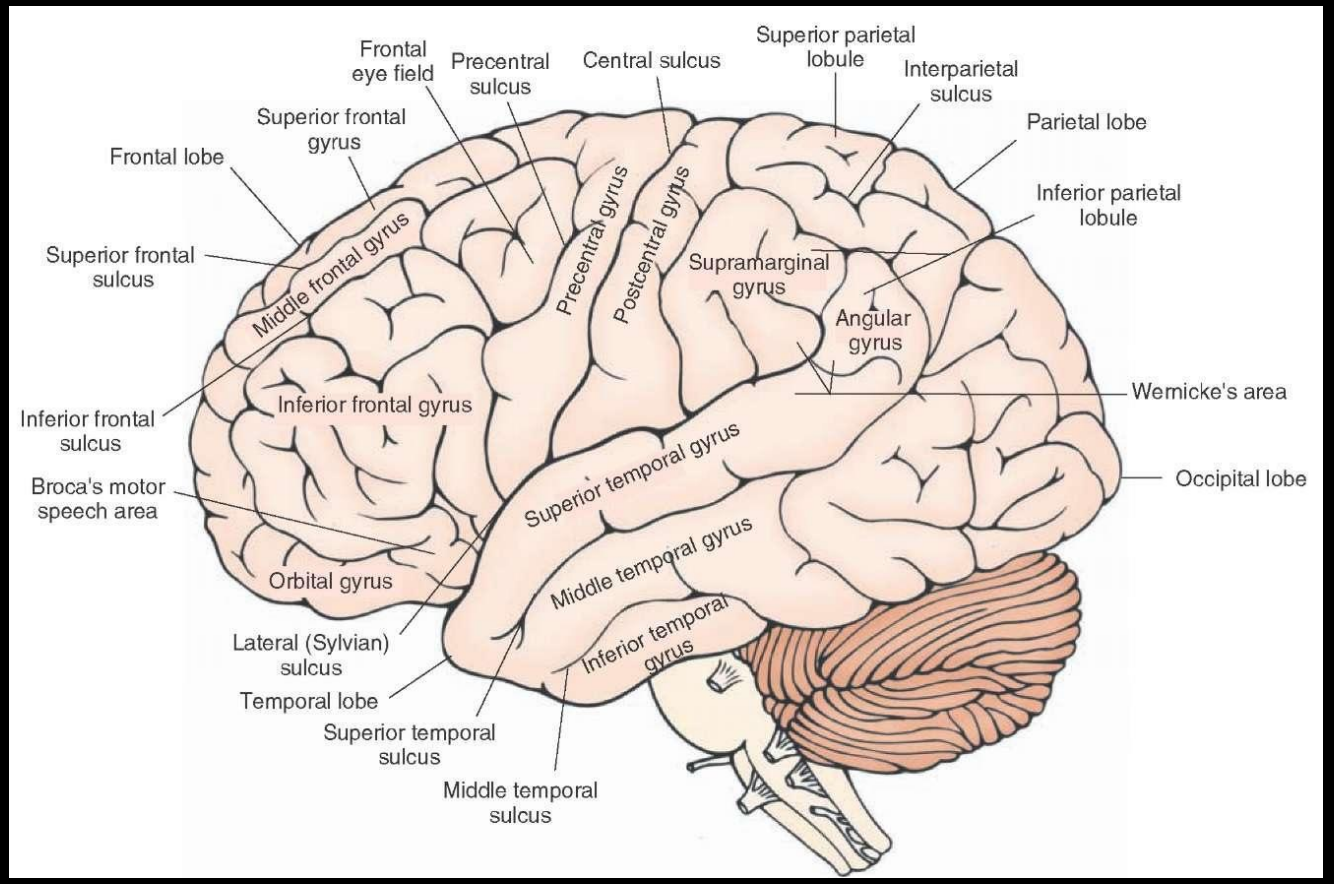
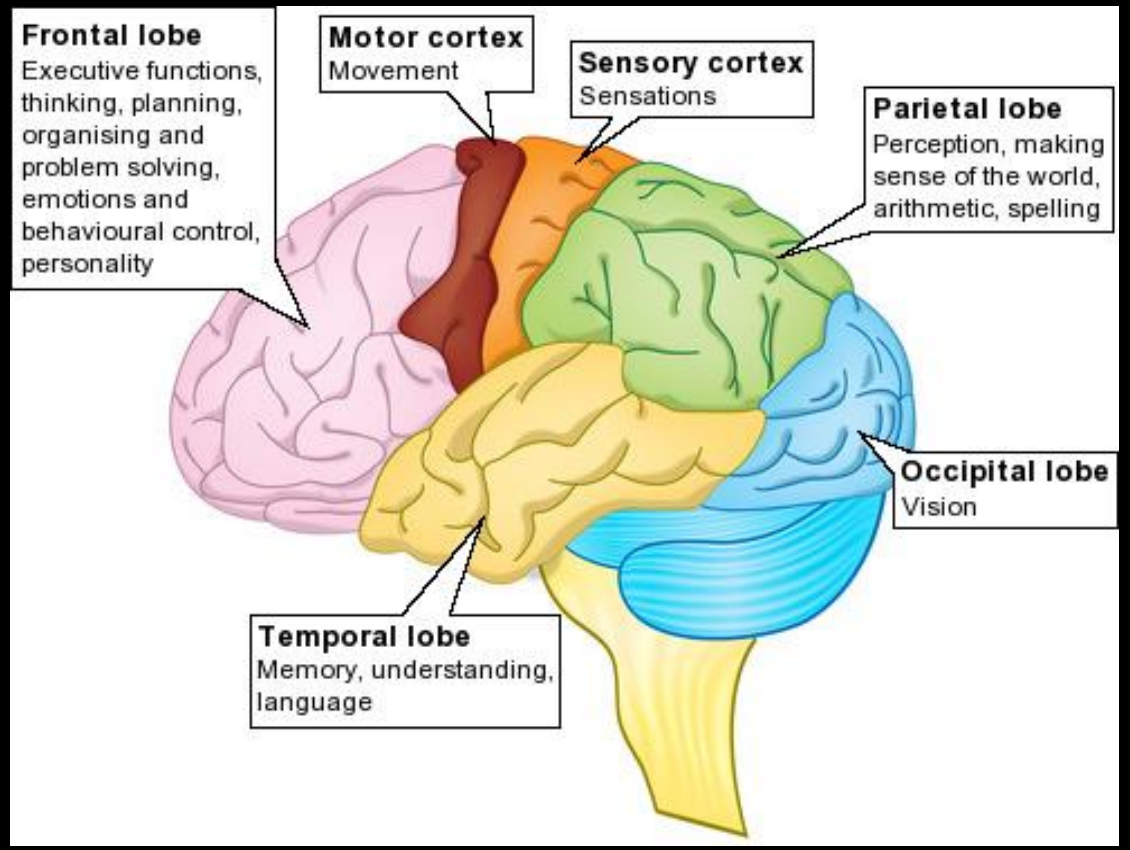
BRAIN: REGIONS AND FUNCTIONS



https://www.studyblue.com/



https://www.headway.org.uk/

MAGNETIC RESONANCE IMAGING

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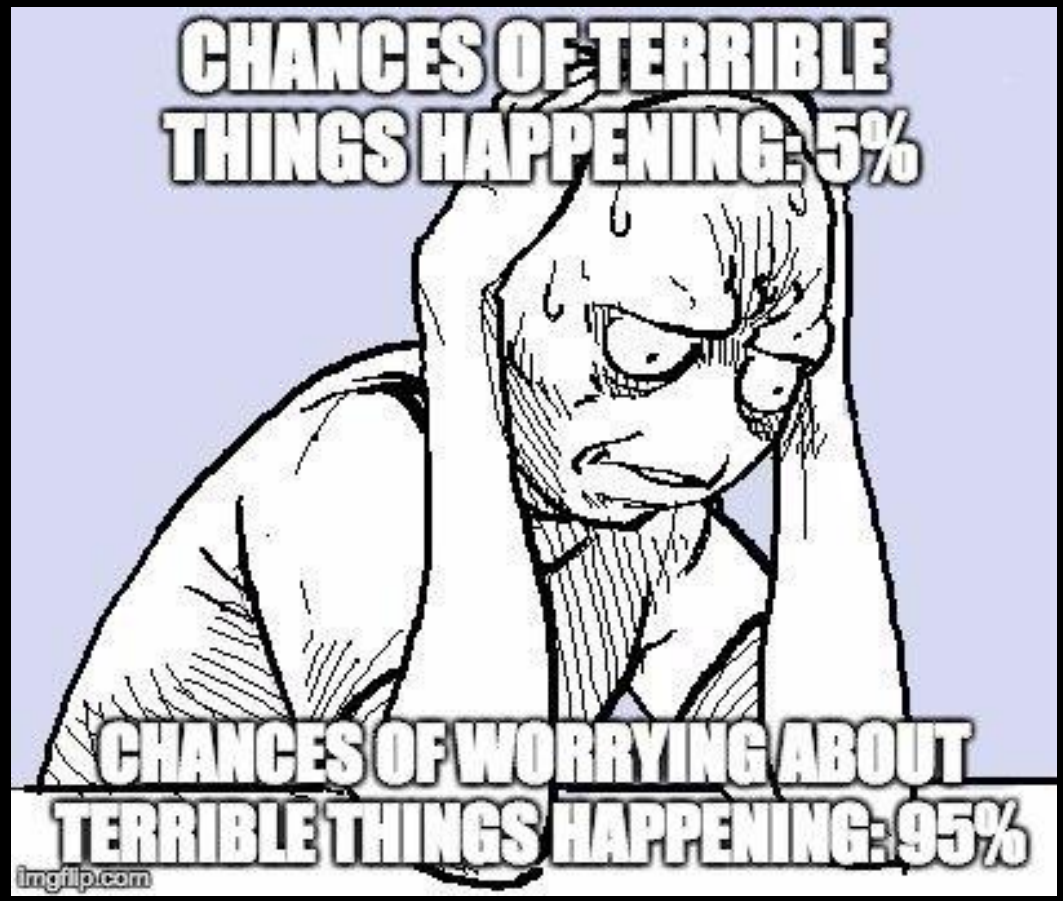
Search: Picking Low Hanging Fruit is Motivating

fMRI: Water, Magnets, Tops and *Spooky* Actions

Data Analysis: From Behavior to Brain in a SNAP

What were we thinking?

What Do Findings Look Like?


CHANCES OF TERRIBLE THINGS HAPPENING: 5%
CHANCES OF WORRYING ABOUT TERRIBLE THINGS HAPPENING: 95%
imgflip.com

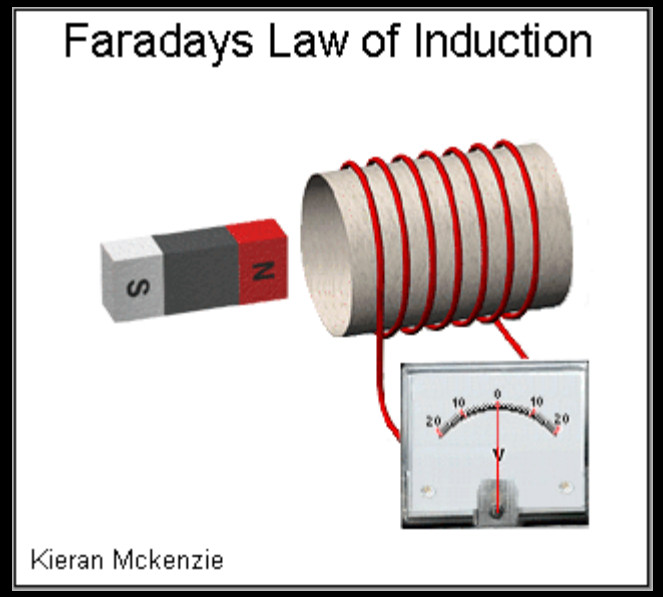
QUANTUM MECHANICS
QUANTUM INFORMATION THEORY
FUNCTIONAL MAGNETIC RESONANCE IMAGING

OR

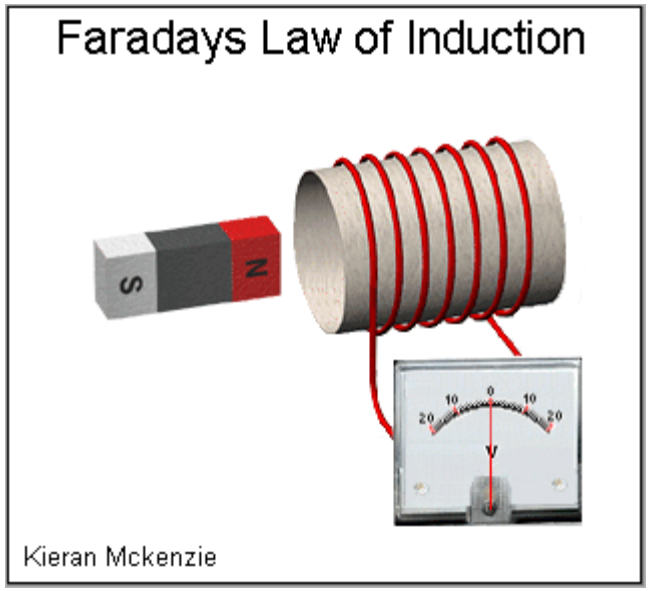
Water, Magnets, Tops and *Spooky* Actions

Water, Magnets, Tops and *Spooky* Actions

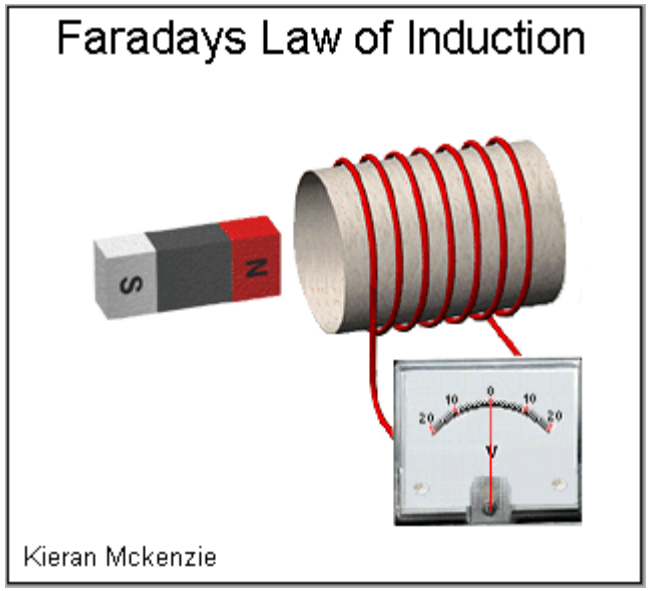
FARADAYS LAWS



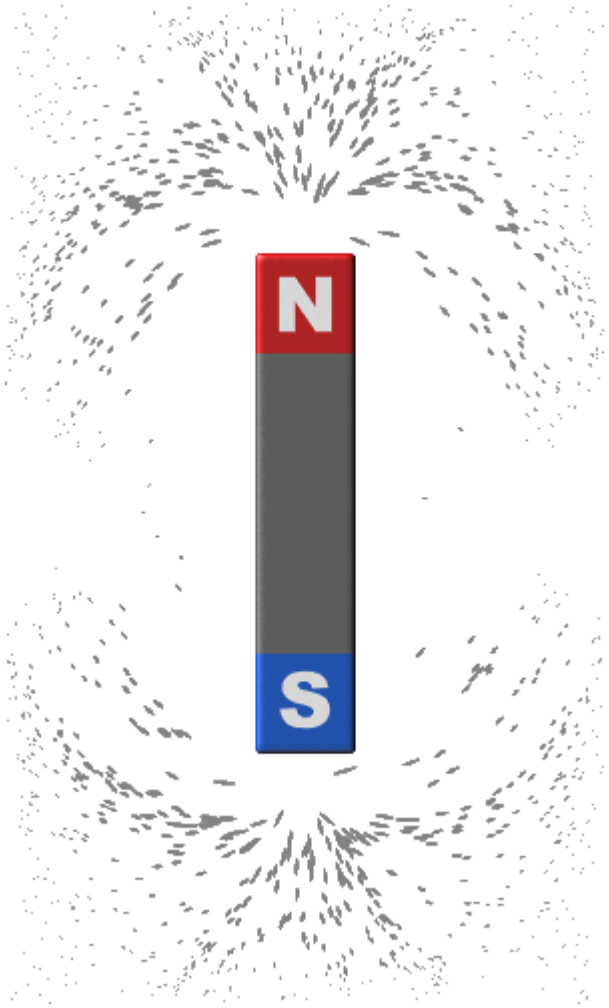
Faradays Laws

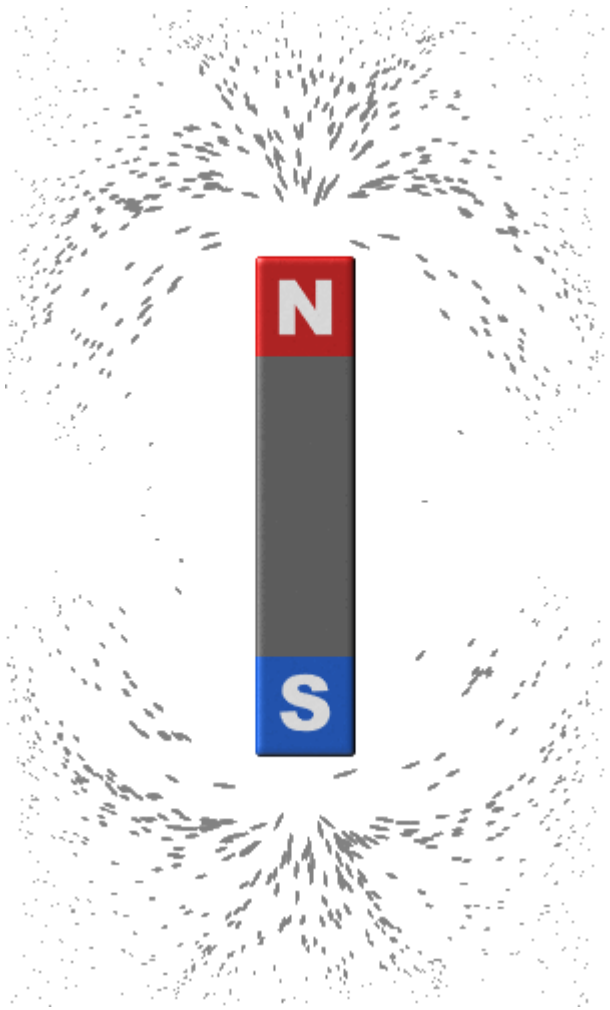


Faradays Laws



Series Of Fortunate Events




N
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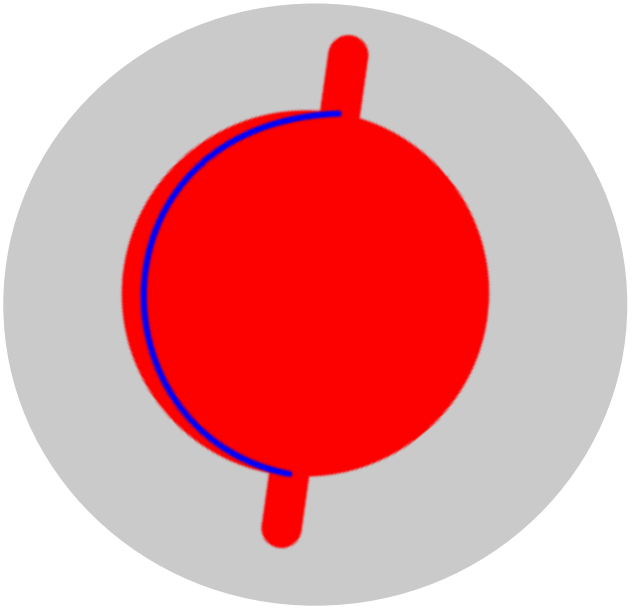
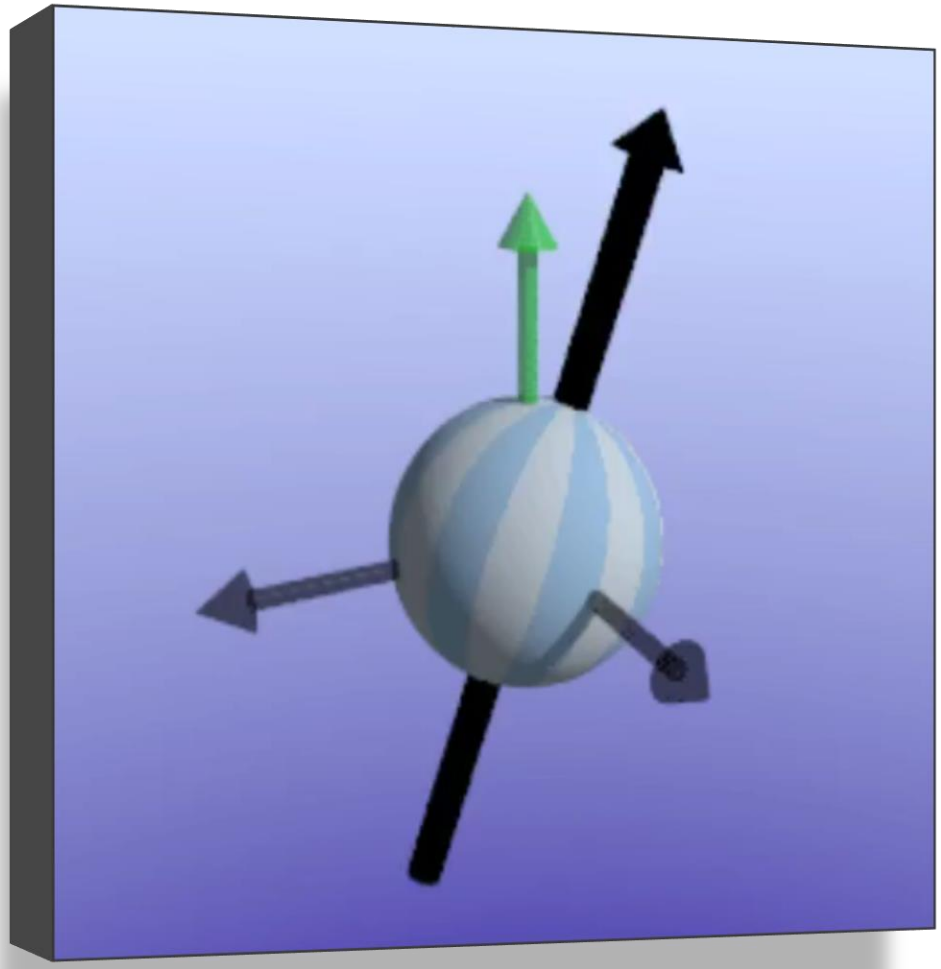
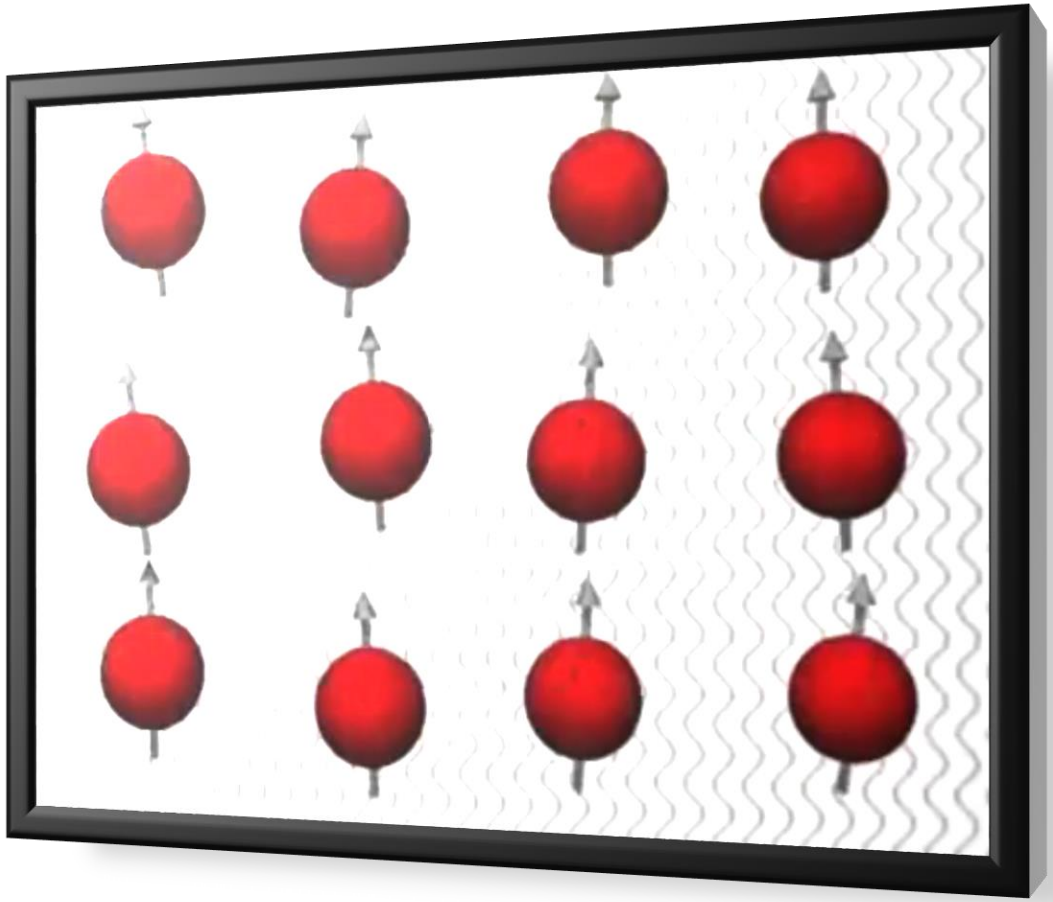
How Does fMRI work

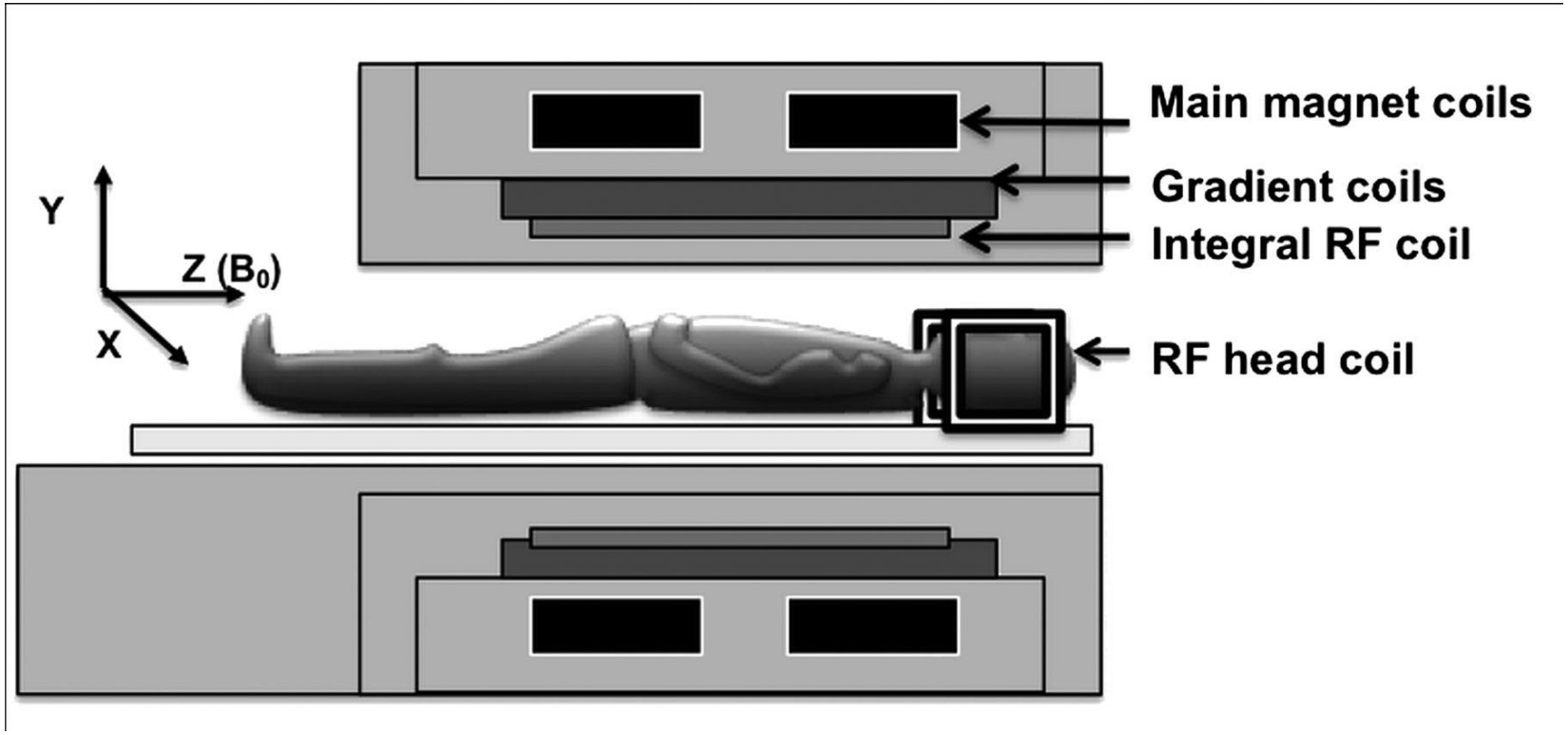
Physics of MRI







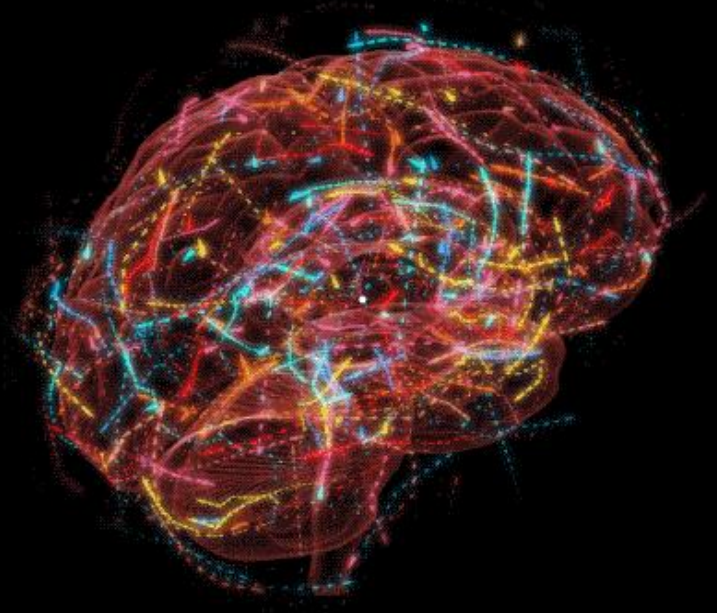
Schematic demonstrating the relative positions of the different magnet coils comprising the MR machine.



Stuart Currie et al. Postgrad Med J 2013;89:209-223

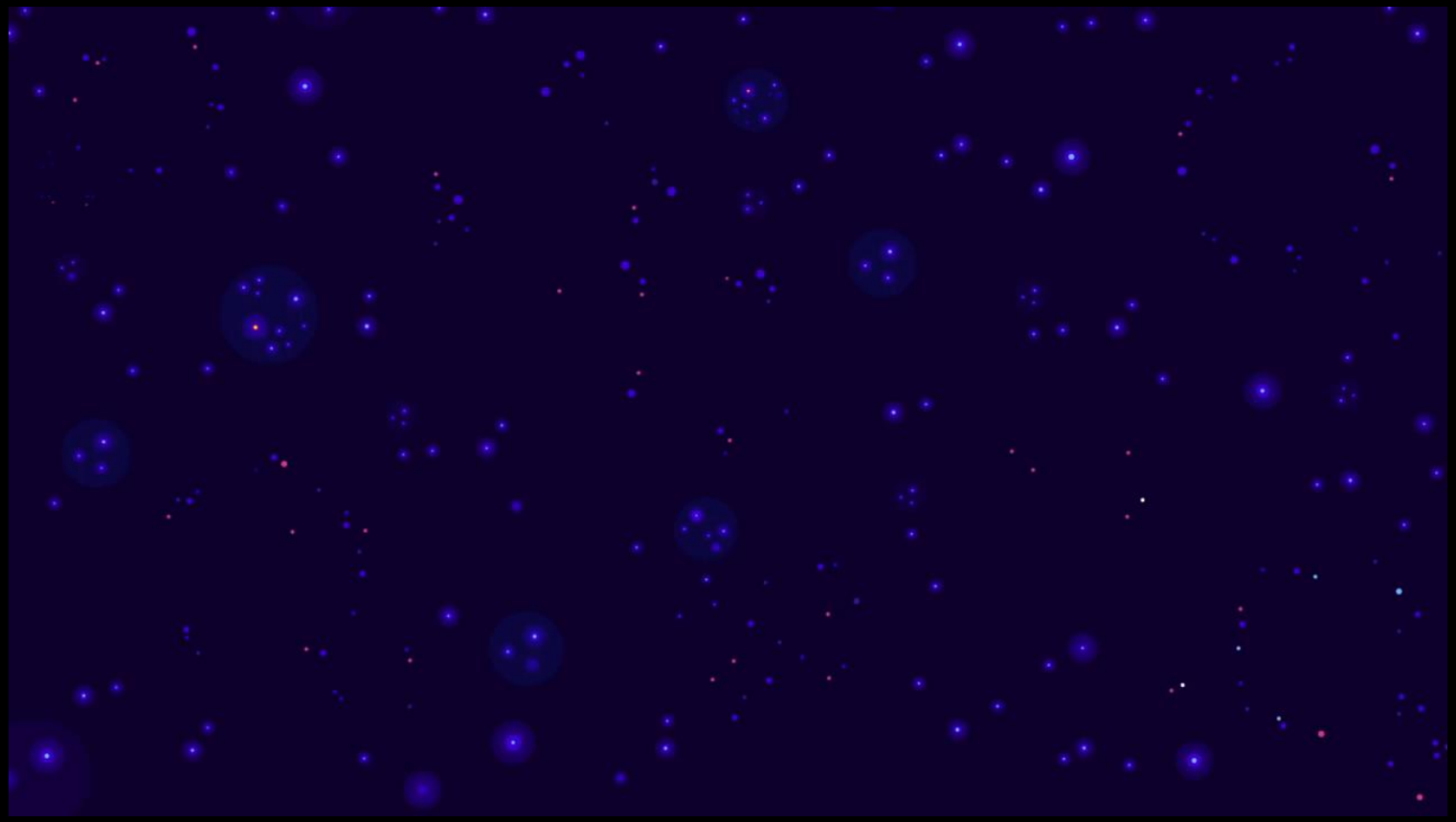
HOW DOES MRI WORK

QUANTUM COGNITION & IN FORMATION THEORY



https://www.quantamagazine.org/a-new-spin-on-the-quantum-brain-20161102/

BLACK HOLES COULD DELETE THE UNIVERSE



10 mins

"SPOOKY ACTION AT A DISTANCE"

Einstein's 1930s Thought Experiment to Test Theory of Quantum Entanglement

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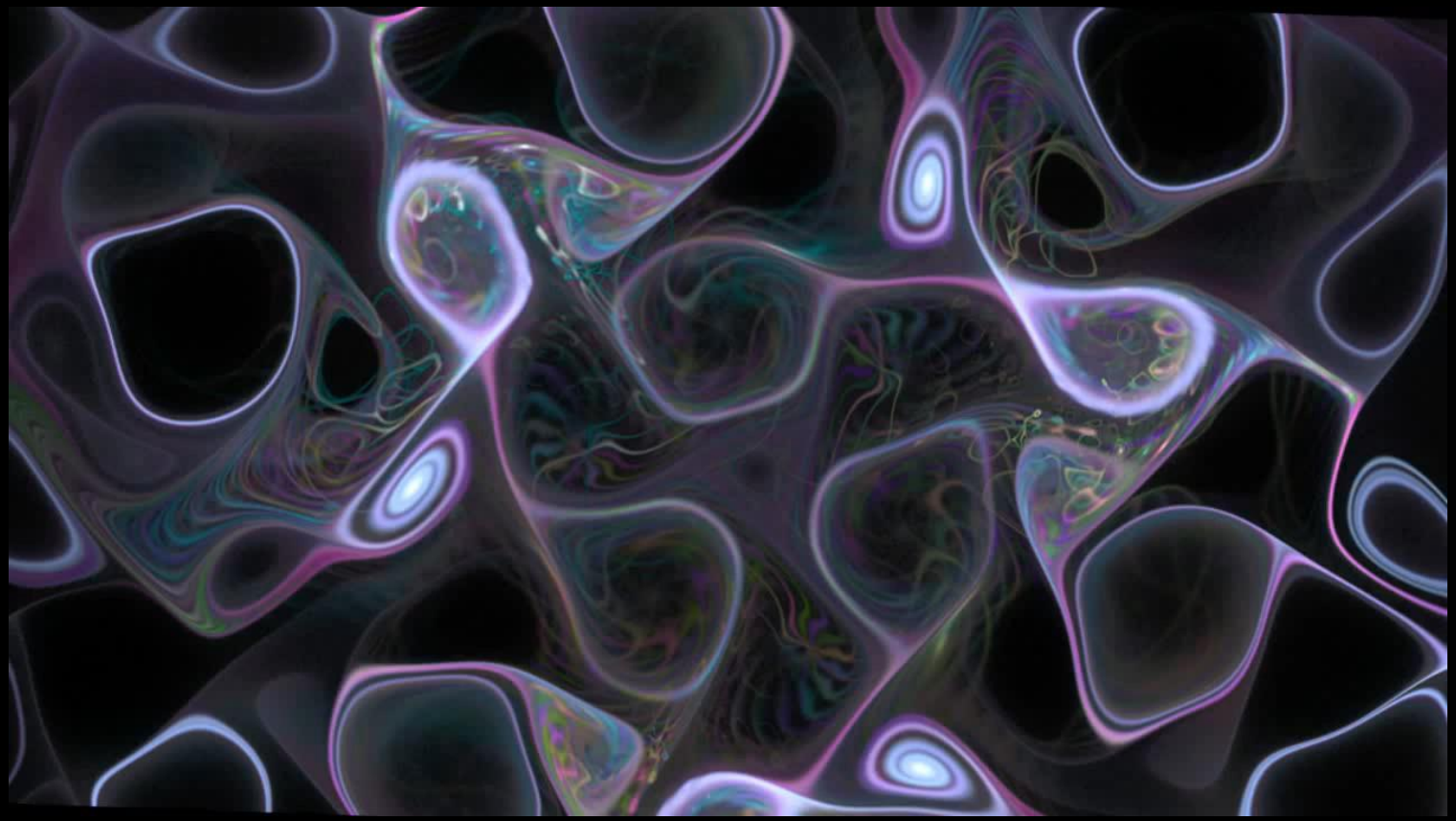
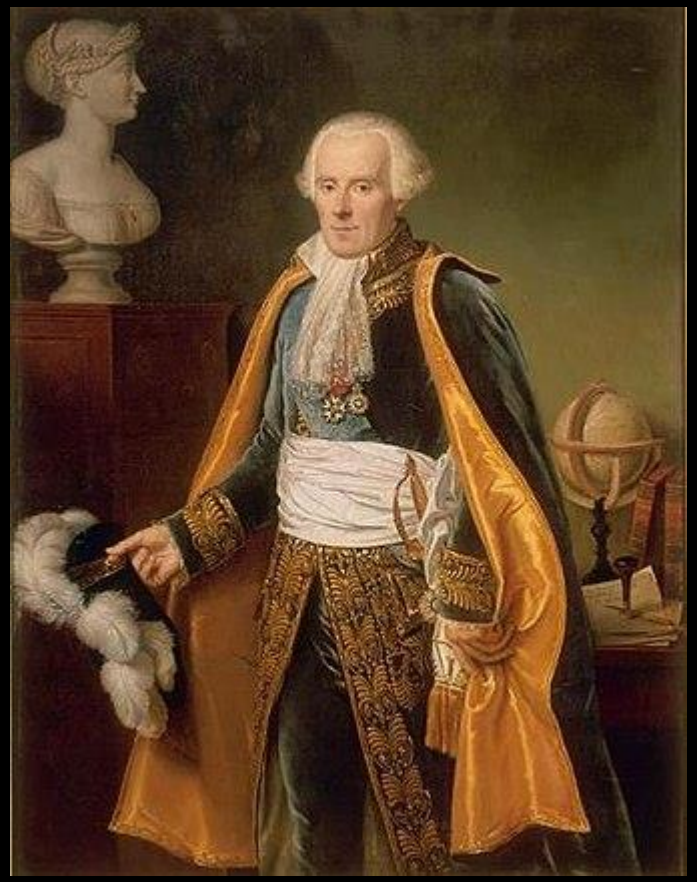
SCHRODINGER'S CAT



3.5 min

second order partial differential equation named after Pierre-Simon Laplace who first studied its properties. This is often

Pierre-Simon, marquis de Laplace 23 March 1749 – 5 March 1827)



Pierre-Simon Laplace (1749–1827)

portrait by Jean-Baptiste Paulin Guérin, 1838

French Scholar: *Mécanique Céleste*

- mathematics, statistics, physics and astronomy.
- Translated geometry into calulus

https://en.wikipedia.org/wiki/Pierre-Simon_Laplace

EINSTEIN'S 1930S THOUGHT EXPERIMENT TO TEST THEORY OF QUANTUM ENTANGLEMENT

- 2 particles entangled
- Particles formed spontaneously out of energy
- Formed Simultaneously
- Law of Conservation of Angular Momentum :
  - Angular momentum of the universe remains constant

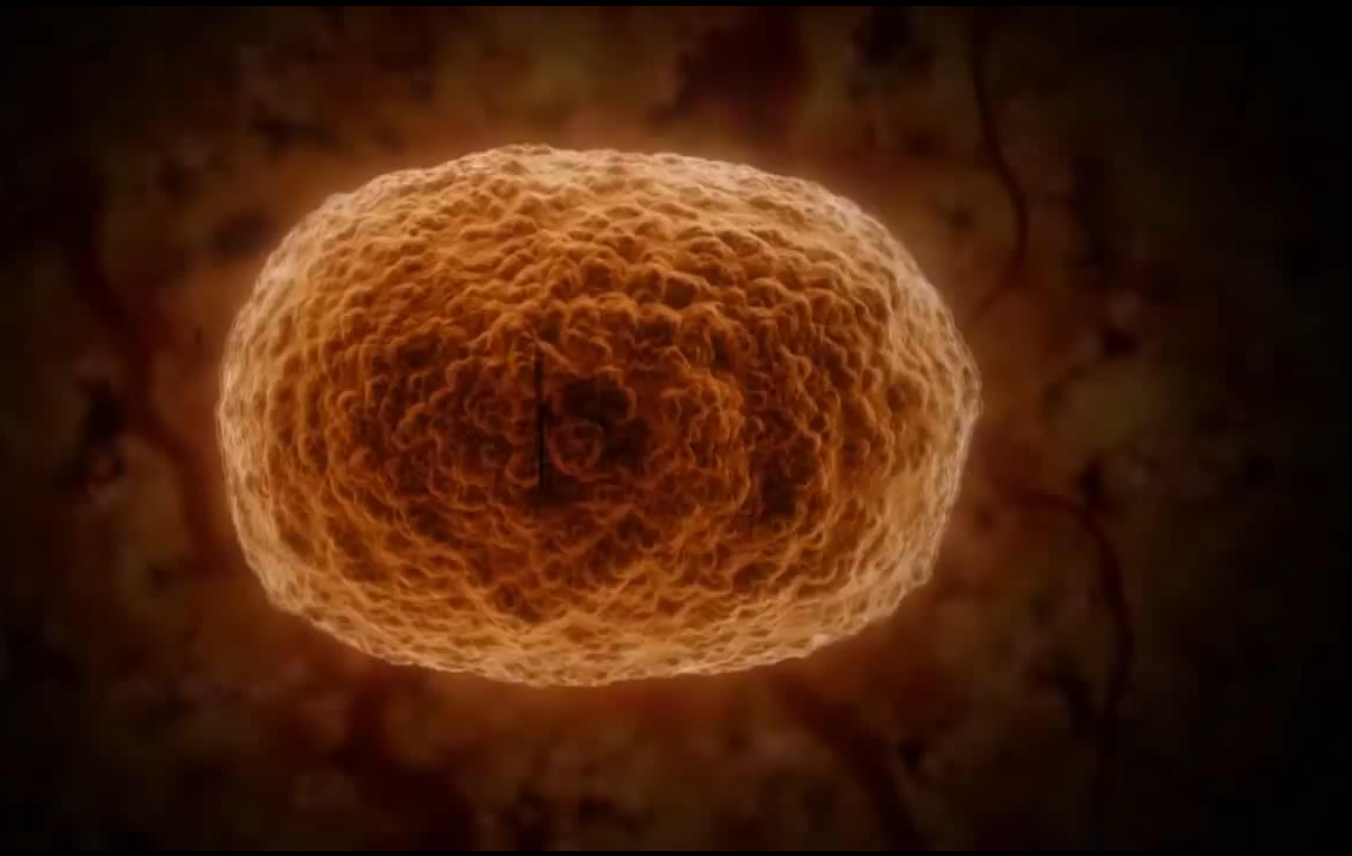
https://www.youtube.com/watch?v=ZuvK-od647c

EINSTEIN'S 1930S THOUGHT EXPERIMENT TO TEST THEORY OF QUANTUM ENTANGLEMENT

- If:
  - 1 particle measured to have “spin up”
  - 2nd particle, measured in the same direction, must have spin down

https://www.youtube.com/watch?v=ZuvK-od647c

SCIENTISTS FIND EVIDENCE THAT THE UNIVERSE IS A BIG BRAIN



4 min

SNAP

Search induced Neural Activation Patterns

BACKGROUND: DIFFERENTIAL IMPACT

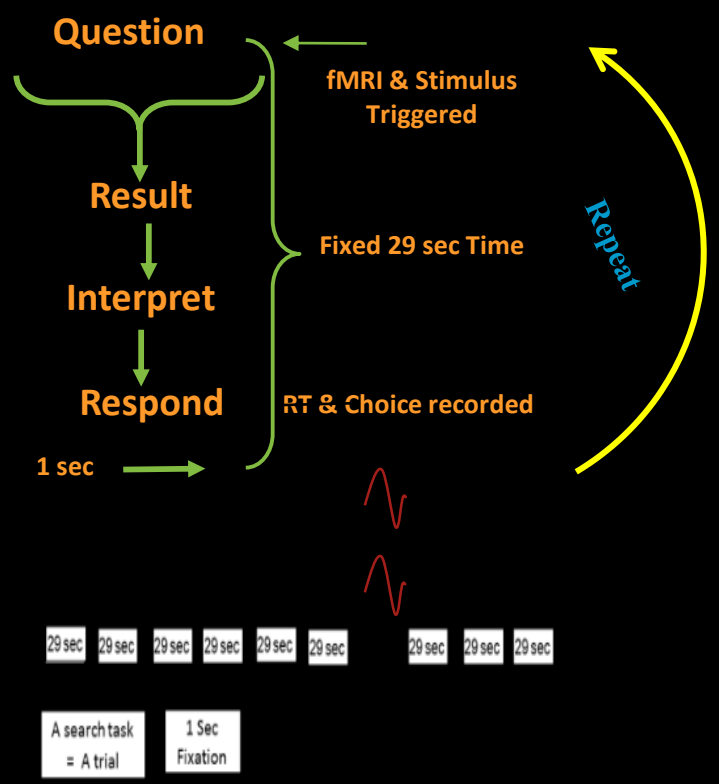
- Graded brain challenge, which impose increasing amount of cognitive load, have differential impact on subjects that subsequently experience severe memory decline

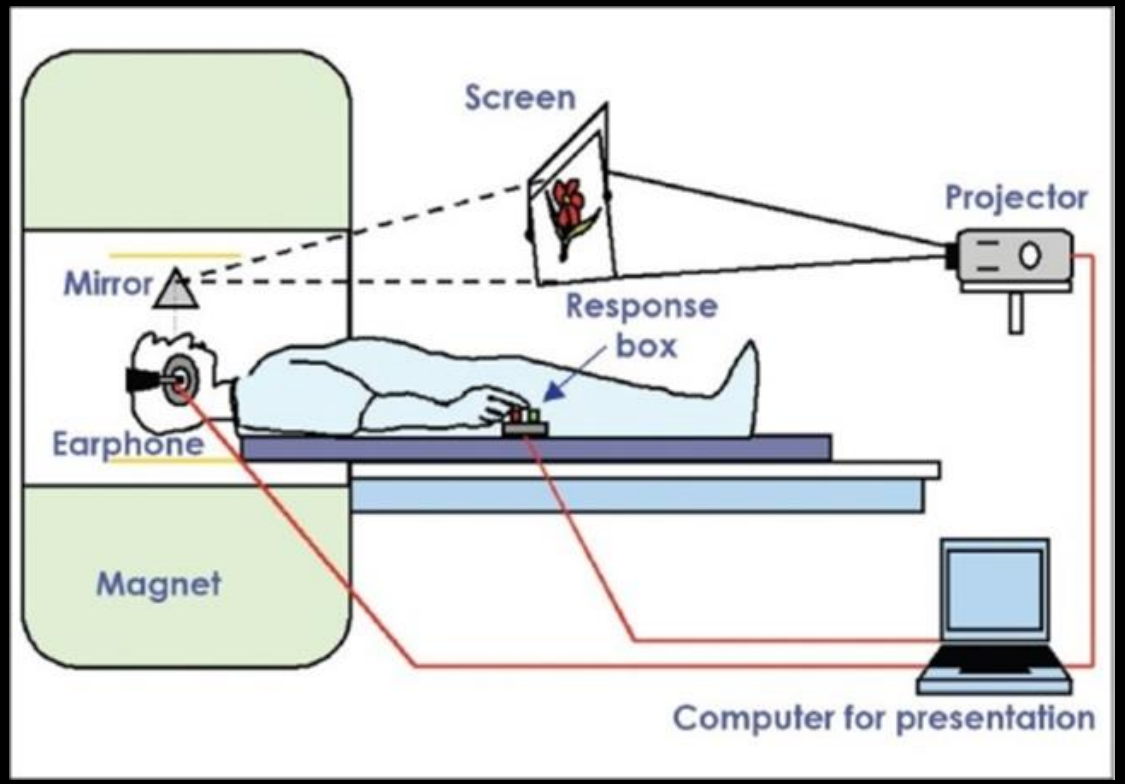
- The cause has been localized to a specific brain region known as the posteromedial cortex

http://en.wikipedia.org/wiki/Posterior_cingulate

- Nichole A. Kochen, Michael Breakspear, Michael Valenzuela, Melissa J. Slavin, Henry Brodaty, Wei Wan, Julian N. Troller, Andrew Turner, John D. Crawford, & Perminder S. Sachdev. Cortical responses to a graded working memory challenge predict functional decline in mild cognitive impairment. *Biological Psychiatry*, 70, 123-130, 2011.

Non-invasive Investigation Of Human Resting-state





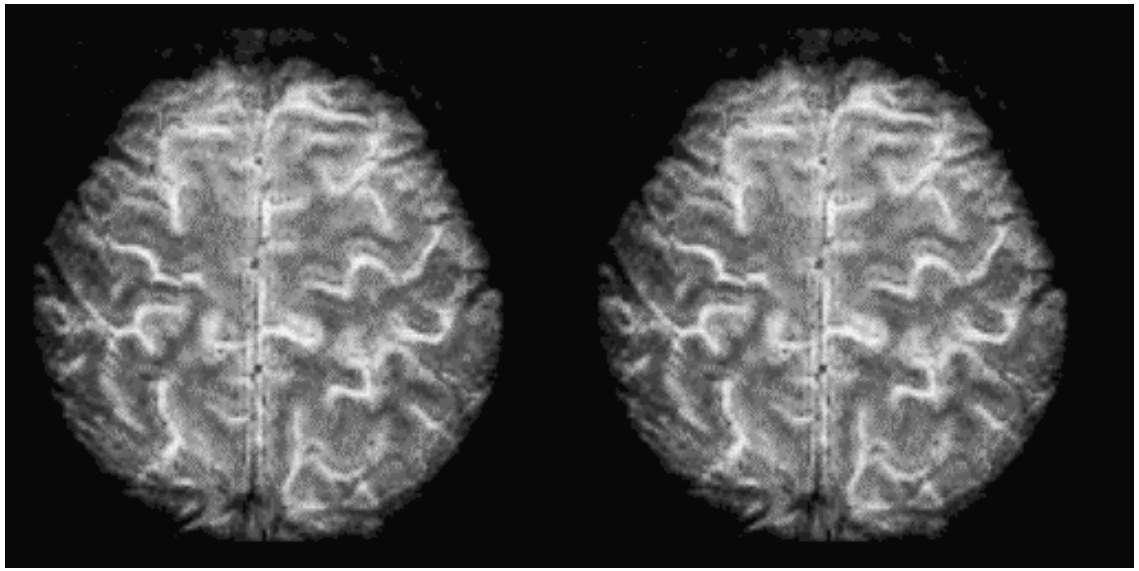
INFORMATION SEEKING

- New methodologies
- Information seeking
- Behavioral Models

MOTIVATION

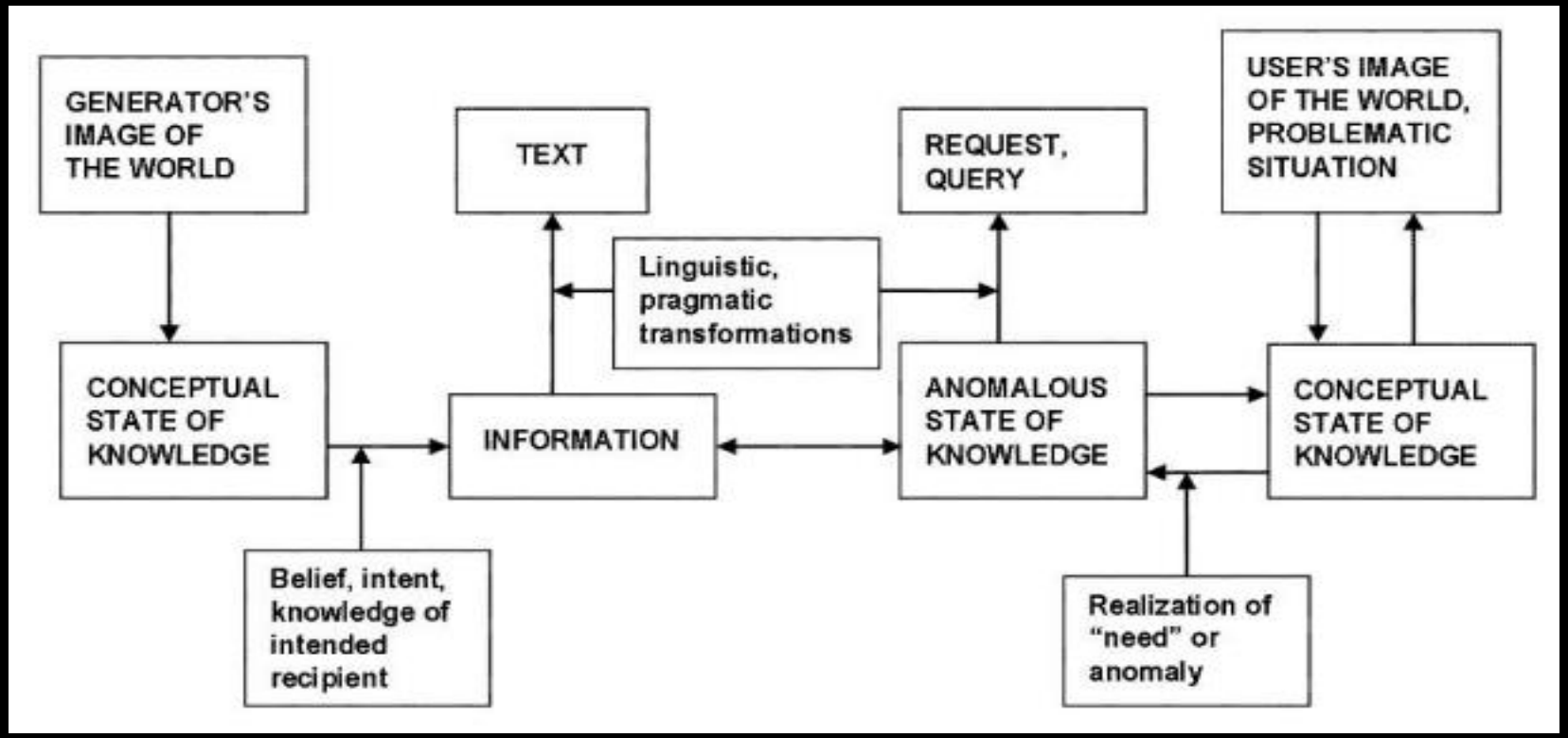
Foraging

Ubiquitous



- New methodologies
- Information seeking
- Behavioral Models

A COGNITIVE COMMUNICATION MODEL FOR INFORMATION RETRIEVAL



Belkin, 1980

HUMAN COMPUTER INTERACTION

- Progressively intensive Tasks
  - Tasks varying levels of difficulty
  - Progressively intensive cognitive load
  - Identify patterns of blow flow changes in brain
  - Patterns of behavior

WHAT DOES THIS MEAN?

- Theorized direct association between patterns of cerebral blood flow and search behavior

- Develop evidence for an association between neurological patterns and behavioral patterns.
- Changes in Behavior → Neurological patterns

WHAT DOES THIS MEAN?

- HCI with progressively intensive cognitive load
  - Tasks varying levels of difficulty
  - Progressively intensive cognitive load
  - Identify patterns of blow flow in brain
  - Induce characteristic errors
  - Systematic performance patterns of behavioral markers

- Thus, a potentially important outcome of the project will be evidence for establishing a stronger association among neurological biomarkers and behavioral markers.

PROBLEM 1: SNAP

- What particular regions of the brain are activated during search?
- Are there regional differences associated with search types? Particularly factual vs. conceptual?
- Do the regions elucidate our understanding of impact of search type on cognition?

PROBLEM 2: SEARCH-INDUCED BEHAVIOR

- How do different search types impact behavioral response?
  - Reaction Time
  - Accuracy

- What is the relationship between search result presentation and behavioral response?

METHOD: BEHAVIORAL INDEPENDENT VARIABLES

- Task types x Presentation Mode

- Task type 1: Factual
  - Example: What is the capital of Burundi?

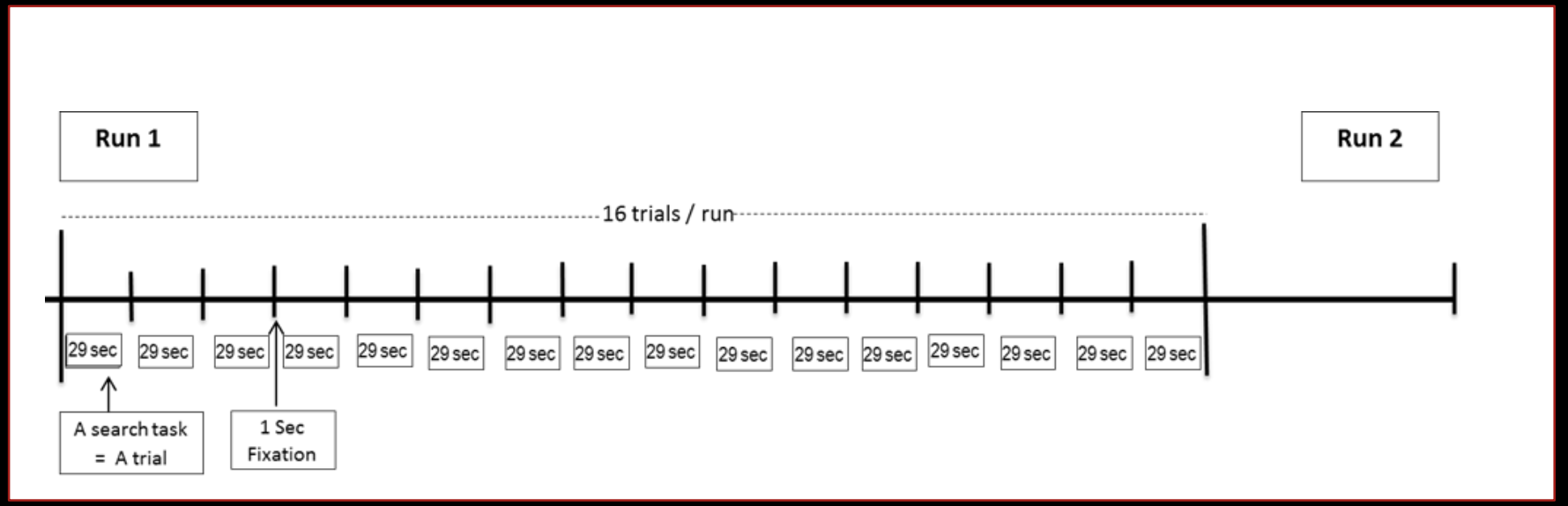
- Task type 2: Topical
  - Example: What was the impact of black plague on Europe?

- High precision: Correct results presented at the top
- Low precision: Correct results presented at the bottom

METHOD: FMRI SESSIONS I

- While in the fMRI scanner and perform 80 tasks, divided into blocks of 5 runs, each containing 16 tasks
  - Tasks were pseudorandomized so that no task type was repeated more than 3 times in a row
  - Subjects had to select “one best answer” by pressing on two numeric keypads (designed to be immune to electro-magnetic interference)

METHOD: FMRI SESSIONS II



- An event-based design was used to avoid repetition and "learning effect" (block-based design demands repetition of task type)

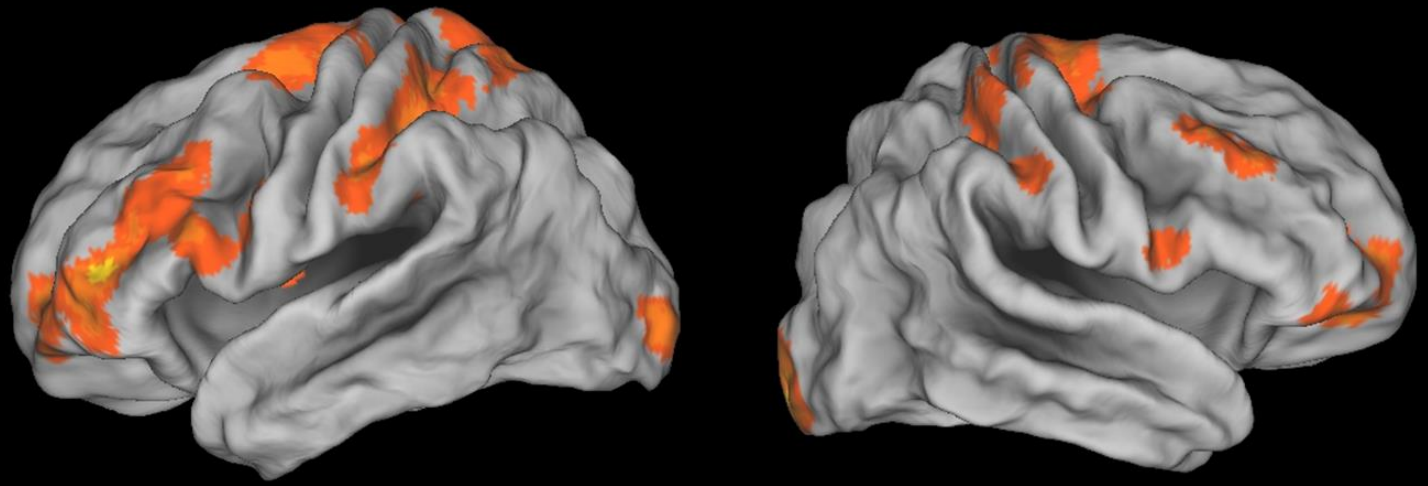
RESULT: FULL FACTORIAL ANALYSIS OF VARIANCE

Table 1. Neural activation results from full factorial analysis of variance

Contrast	Region of Activation	Hemisphere	BA	MNI Coordinates x	y	z	t	k
Main effect of Type								
Factual > Topical	Middle Frontal Gyrus	R	6	30	18	58	6.24	2972
	Middle Frontal Gyrus	L	6	-26	4	52	5.72	4300
	Thalamus	R	N/A	8	-10	2	5.15	375
	Inferior Temporal Gyrus	L	20	-54	-52	-8	4.53	124
	Precuneus	L	7	-24	-62	40	4.48	272
	Inferior Frontal Gyrus	R	46	44	48	-10	4.24	108
	Inferior Temporal Gyrus	R	20	54	-26	-16	4.14	47
	Parahippocampal Gyrus	R	35	34	-24	-24	3.90	13
	Sub-Gryal	R	37	54	-44	-10	3.88	19
	Thalamus	L	N/A	-8	-20	12	3.80	10
	Superior Occipital Gyrus	R	19	36	-68	32	3.74	60
	Thalamus	L	N/A	-10	-12	4	3.70	9
	Superior Parietal Lobule	R	7	30	-66	48	3.70	38
	Middle Frontal Gyrus	L	10	-38	56	8	3.66	6
Topical > Factual	Superior Temporal Gyrus	L	38	-44	10	-32	5.67	291
Main effect of Precision								
High > Low	Postcentral Gyrus	R	3	38	-26	60	4.34	308
	Middle Frontal Gyrus	R	8	56	22	34	4.04	47
	Superior Frontal Gyrus	R	6	30	16	62	3.73	33
Low > High	Precentral Gyrus	L	4	-36	-24	68	6.02	882
Precision X Accuracy								
LPC > All	Postcentral Gyrus	L	2	-38	-26	68	6.41	705

Note: BA = Brodmann Area, k = cluster size, LPC = low precision correct

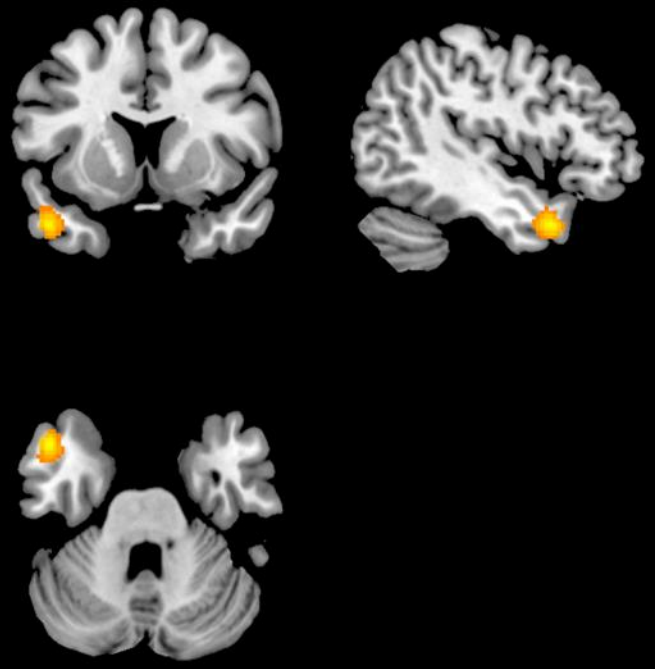
RESULTS: FMRI: RESTING VS. SEARCH



- All search tasks compared to fixation: Anterior Frontal, Dorsolateral Prefrontal Cortex (DLPFC), Ventrolateral Prefrontal Cortex (VLPFC), Inferior Frontal Gyrus (IFG), Insula, Parietal lobe. Mostly bilateral activity.

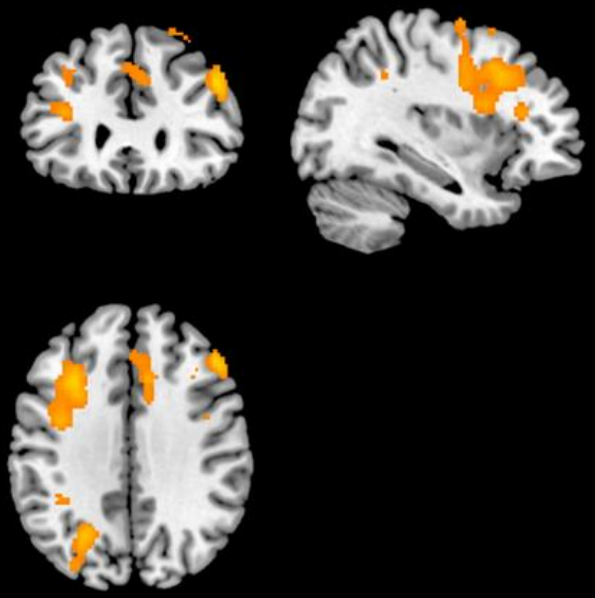
- The lateral PFC is generally associated with decision making and working memory where the more dorsal regions are associated with the decision making process and the more ventral regions are associated with working memory. All of these regions together aid in processing the task and execute a decision based on goals and the available information.

RESULT: TOPICAL > FACTUAL



- Did not lead to greater frontal activation, but does lead to greater activation within the left superior and middle temporal gyrus. This region is implicated in understanding word meaning which may suggest greater language use or greater reading needed within the topical search.

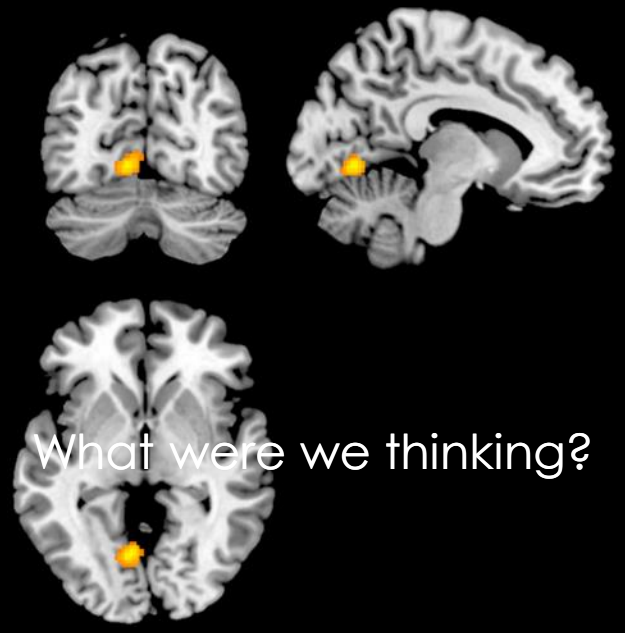
RESULT: FACTUAL > TOPICAL



- Multiple regions involved and bilateral

- Factual searching requires direct extraction of "acquired knowledge"
- Our observation of broad activation patterns, ranging from bilateral MFG, bilateral inferior temporal gyrus, right parahippocampal gyrus, right IFG, to superior occipital gyrus and superior parietal lobe may partly be representative of the participant involved in extracting a known answer rather than confirming or disconfirming an answer presented to them.

RESULT: LPC > ALL



What were we thinking?

- The somatosensory cortex, part of the left postcentral gyrus, is known to be involved in motor planning
- For the low precision correct (LPC) > all other trial types the dominant activation in the somatosensory cortex implies that motor planning was being carried out. Subjects in these trials anticipated finding the correct results at the bottom. Hence, it is likely that they began planning to respond with their right hand while browsing and reading the top items
- Generally, the differentiated response to ranking may be partially due to motor planning

FUTURE WORK: LEVERAGING BEHAVIORAL MARKERS FOR DETECTING NEURODEGENERATIVE CONDITIONS

- Predictions and stratification
- Adaptation

QUESTIONS

REFERENCES

Belkin, N. J. (1980). Anomalous Stater of Knowledge as Basic or Information Retrieval. *The Canadian Journal of Information*, *5*, 133–143. Retrieved from https://sakai.unc.edu/access/content/group/7d9a7cc6-7b5c-4dd2-b892-2094526ab817/Readings%20not%20available%20elsewhere/Belkin1980.pdf

Fisher, M. P. A. (2015). Quantum cognition: The possibility of processing with nuclear spins in the brain. *Annals of Physics*, *362*(Supplement C), 593–602. https://doi.org/10.1016/j.aop.2015.08.020

Hornak, Ph.D., J. P. (999). *The Basics of MRI* (XVII). Henietta, NY: Interactive Learning Software,. Retrieved from https://www.cis.rit.edu/htbooks/mri/index.html (Hornak, 2017)

Kiselev, V. G. (2017). Fundamentals of diffusion MRI physics. *NMR in Biomedicine*, *30*(3), n/a-n/a. https://doi.org/10.1002/nbm.3602