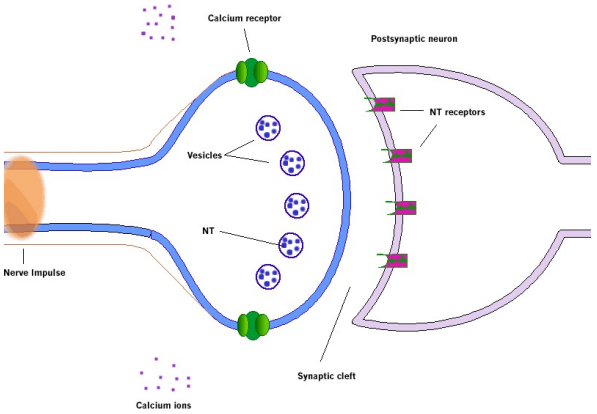


Connection gap between two neurons

The communicative neurons

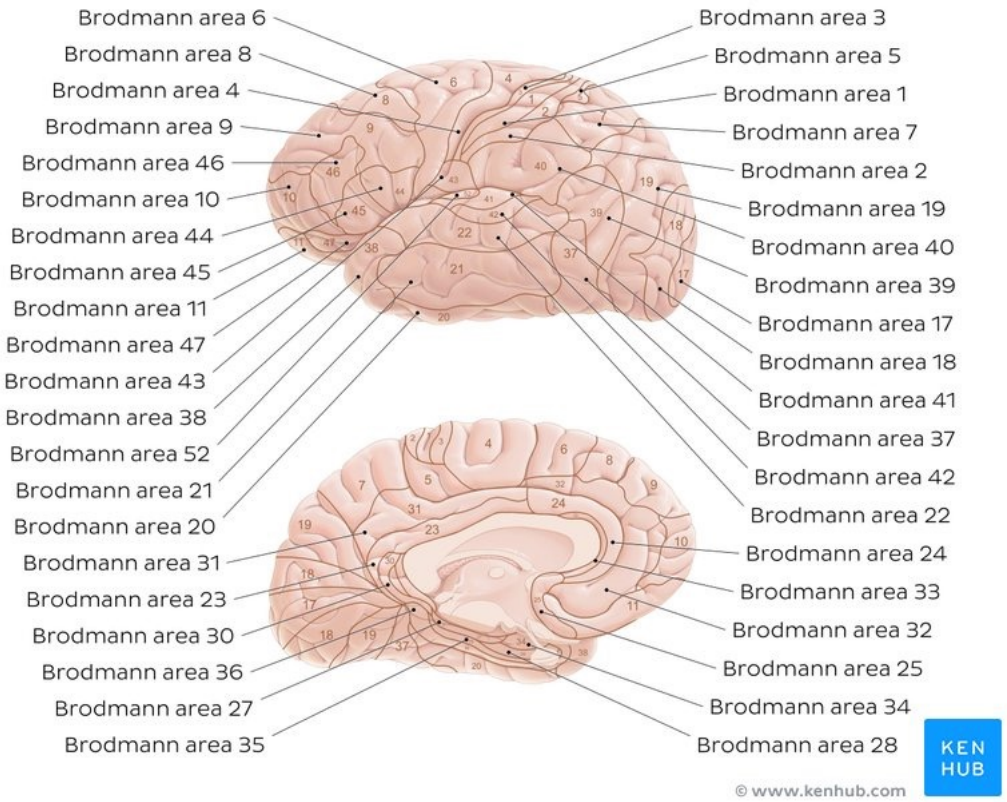


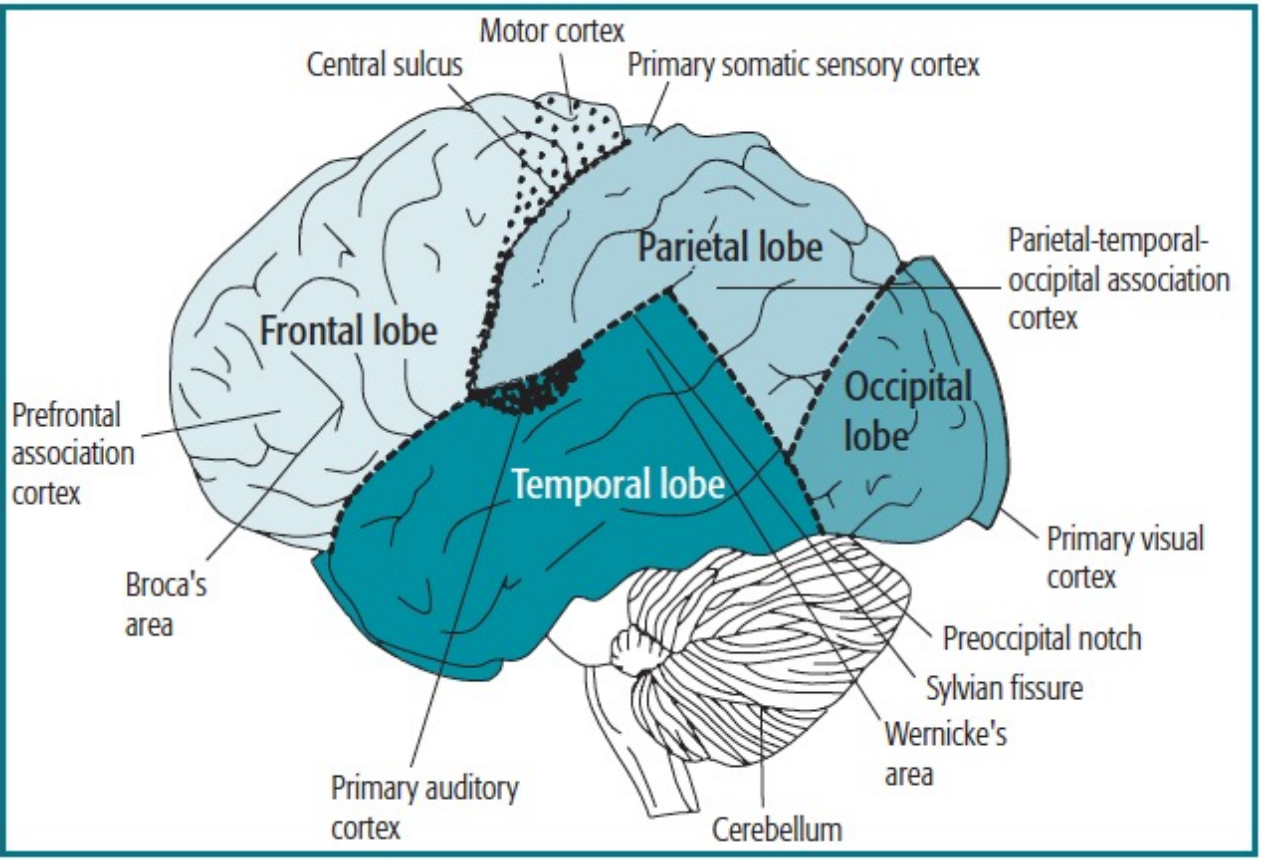
- Neurotransmitter: Chemical that crosses the synapse from the terminal bouton of one neuron to alter the electric potential of the next neuron
  - How one neuron communicates with the next
- That is, it causes the transmitter gated ion channels to open in the dendrite of the post-synaptic neuron
- These opened channels causes the postsynaptic neuron to become either de-polarized or "excited" (e.g. glutamate) or hyper-polarized or "inhibited" (e.g. GABA)



Organization of the brain

- The central nervous systems (CNS), includes the brain but also the spinal cord, which links to the nerves throughout the body
- In terms of anatomy, the cerebral cortex is distinct as the more recently evolved
  - Convolved with gyri and sulci
  - Conventionally categorized based on cell type differences, using Brodmann areas, o based on the different lobes, using major sulci or fissures as "borders"





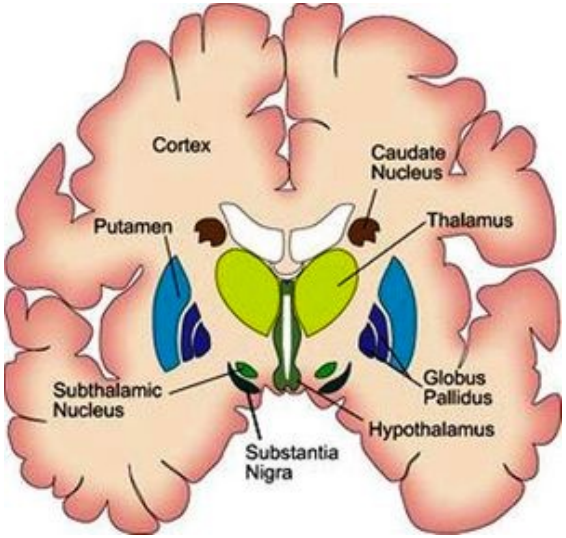
- Frontal lobe = sensory integration, judgement, reasoning
- Parietal lobe = touch, pressure, pain
- Temporal lobe = hearing, complex visual processing
- Occipital lobe = received signals from eyes, vision

Lateral (side) view of the cerebral cortex

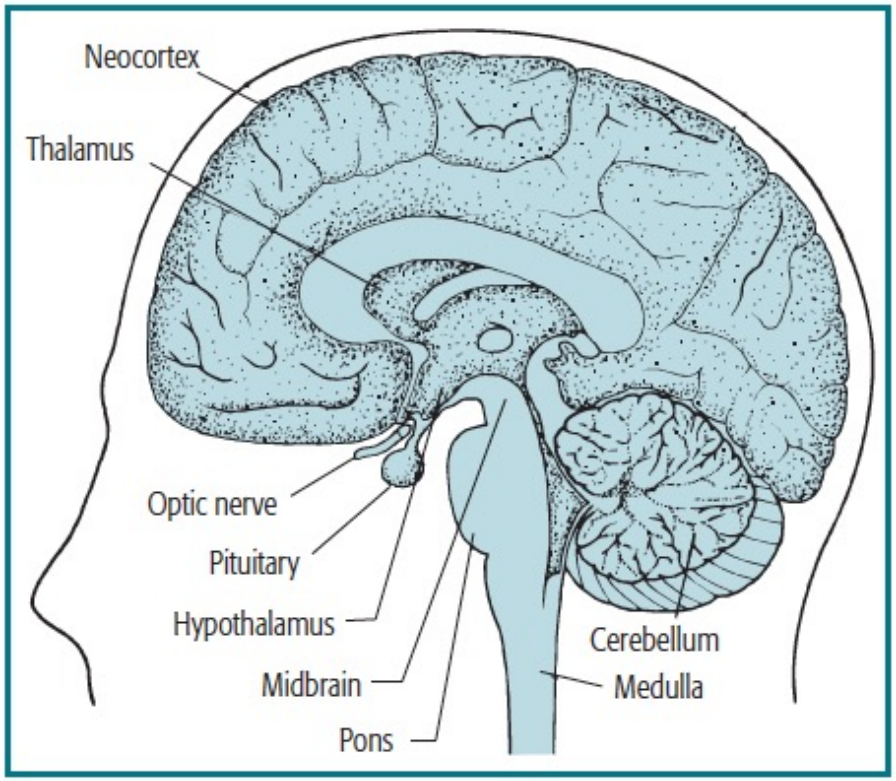
Organization of the brain

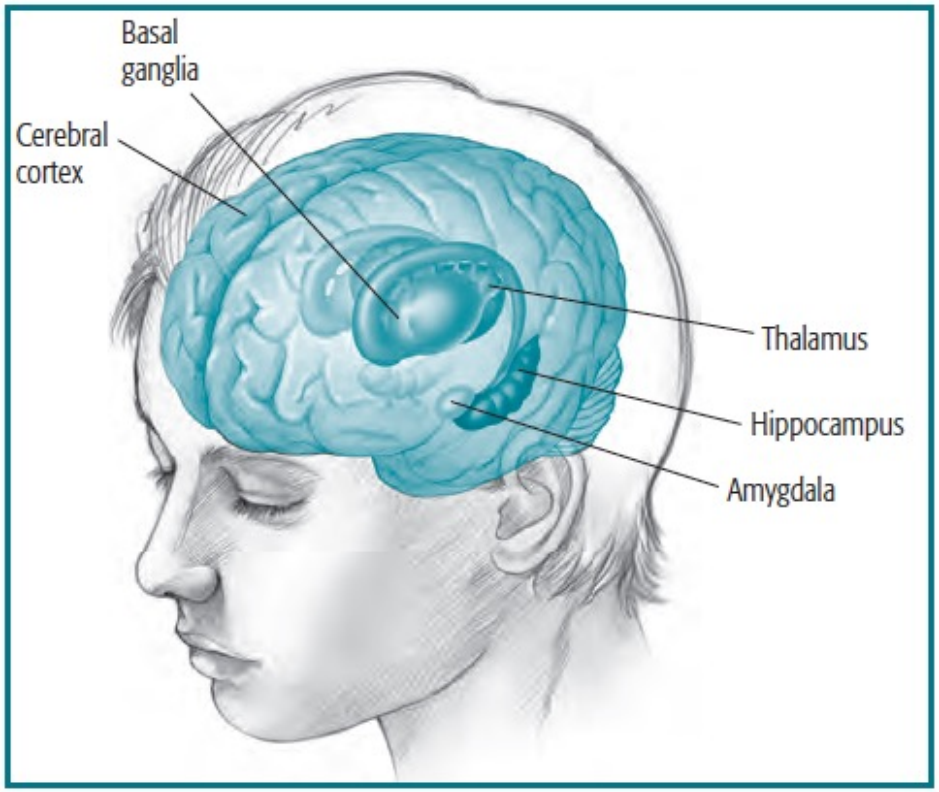
› Underneath the neocortex are the subcortical structures

› These serve more primitive functions, such as breathing and heartbeat (medulla), basic drives (hypothalamus), voluntary movement (cerebellum), memory (hypocampus), basic emotions and threat responses (amygdala), and *many many more* -

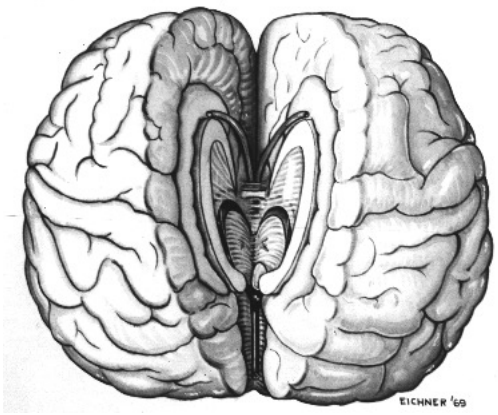


Cross-sectional (medial) view – and the limbic system





Brain Organization

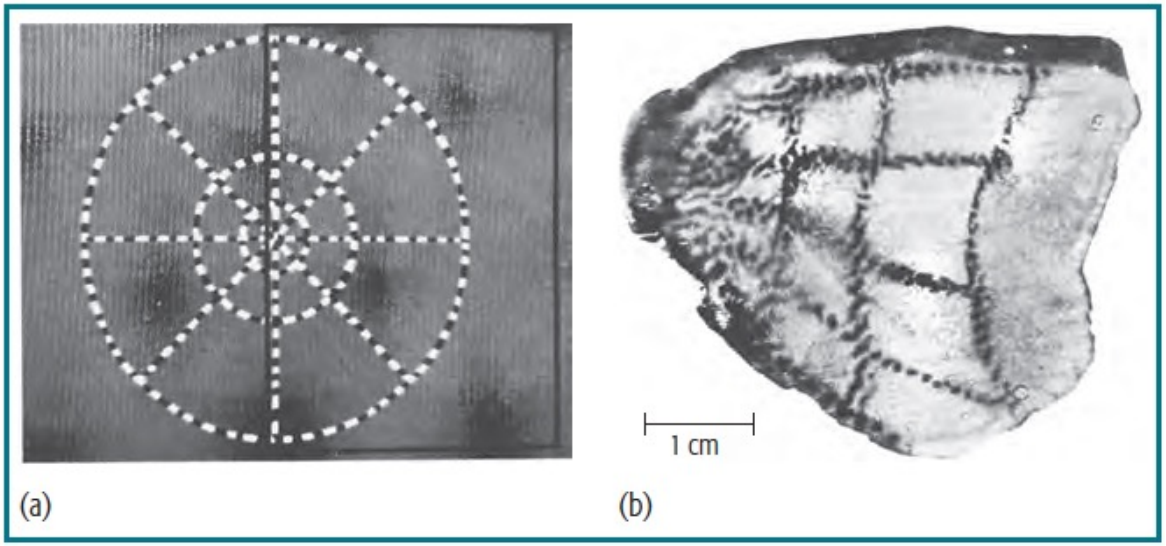


SPLIT-BRAIN PATIENTS

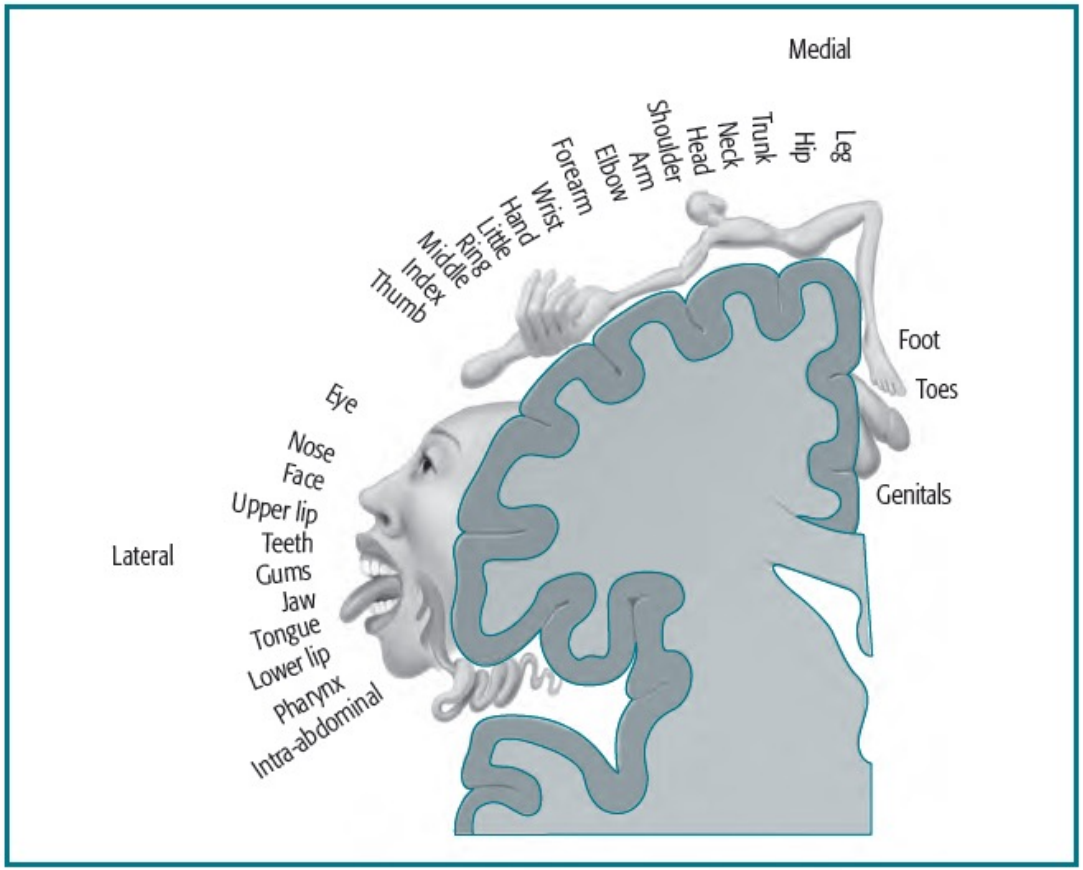
- Have had an operation that surgically severed the corpus callosum
- The two hemispheres differ in their specialization.
  - Research has shown a linguistic advantage for the left hemisphere; the right hemisphere outperforms the left hemisphere in manual tasks.

Organization of the brain

- In some areas of the cortex, information is structured spatially, displaying topographical organization
- For example, adjacent areas in the visual cortex represent information from adjacent areas of the visual field



Topographical organization of the brain: Somatosensory cortex



Single neurons in the visual system

- Feature detectors = are neurons that respond specifically to one specific feature, such as movement, orientation, length, etc.

- Neurons in temporal lobe of the brain respond to complex stimuli
  - Some of these neurons respond to complex geometrical stimuli
  - Other neurons respond to faces

Sensory coding

Sensory coding = how neurons represent the environment

3 type of sensory coding:

- Specificity coding = one neuron responds only to that object
- Population coding = many neurons respond in a specific pattern in response to only that object
- Sparse coding = a few neurons respond in a specific pattern in response to only that object

Specialized visual areas

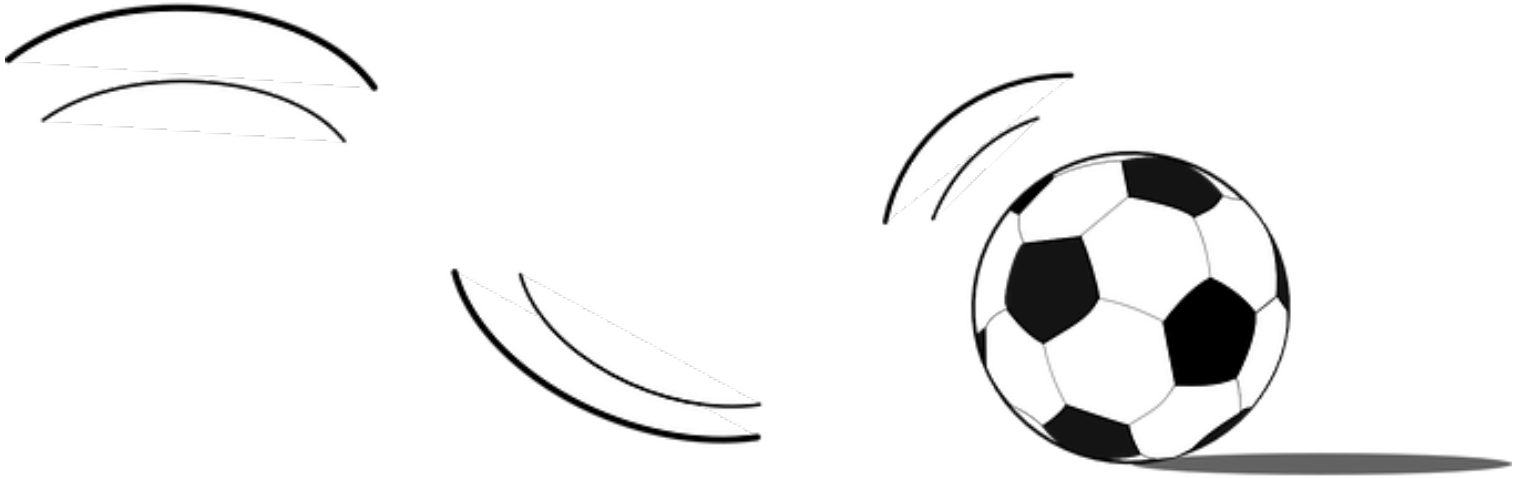
- Fusiform face area (FFA) = activated when viewing faces
- Parahippocampal place area (PPA) = activate for spatial layer (e.g., houses, rooms)
- Extrastriate body area (EBA) = activated when viewing bodies (but not faces)

Distributed representation

Distributed representation = many areas of the brain may be activated in response to specific cognitive functions

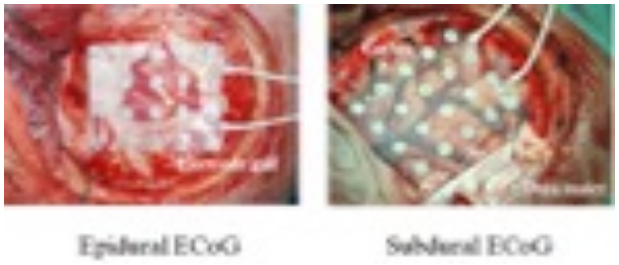
- E.g., ball rolling

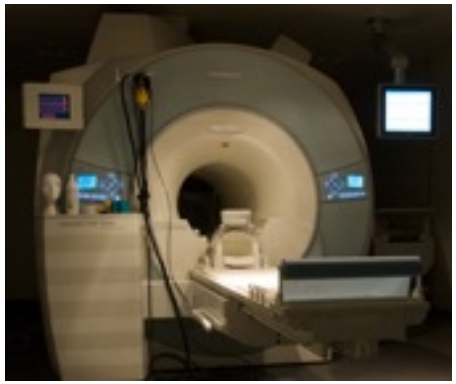
› Neural networks = groups of neurons that connect to each other

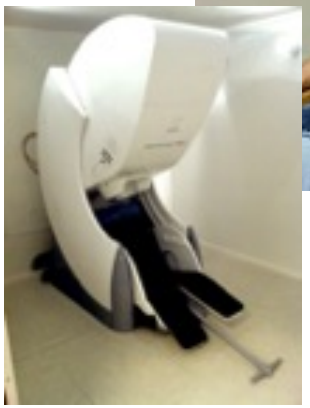


Methods in Cognitive neuroscience

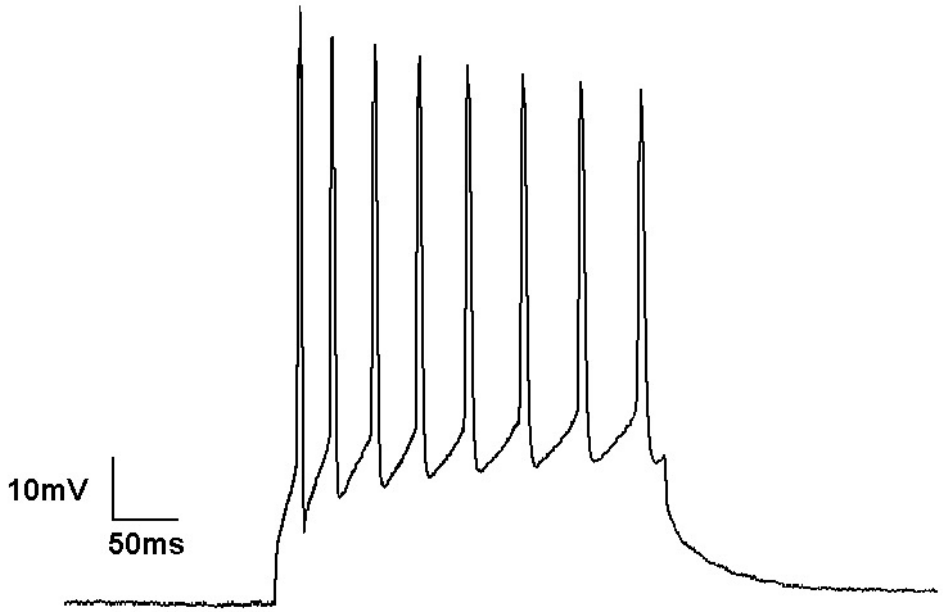
- Neural imaging techniques, the most common:
  - Single-cell recording
  - Electroencephalography (EEG)
  - Event-related potentials (ERPs)
  - Magnetoencephalography (MEG)
  - Positron emission tomography (PET)
  - Functional magnetic resonance imaging (fMRI)
  - Transcranial magnetic stimulation (TMS)
  - Functional near-infrared spectroscopy (fNIRS)



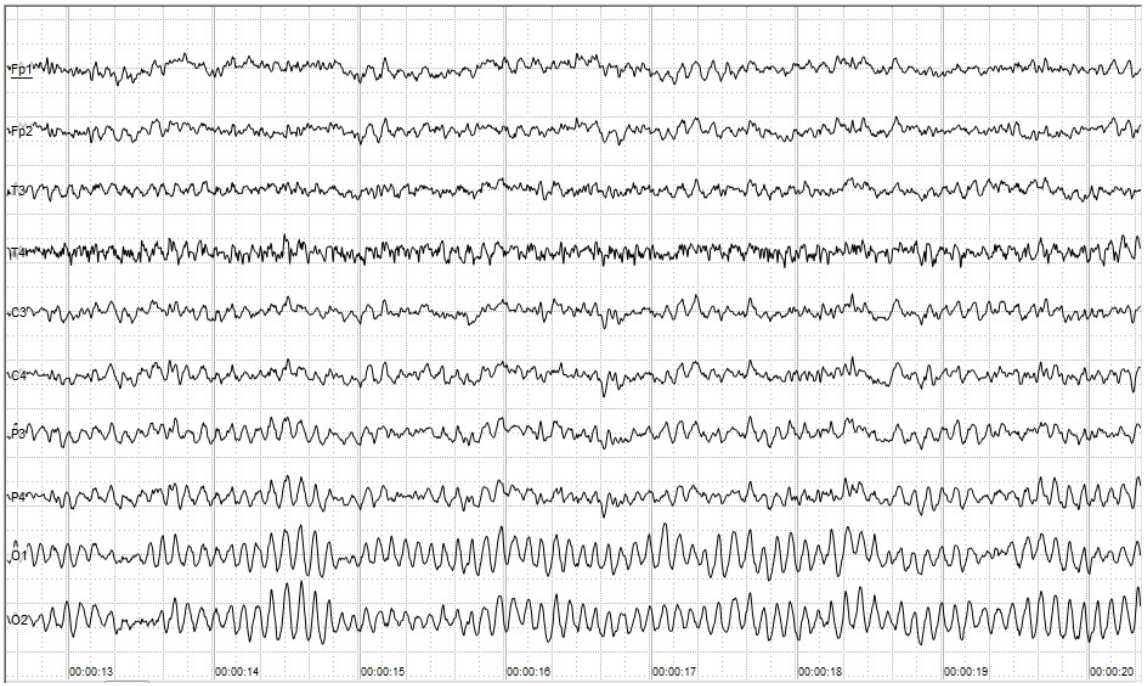




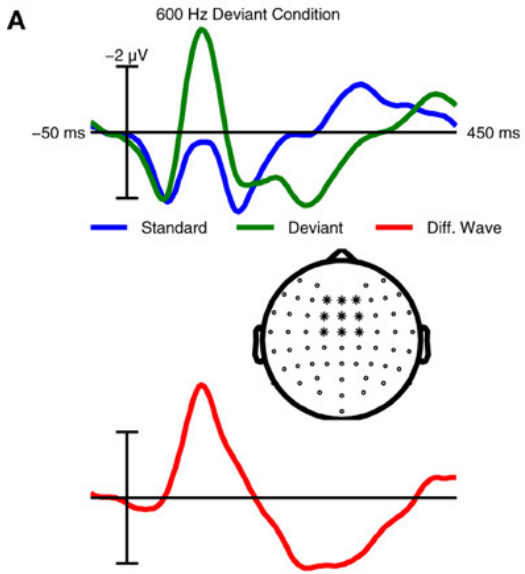
Single-cell recording



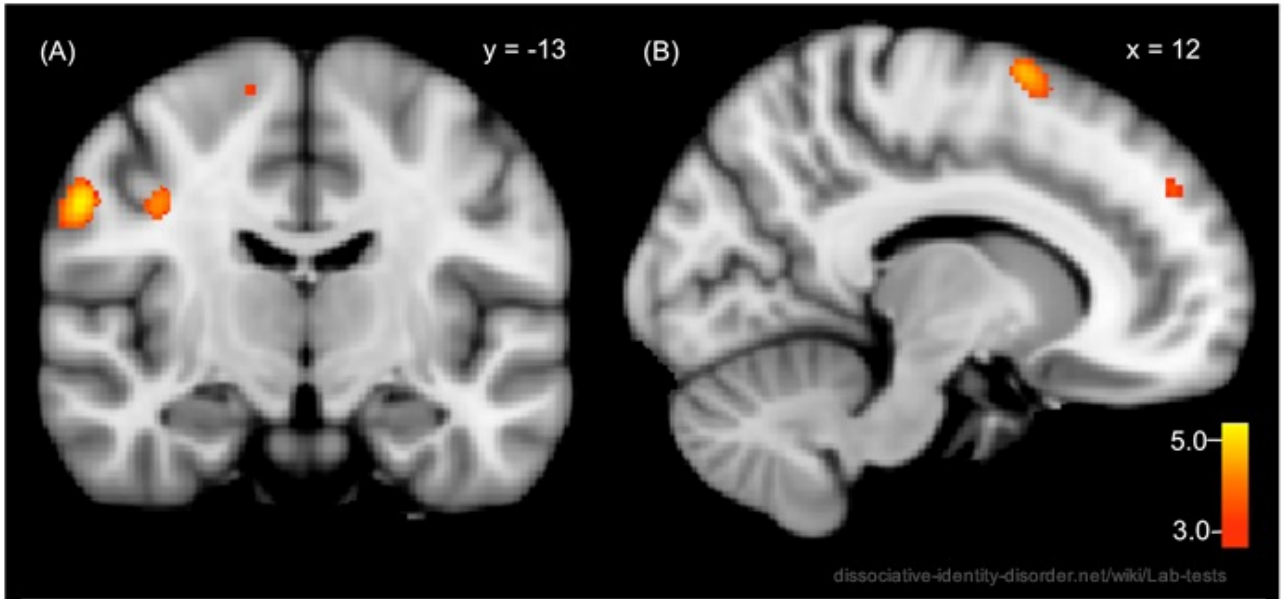
Electroencephalography (EEG)



Event-related potentials (ERPs)



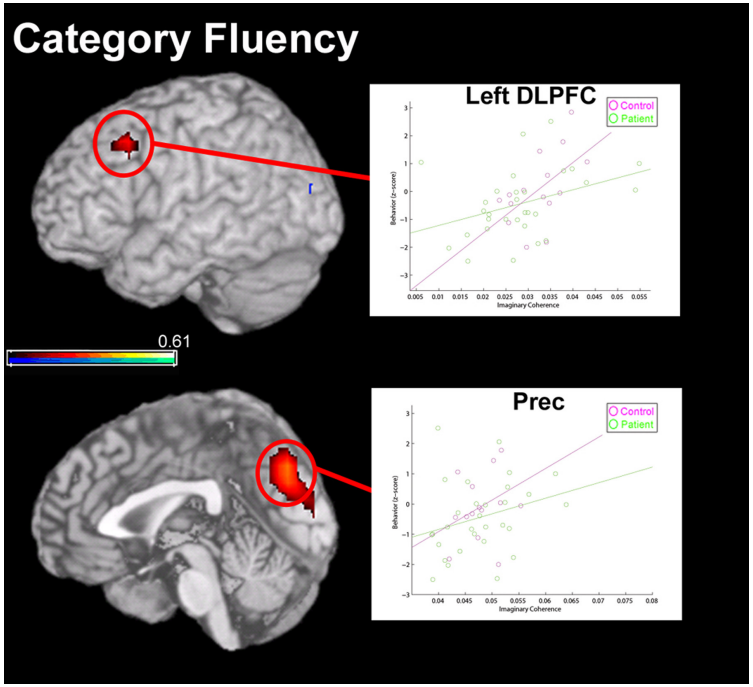
Functional magnetic resonance imaging (fMRI)



Significant rCBF increases in genuine Emotional Part (DIDep) compared to genuine Apparently Normal Part (DIDanp) in (A) the primary somatosensory cortex, primary motor cortex, premotor cortex and in (B) the pre-SMA and DMPFC.

Source: Schlumpf, Y.R.; Reinders, A. A., Nijenhuis, E. R., Luechinger, R., van Osch, M. J., Jäncke, L. (y). Dissociative Part-Dependent Resting-State Activity in Dissociative Identity Disorder: A Controlled fMRI Perfusion Study. PloS one, 9 (6), 2014. (doi:10.1371/journal.pone.0098795)

Magnetoencephalography (MEG)



Opened 15 September 2020

fNIRS & the IMC Lab

The IMC will open Denmark's first All-Ages fNIRS Laboratory

New tech ☺

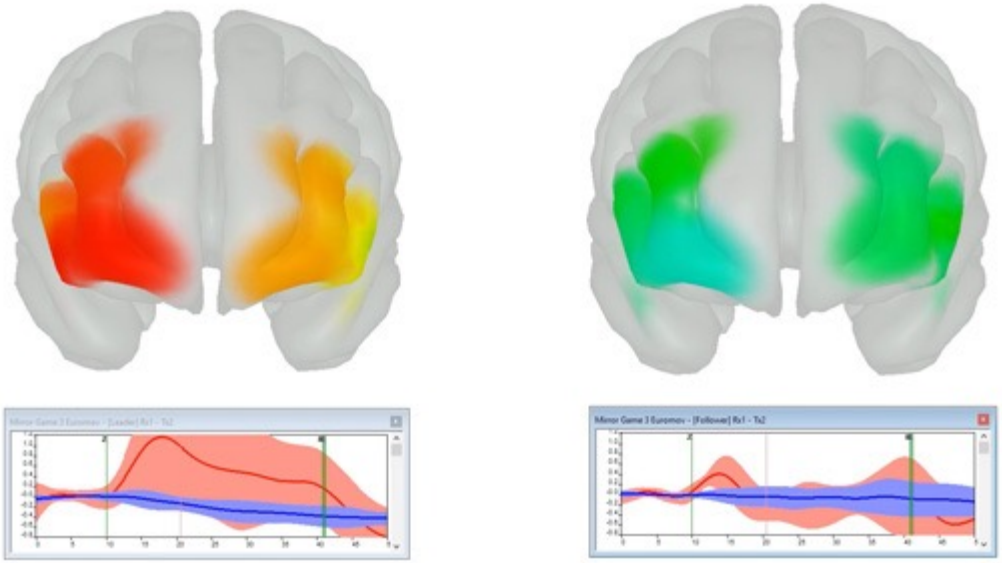
High-quality fNIRS equipment to study human interaction

2020.08.14 | ANNE-METTE PEDERSEN

We are very pleased to announce the opening of **Denmark's first all-ages fNIRS laboratory** this September! This addition to the IMC's resources brings new potential for research and collaborations. The fNIRS devices are portable and tolerate movement, so they can be used to study humans interacting with each other and the world around them.

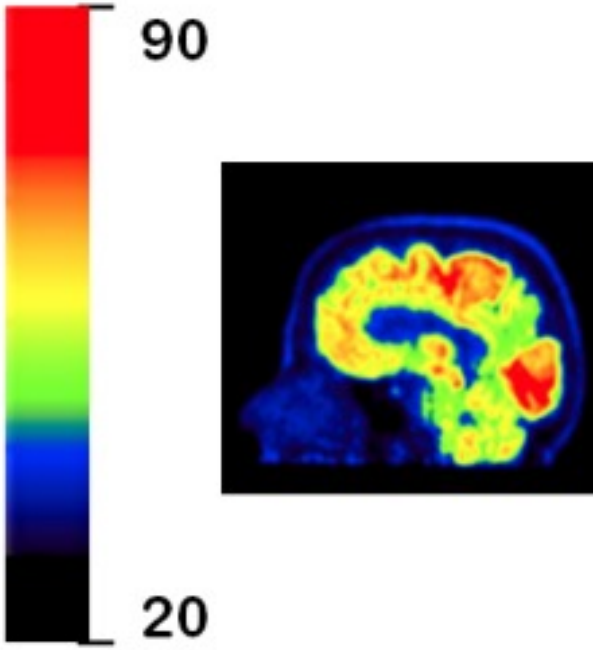
NIRx – and especially high-quality leader in fNIRS development – has be awarded the contract, which is funded by the **CarlsbergFondet**. The fNIRS devices can record up to 3 people simultaneously while they interact with each other or complete solo experiments. They are wireless and wearable so they may be used indoors or in outdoor

Functional near-infrared spectroscopy (fNIRS)

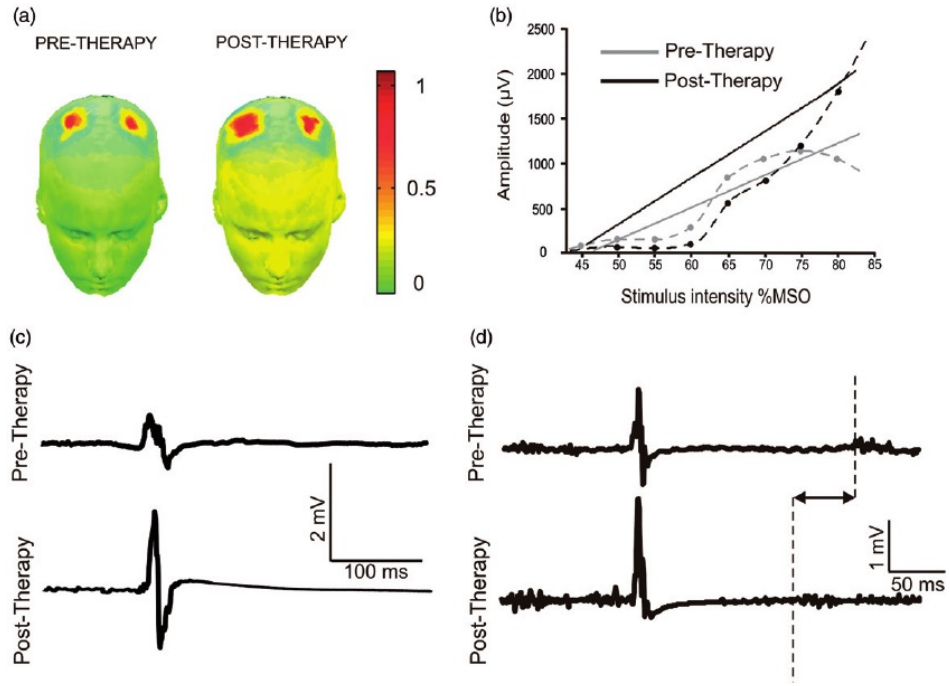


Positron emission tomography (PET)

Concentration	Red	Green	Blue
< 0	0	0	0
0 – 20	0	0	0
20 – 25	16	0	63
25 - 30	0	34	127
30 - 35	0	42	240
35 -40	0	63	127
40 - 45	196	254	55
45 - 50	254	243	54
…	…	…	…
> 90	255	0	0

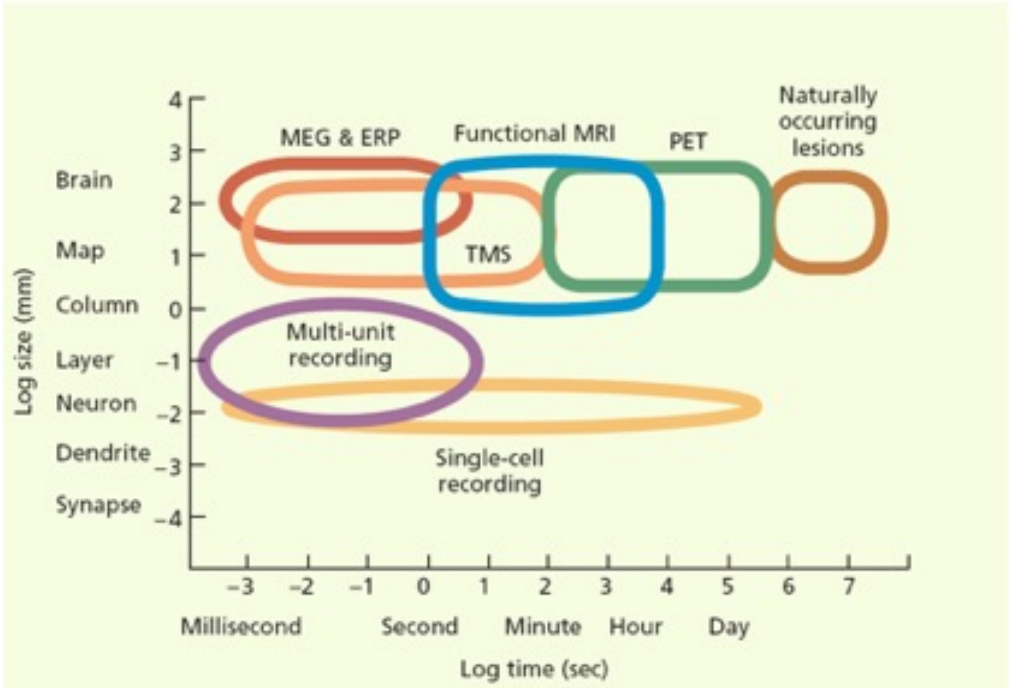


Transcranial magnetic stimulation (TMS)



Methods in Cognitive neuroscience

Spatial and temporal ranges of the methods



The Hippocampus of Taxi Drivers

Experimental Design

Samples: 16 male Taxi Drivers vs. 50 healthy males who don't drive taxis
- Right-handed

Data Collection Method: sMRI scan (s = structural)
- Not fMRI

Data Analysis Method: VBM (voxel-based morphometry)
- Voxel vs. Pixel
- "Significance levels were set at $P<0.05$"

Data Analysis Method: Pixel counting
- Blinded

Results and Conclusions

Results: "Anterior hippocampal volumes revealed a main effect of group"

- Anterior right hippocampus was greater than left hippocampus
- Posterior hippocampus was greater in taxi drivers than in controls

Conclusions: Hippocampus becomes larger through navigating difficult areas

- Is that the only possible interpretation of these results?
- Levels of analysis: Shouldn't there have been some behavioral data collected?

Collecting Data on Diverse Populations

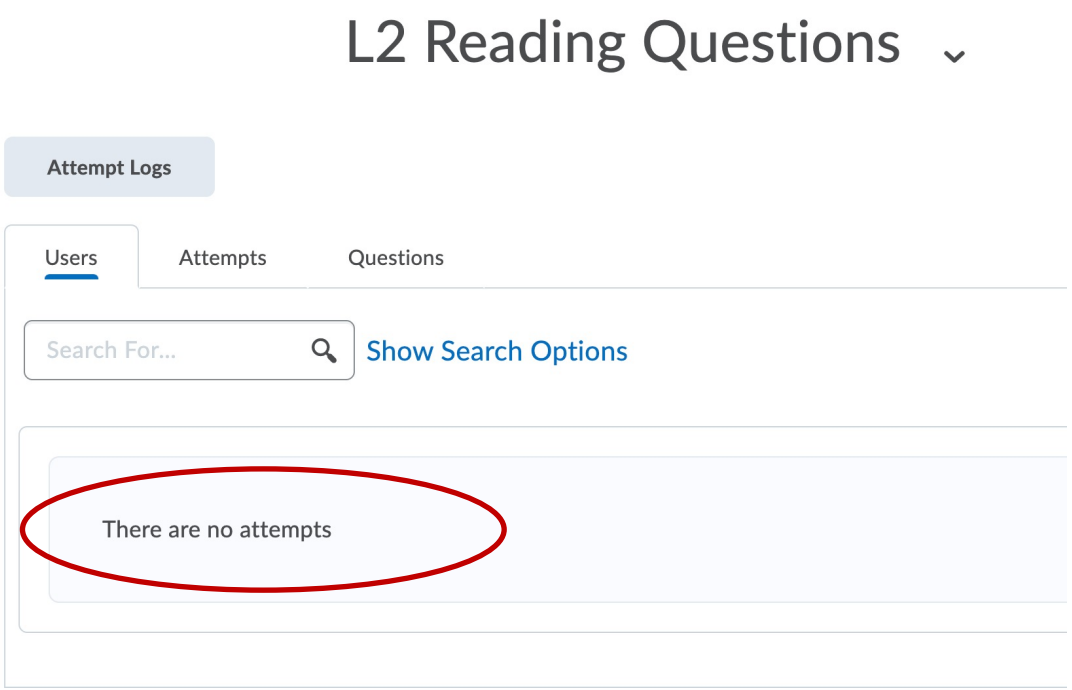
Are all brains the same? No.

Are these results true for every taxi driver?

- Taxi Drivers in London vs. Taxi Drivers elsewhere
- Many studies use people who have recently immigrated
  - Are these results valid?

Your Questions on Chapter 2

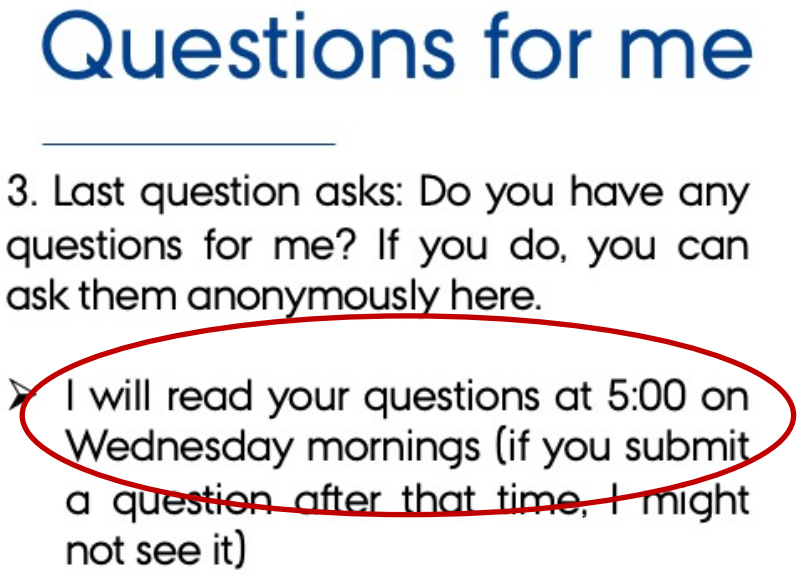
There were no questions about Cognitive Neuroscience??? Seems unlikely...



Where to post questions about today's lecture

From last week's slides

- **You should ask questions about the reading before 5:00 on Wednesday morning ☺**
- Is it after 5:00 on Wednesday morning? Then post new questions in the NEXT WEEK'S 'Questions for Me' section.
- Therefore, questions that occur to you during today's lecture should be posted in the L3 Reading Questions form.



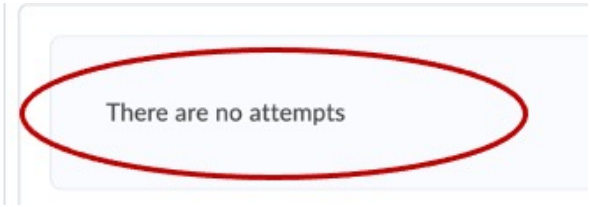
Questions for me

3. Last question asks: Do you have any questions for me? If you do, you can ask them anonymously here.

I will read your questions at 5:00 on Wednesday mornings (if you submit a question after that time, I might not see it)

If you had questions from me in L1

› Because of this:

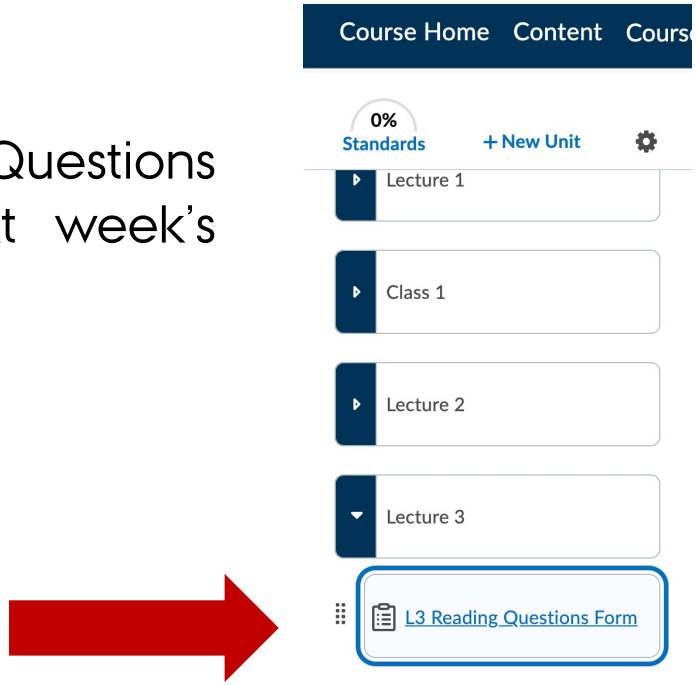


› I made an exception this week only and checked the L1 Reading Questions ☺

› Why don't I usually revisit past weeks? 3 important reasons!
  › You should answer the other Reading Questions when you're working through the chapter
  › You'll learn more efficiently if the answers that I give are provided during the topic lecture
  I don't want you to spend a whole week with misunderstanding important concepts! (when possible – it's always fine to ask questions about previous chapters/lectures/readings…in this week's form)
  › Even more important this year: If you're asking me questions about Lecture 11 after the lecture….**I won't be here to answer them**

L3 Reading questions are up

I will answer the L3 'Questions for Me' during next week's lecture



Here are your questions (posted erroneously in L1)

A question about the reading questions

- "The book only mentions...so I don't know how to answer the question"
- ANSWER: Great question! Science requires expansive thinking. Only looking at the book, forgets about the other parts of the course. So, let's expand. :-) The reading questions are learning materials, not exam prep. Understanding the textbook is the bare minimum for learning. Therefore, **the reading questions include important course content from other documents too, such as my slides and other readings**. EVERYTHING we discuss in this course is relevant to you. Spoiler alert: For example, Lecture 1 is a foundation that Philosophy of Cognitive Science will build on. Some of your 4th semester courses will assume that you have learned the on content from Lecture 2. Etc.

› What were the 3 influences of the Cognitive revolution?

› Answer: Refer to last week's slide #55

- I see discussion of structural models or process models in the textbook. What is a schematic model?

- ANSWER: The Reading Question is 'why are schematic models useful?' The word *schematic* means that something is diagram or picture. Here's another way to ask the same question: 'What are models that use diagrams useful?' The point of this question is to start you thinking about the role of models, since L2 includes a lot of models of the brain (mostly as diagrams or pictures). Both structural and process models use images.

- Is there anything i cant do with an PDF-version of the book compared to the physical version, as i greatly prefer PDF-books
- ANSWER: This is a great question for someone who has compared the two texts, such as a bookstore or published.

- Many conceptions of the mind (think the periodic table of the mind) have been shown to depend on largely historical and societal trends, in science or not (e.g. the periodic table of elements). What is to say that Cognitive Science isnt simply a case of the same reasoning, a (methodical) scientism of the mind heavily influenced by trends in computer science and certain popular conceptions?

- ANSWER: Excellent observation! Science is always contextualized by 1) current thinking/events/technology, 2) historical reflections, and 3) your culture. Remember – last week I told you that science will keep changing as we learning and discover new concepts and methods. This is part of what I mean. Next semester, you'll learn more. The course Philosophy of Cognitive Science will discuss how science changes across time in depth.

Have Neuroscience Questions?

GREAT!

- **POST THEM IN L3 READING QUESTIONS FORM BEFORE 15 SEPT AT 5:00 – I WILL NOT LOOK AT L2 AGAIN**

Here are last year's questions about L2

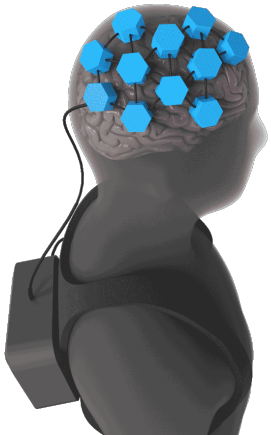
Spatial resolution = **where** brain activation occurs

Temporal resolution = **when** brain activation occurs

fMRI vs. EEG vs. fNIRS

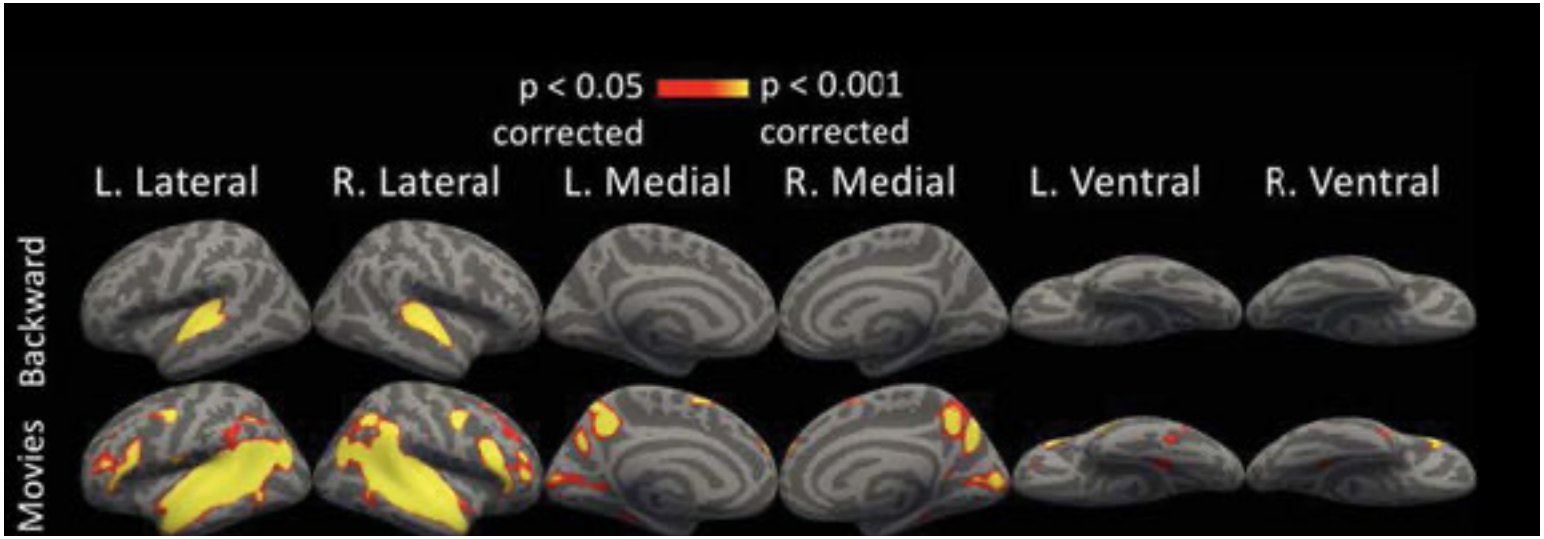
For all: When you compare conditions, you are using the subtraction method

- fMRI = good spatial resolution = measures Hemodynamic changes
  - Devices uses magnets but is not measuring magnetic properties of brain
- EEG = good temporal resolution = measures 'brain waves' = correlates with fMRI
- fNIRS = spatial resolution as good as fMRI; temporal resolution *almost* as good as EEG = measures Hemodynamic changes

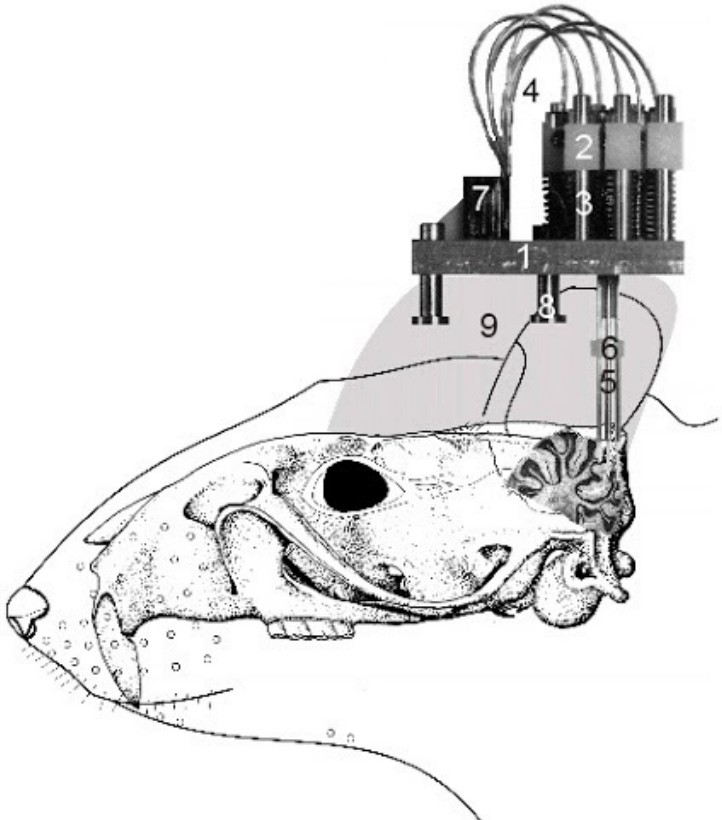


Clarification of terms: Neural Representation

› The pattern of activation that reflects external stimuli or internal states

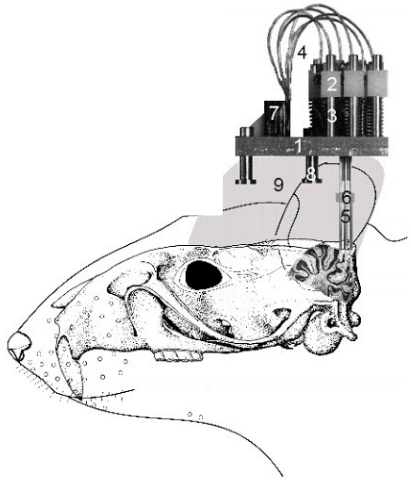


How to Record a Neuron Firing



How to Record a Neuron Firing

› How accurately do animal studies reflect humans???



Clarification of terms: Hyperpolarization

Resting potential of neuron = -70 (i.e., negative relative to its environment)

Hyperpolarization = neuron becomes even more negative because neurotransmitters change its composition

- Caused by **inhibitory** neurotransmitters

Depolarization = neuron becomes more positive

- Caused by **excitatory** neurotransmitters
- When this change is big enough, it creates an action potential
- Action potentials are all-or-nothing – either the neuron fires or it doesn't

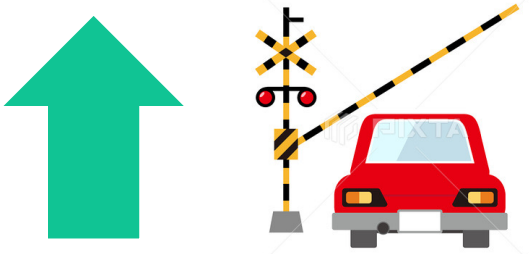
Hyperpolarization

(Think: "Hyper" = more extreme)

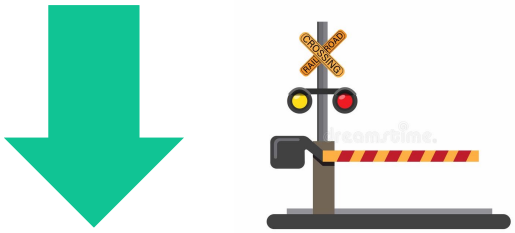
Depolarization

(Think: "De" = less extreme)

More positive



-70



More negative

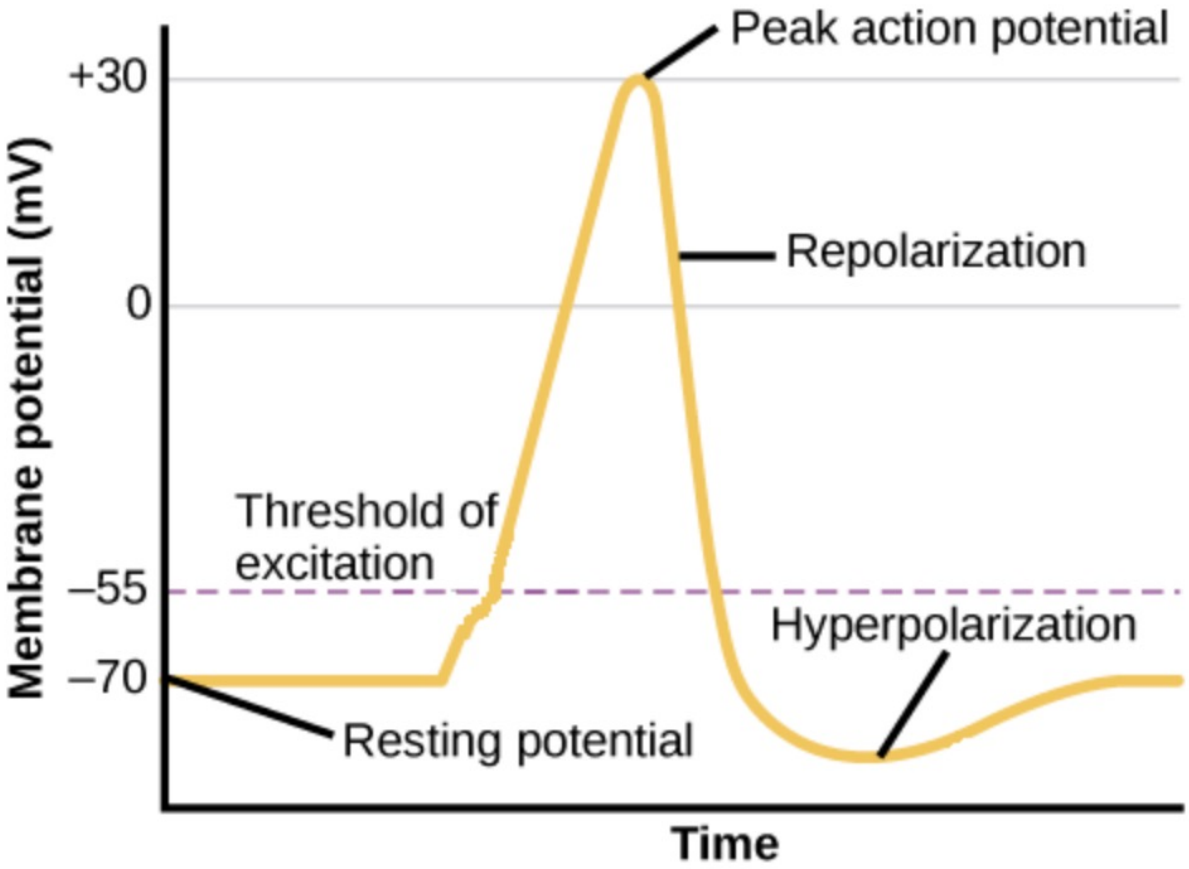


Image modified from "How neurons communicate: Figure 3," by OpenStax College, Biology (CC BY 3.0).

Source: https://www.khanacademy.org/science/biology/human-biology/neuron-nervous-system/a/depolarization-hyperpolarization-and-action-potentials

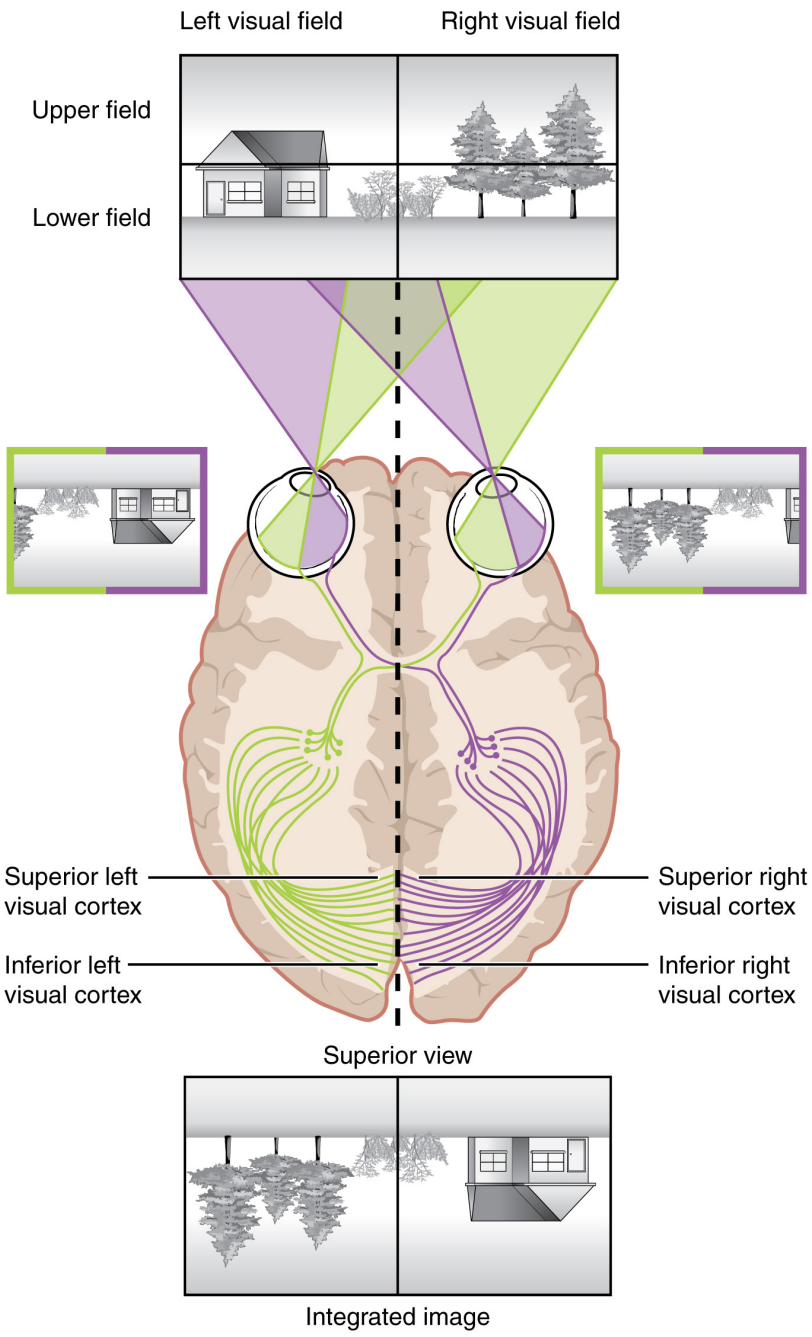
Clarification of terms: Electric Potential vs. Action Potential

- **Electric potential** = Answers the question: What is the neuron's charge?
  - i.e., is it still at -70 or something else?
- **Action potential** = Answers the question: What is the neuron doing?
  - i.e., is it firing?

DAINA CRAFA
ASSISTANT PROFESSOR

Topographical Organization

1:1 correspondence with an object in the world and a location in the brain



Clarification of terms: Neural circuits vs neural networks

- **Neural circuits** = actual anatomical connections between neurons
- **Neural networks** = modelled interpretation of how neurons are connected
  - Why do we need a model? Because you can't perform single cell recordings on living humans.

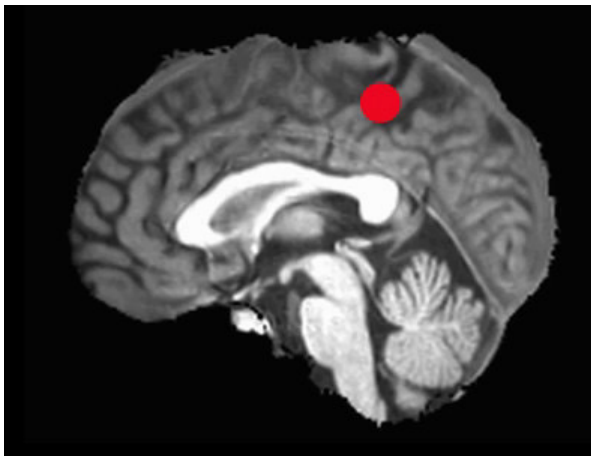
Clarification of terms: 3 Types of Sensory Coding

- Specificity coding = one neuron responds to one thing
- Population coding = most neurons in an area respond to one thing – pattern of response matters
- Sparse coding = some neurons in an area respond to one thing – pattern of response matters

Just for fun: Averaging Brains Together

Voxels -> Spatial Normalization

A voxel is a 3D pixel. Brains are averaged together by averaging corresponding voxels across brains. Voxel 1 in person 1 is averaged with voxel 1 in person 2.



Just for fun:
Is the FFA still active in blind people?

The specialization of cross-modality tactile face processing in the blind: an fMRI study

Rui Dai; Zirui Huang; Xuchu Weng; Sheng He

Abstract

PURPOSE: Previous studies demonstrated that fusiform face area (FFA) is the core region of face processing, which is largely innate and tuned by visual experience. However, the degree to which the face-selectivity of FFA was genetic determined remains unclear. Moreover, evidence is still lacking on elucidating the neural plasticity of the FFA in other sensory modalities (e.g. tactile).
METHODS: To investigate these questions, we studied 38 eyesight obstacle disabled subjects, who consist of four sub-groups: congenital blind, early blind, late blind and low vision. All subjects were trained ~3 hrs on perceiving man-made tactile faces and other complex object categories. Functional magnetic resonance imaging (fMRI) was performed both before and after training.
RESULTS: We found robust face-selective activation in the FFA in both the early blind and low vision subjects after training. In contrast, this was not seen in the congenital blind or late blind subjects.
CONCLUSIONS: Our results suggest that even after more than 14 years of absence of visual face exposure, the FFA can still quickly become engaged in processing face information, and even from a different sensory modality. However, despite of strong genetic determined, the specialization of face processing requires an initial visual driven start.

Thanks for listening!