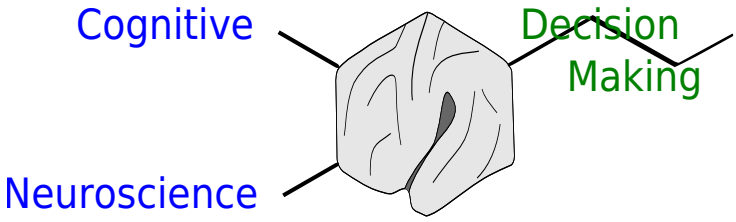


Topic: Reasoning

Strategic thinking about problems and decisions.

Article Discussed

Johnson-Laird, P. N. (1999). Deductive Reasoning. *Annual Review of Psychology*, *50*(1), 109–135. https://doi.org/10.1146/annurev.psych.50.1.109

Brief Summary

The topic of this article is on deductive reasoning in the brain. Two different cognitive theories of deduction were explored and clinical evidence that opposed the mental model theory was presented. The critical reading questions focused on topics like how different kinds of brain scans work, the difference between content dependent and content independent theories of reasoning, the types of different problem-solving tasks used in reasoning research and brain hemispheres associated with reasoning, and their similarities and differences. The classroom discussion featured topics such as illusions, intensity matching, affect heuristics, and substitution questions.

This summary includes discussions of two questions that were not answered in the class discussion. The first question was about whether or not more recent research has been done (because the article is about 20 years old) on the right hemisphere’s contribution or lack thereof on reasoning.

The second unanswered question was asking if there was further investigation (again because the article was from 1998) on preliminary conclusions via “contemporary neuroimaging.”

Cognitive Process Neuroimaging Analysis

Neurosynth: “reasoning”

Top 5 PubMed Articles:

1: Yazdani S, Hosseinzadeh M, Hosseini F. Models of clinical reasoning with a focus on general practice: A critical review. J Adv Med Educ Prof. 2017 Oct;5(4):177-184. PubMed PMID: 28979912; PubMed Central PMCID: PMC5611427.

2: Rohde E, Domm E. Nurses' clinical reasoning practices that support safe medication administration: An integrative review of the literature. J Clin Nurs. 2018 Feb;27(3-4):e402-e411. doi: 10.1111/jocn.14077. Epub 2017 Dec 6. Review. PubMed PMID: 28926146.

3: Amey L, Donald KJ, Teodorczuk A. Teaching clinical reasoning to medical students. Br J Hosp Med (Lond). 2017 Jul 2;78(7):399-401. doi: 10.12968/hmed.2017.78.7.399. PubMed PMID: 28692355.

4: Ackerman R, Thompson VA. Meta-Reasoning: Monitoring and Control of Thinking and Reasoning. Trends Cogn Sci. 2017 Aug;21(8):607-617. doi: 10.1016/j.tics.2017.05.004. Epub 2017 Jun 15. Review. PubMed PMID: 28625355.

5: Gilliland S, Wainwright SF. Patterns of Clinical Reasoning in Physical Therapist Students. Phys Ther. 2017 May 1;97(5):499-511. doi: 10.1093/ptj/pzx028. PubMed PMID: 28371873.

Top 5 Neurosynth Articles:

Eldaief, M. C., Deckersbach, T., Carlson, L. E., Beucke, J. C., & Dougherty, D. D. (2012). Emotional and cognitive stimuli differentially engage the default network during inductive reasoning. *Social Cognitive and Affective Neuroscience*, *7*(4), 380–392. https://doi.org/10.1093/scan/nsr003

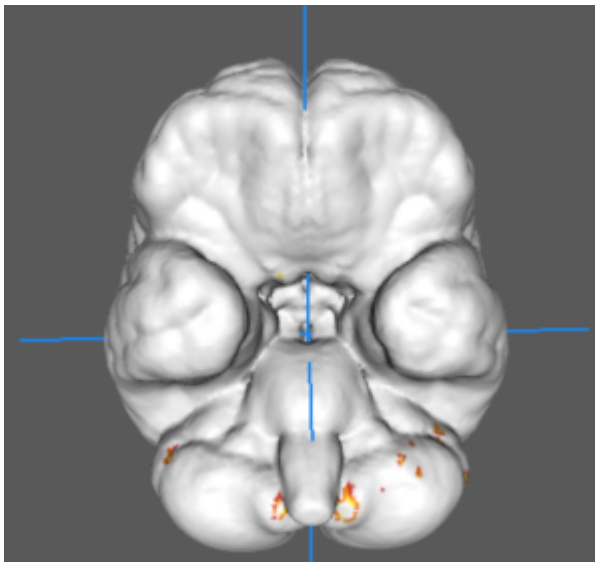
Krawczyk, D. C., Michelle McClelland, M., & Donovan, C. M. (2011). A hierarchy for relational reasoning in the prefrontal cortex. *Cortex; a Journal Devoted to the Study of the Nervous System and Behavior*, *47*(5), 588–597. https://doi.org/10.1016/j.cortex.2010.04.008

Melrose, R. J., Poulin, R. M., & Stern, C. E. (2007). An fMRI investigation of the role of the basal ganglia in reasoning. *Brain Research*, *1142*, 146–158. https://doi.org/10.1016/j.brainres.2007.01.060

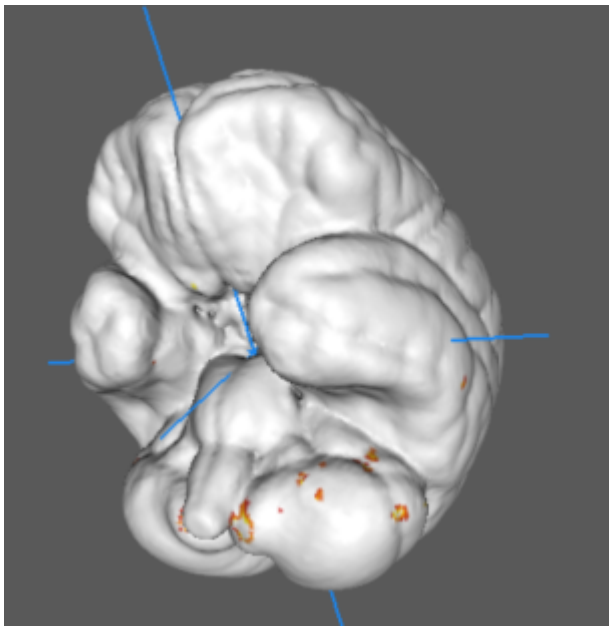
Reis, D. L., Brackett, M. A., Shamosh, N. A., Kiehl, K. A., Salovey, P., & Gray, J. R. (2007). Emotional Intelligence predicts individual differences in social exchange reasoning. *NeuroImage*, *35*(3), 1385–1391. https://doi.org/10.1016/j.neuroimage.2006.12.045

Rodriguez-Moreno, D., & Hirsch, J. (2009). The dynamics of deductive reasoning: an fMRI investigation. *Neuropsychologia*, *47*(4), 949–961. https://doi.org/10.1016/j.neuropsychologia.2008.08.030

Neurosynth Map for the Term

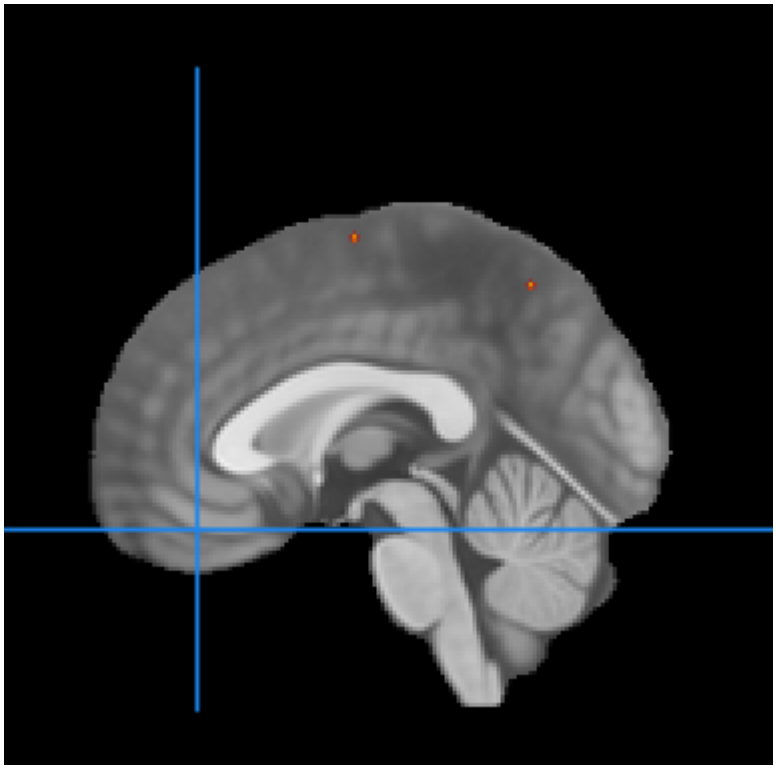


(We added a second image of the map for easier viewing_reasoning.)



Brain Region Chosen for the Term

Brain region “ventromedial prefrontal” also known as the “ventromedial frontal cortex”



Other Neurosynth Terms Associated with this Brain Region

MNI Coordinates: 0, 44, -20

	Individual voxel	Seed-based network		
Name	**z-score**	**Posterior prob.**	**Func. conn. ®**	**Meta-analytic coact. ®**
ventromedial	7.92	0.8	0.43	0.35
ventromedial prefrontal	6.95	0.8	0.4	0.35
theory mind	6.48	0.82	0.35	0.36
social	6.26	0.72	0.37	0.37
mentalizing	6.21	0.83	0.3	0.31
orbitofrontal cortex	6.12	0.75	0.39	0.25
mental states	5.91	0.83	0.3	0.33
ofc	5.88	0.8	0.29	0.17
orbitofrontal	5.86	0.73	0.4	0.24
mind tom	5.75	0.86	0.28	0.29

Questions posed by the class

Background Terms

Q: What is deductive reasoning?

RavioliJaguar: Deductive reasoning draws their conclusions from general ideas or premises. Sometimes deductive reasoning is also known as “top-down” reasoning. It starts off with an assumed belief or theory and then their thought process through deduction will narrow down pieces of information to come to a

conclusion.

Johnson-Laird, P. N. (1999). Deductive Reasoning. Annual Review of Psychology, 50(1), 109–135. https://doi.org/10.1146/annurev.psych.50.1.109

Deductive Reasoning. (n.d.). Retrieved April 2, 2019, from https://www.csun.edu/science/ref/reasoning/deductive_reasoning/index.html

Q: Clarification/Related: What are aphasics?

CoolActive: Aphasics are those affected with speech, reading, and/or writing impairments. Aphasia is always caused by brain injuries - most commonly caused by strokes.

> Aphasia Definitions - National Aphasia Association. (n.d.). Retrieved April 2, 2019, from

https://www.aphasia.org/aphasia-definitions/

Q: What are somatic responses?

PaintLevel: Somatic responses are how the body reacts to a stimulus that moves a part of the body. These movements are voluntarily and therefore the nervous system is acting skeletal muscles during somatic responses.

Gautron, M. & Gulibaud, G. (1982). Somatic responses of ventrobasal thalamic neurons in polyarthritic rats. *Brain Research, 237*(2), 459-471.

Q: What exactly are heuristics such as in the heuristic-analytic theory?

SincereZigzag: The theory was designed to explain the prevalence of cognitive biases in reasoning tasks and the puzzling fact that logical competence demonstrated on one task often failed to be exhibited on another. The heuristic analytic theory proposed that two kinds of cognitive process were involved: heuristic processes, which generated selective representations of problem content, and analytic processes, which derived inferences or judgments from these representations. Biases were accounted for by the proposal that logically relevant information might be omitted, or logically irrelevant information included at the heuristic stage. Since analytic reasoning could be applied only to these heuristically formed representations, biases could result.

Evans, J. S. B. T. (2006). The heuristic-analytic theory of reasoning: Extension and evaluation. *Psychonomic Bulletin & Review*, *13*(3), 378–395. https://doi.org/10.3758/BF03193858

Q: How does electroconvulsive therapy (ECT) work? What is it used for?

Electroconvulsive therapy (ETC) is a procedure in which small electric currents are passed through the brain to trigger a brief seizure. This causes changes in brain chemistry that can help to reverse symptoms of mental health issues. It is only used when other treatments are unsuccessful. It is used for treatment of severe depression, treatment-resistant depression, mania, catatonia, and dementia.

> Electroconvulsive therapy (ECT) - Mayo Clinic. (n.d.). Retrieved April 2, 2019, from

https://www.mayoclinic.org/tests-procedures/electroconvulsive-therapy/about/pac-20393894

SodaOxford

Different Types of Brain Scans and How They Work

Q: How does a PET scan work and what information does it provide to someone conducting a PET study?

DivideSegment: A PET or (positron emission tomography) scan allows for doctors to check your body for diseases, it is used to see how well your organs and tissues are working. It uses a dye that contains radioactive tracers that gets injected, swallowed or inhaled into the veins. On the PET scan the dye shows up as bright spots in areas of high chemical activity, which translates to areas of disease. PET scan can inspect oxygen intake, blood flow, and metabolism of organs and tissues.

PET Scan: Definition, Purpose, Procedure, and Results. (2018, April 23). Retrieved April 2, 2019, from Healthline website:

https://www.healthline.com/health/pet-scan

Q: What is the difference between an fMRI study and a PET study?

ZeroCanary: Both Functional magnetic resonance imaging (fMRI) and Positron Emission Tomography (PET) scans measure blood flow in the brain, recording brain activity. The difference is that PET scans do not require the person to remain as still, whereas with fMRI scans small movements can obscure data. The downside to PET scans is that the resolution of the scans is lower. PET scans are more expensive since it uses radioactive isotopes and a special machine. fMRI can be done at most hospitals around the world.

In a comparison study of PET and fMRI activation patterns during declarative memory processes, PET scans were picked up frontopolar activations that fMRI did not, due to susceptibility artifacts. However, the fMRI scan showed parahippocampal activation and cerebellar activation that the PET scan did not encode. This is most likely because of the whole brain coverage scan that the fMRI can encode. Both scans had a 93% mean recall accuracy so in conclusion, the difference between PET and fMRI scans depends on study design (single subject vs. group study) and the task of interest. (https://www.ncbi.nlm.nih.gov/pubmed/11127048)

Q: What are some other applications and benefits of PET (positron emission tomography) vs. other neuroimaging techniques?

Some of the benefits of PET compared to other neuroimaging techniques include having a shorter duration of only about 30 minutes, being noninvasive and thus being less painful and discomforting compared to others, and also better detecting tumors in some instances (“What to Expect,” n.d.). For example, one physician had only seen a single tumor with a CT scan, but detected an additional tumor when a PET scan was performed (“What to Expect,” n.d.). He noted this changed the entire treatment plan for the better (“What to Expect,” n.d.).

> What to Expect. (n.d.). Retrieved April 2, 2019, from https://stanfordhealthcare.org/medical-tests/p/pet-ct-scan/what-to-expect.html

-TelecomElegant

Content Dependent and Content Independent Reasoning

Q: What is an example of a content-dependent theory?

Take for example retargeting someone visited your website and looked at a product. Now you recognize this person elsewhere on the web and you promote the same product again in a banner. Since the person is on a totally different website, a lot of the cues are gone. Cue dependent forgetting tells us that it helps to include original elements of your site in the banner (colors, logo's, icons, etc). You might even show the banner that is already on your site, so that people will recognize the banner easily somewhere else.

"Memory & Learning." **MoblieSuper**

Q: What is content-independent reasoning vs. content-dependent reasoning?

NitroMotor: The article defines 'reasoning' as "thinking in which there is conscious intent to reach a conclusion and in which methods are used that are logically justified" (p.54). It defines 'content' as the "degree to which statements contain information relevant to an individual's beliefs, values, goals, and plans" on p. 54, as well.

So, content-independent reasoning relies on domain-general process schemas such as 'if, then, therefore' to come to the most logical conclusion, since there is no relevant information or experiences to reflect on. This type of reasoning represents the general, foundational reasoning processes of humans. Think of it as a template to solve a math problem; it is a logical, learned process designed to reach the best conclusion.

Content-dependent reasoning appears to be a completely different system. Personal content relevance largely affects the way we think about and process a statement or problem. Content-dependent reasoning may be explained by the pragmatic reasoning schema (PRS) theory. A pragmatic reasoning schema uses a set of general context-sensitive rules concerned with a specific social-interaction goal, such as 'permission','obligation' or 'causation'. These rules are completely individual and induced from experience. Heuristic-analytic theory is another possible explanation of the content-depending reasoning process. This theory states that analytical reasoning processes are applied to problem representations that are initially formed by rapid, preconscious heuristic processes. There is still much debate over content-dependent reasoning processes, but the bottom line is that it is an individual process influenced by experience and emotion.

The article states that there is a neuroanatomical basis for two distinct psychological reasoning systems that operate as a function of the presence or absence of relevant content. Studies indicate "that content-independent, domain-general reasoning is mediated by the left hemisphere, and that content-dependent reasoning is mediated by the right hemisphere along with the bilateral ventromedial frontal cortex. However, in normal subjects, even with content-free materials, reasoning inferences might result from the interaction of both systems," (p.56).

Q: Content has a role in deductive reasoning, and it (content) may change by culture. Are there any studies demonstrating the impact of culture in deductive reasoning?

There have been many neurological studies demonstrating the tangible impact that culture has on the brain and specifically on cognition. In one study “They designed an fMRI task in which European-American and Chinese participants were given the option to donate money to a European-American or Chinese confederate… , they found that those with higher group identity, and Chinese participants more so than American ones, showed more activation in areas commonly related to self-control (VLPFC, ACC) and mentalizing (TPJ, DMPFC) when donating to the out-group as opposed to the in-group”(Lin & Telzer, 2017). This demonstrates that culture may impact decision making and reasoning. In another study, a frame-line task was created to examine cultural variation in solving cognitive problems. “they found that the North Americans were more accurate on the absolute problem but less accurate on the relative problem than the East Asians, consistent with the notion that the cognitive toolkits of Easterners suit problems that require the incorporation of contextual information (i.e. the surrounding square) better, whereas the cognitive toolkits of Westerners suit problems that require the insulation of contextual information better”. Other studies have used the frame-line task and other measures to capture more insight on the subject. Some studies support the idea that “all individuals are capable of representing multiple cultures in their minds and switching between representations of cultures”, whereas other studies and theories are more supportive of hard-wired and distinctive differences. Some studies show that while people from different cultures may perform equally well on cognitive tasks, the areas of the brain being used may differ (Zhou & Cacioppo, 2010). -VideoSport

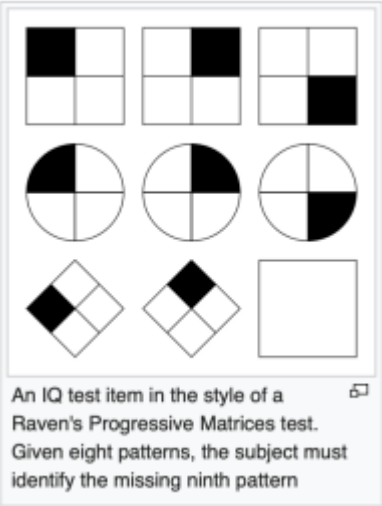
Cognitive Testing

Q: What is the “Tower of Hanoi” problem solving task?

WelcomeSoda: The Tower of Hanoi is a puzzle where you have three different sized rings on one stand and you have 3 stands. You have to move all three of the rings to the last stand while only moving one ring at a time and not placing a larger ring on top of a smaller ring. You can play the game using this link: https://www.mathsisfun.com/games/towerofhanoi.html

- Visual and motor reasoning

Q: What does the “Raven’s progressive matrices” problem solving task involve?



An IQ test item in the style of a Raven's Progressive Matrices test. Given eight patterns, the subject must identify the missing ninth pattern

Ambient Benefit**:** This is a test of fluid intelligence, a factor of general intelligence defined as the capacity to reason and solve problems (“Fluid and crystallized intelligence,” 2019). It is a 60 question, multiple-choice test and questions start out easier and are listed in order of increasing difficulty. Every question consists of a “visual geometric design” with a missing piece (“Raven’s Progressive Matrices,” 2019).

Q: What is an example of cognitive testing that people may experience in life?

The study that I found measured the relationship between cognition tasks one might encounter in everyday life compared to traditional psychometric tests. Some of the cognitive tasks that reflected real-world domains included identifying nutrition information or comparing the value of different financial products. These can both be categorized as cognitively advanced activities of daily living. The image on the left is an example of the types of questions that were asked in the study_reasoning.

Allaire, J. C., & Marsiske, M. (1999). Everyday Cognition: Age and Intellectual Ability Correlates. *Psychology and Aging*, *14*(4), 627–644.

ShelfOpus

Brain Hemispheres/Regions Associated with Reasoning

Q: Which hemisphere is more important for reasoning?

From looking into some of the research, it seems that the cerebrum is responsible for reasoning. The cerebrum is the largest part of the brain and is actually composed of both right and left hemispheres. The cerebrum basically processes our sensory inputs, as well as speech and fine motor movements. This makes me think that reasoning is not localized to one hemisphere of the brain. I actually think the connectedness between the two hemispheres is what produces the thing we call reasoning.

Brain Anatomy, Anatomy of the Human Brain. (n.d.). Retrieved from https://mayfieldclinic.com/pe-anatbrain.htm -**SOCIALANVIL**

Q: Other than inferences by Johnson-Laird, is there any imaging data or studies to confirm that the right cerebral hemisphere plays a significant part in reasoning?

DivideSegment: From the research I looked into, there are arguments that support that reasoning relies on processes that are lateralized for best performance. However, this study did not get conclusive neuroimaging results to support their assumptions.

> Turner, B. O., Marinsek, N., Ryhal, E., & Miller, M. B. (2015). Hemispheric lateralization in reasoning. *Annals of the New York Academy of Sciences*, *1359*, 47–64. https://doi.org/10.1111/nyas.12940

Q: Is the right hemisphere the only part of the brain involved in reasoning? Or does the left play some role as well?

Ambient Benefit: I'd refer to question 11 on this too- I think both sides of the brain play a role in reasoning. A meta-analysis of 47 neuroimaging studies "found activation of the frontoparietal network during both deductive and inductive reasoning, with additional activation in an extended network during inductive reasoning in the basal ganglia and the inferior parietal cortex. Analyses revealed a double dissociation concerning the lateral and medial Brodmann's area 6 during deductive and inductive reasoning, indicating differences in terms of processing verbal information in deductive and spatial information in inductive tasks." (Wertheim & Ragni, 2018)

Plus the neuroimaging studies from the article we read even agree that the brain works together in reasoning “Clinical and neuroimaging studies appear to show that content-independent reasoning is mediated by the left hemisphere, whereas content-dependent reasoning is mediated by regions in the right hemisphere and the bilateral ventromedial frontal cortex.” (“Deductive Reasoning,” n.d.)

Q: Do the left and right hemisphere work in unison for certain problems?

PoloBravo:

Yes, the right and left hemispheres do work in unison for many activities and processes. To show this, it is best to look at split brain patients. In a certain example, one man with a severed corpus callosum had one arm trying to hit his wife and the other arm able to grab that arm and stop it from happening. In rare cases, the split-brain patients can also have a split personality between the hemispheres because your frontal lobes are not working together in unison to create a single personality (Psych Today). Another example of this is when a man named Kim Peek was able to read two pages of a book at the same time and retain all of the information. This could be seen as an advantage, but it is possible because the two hemispheres do not need to work in unison to be able to read and retain information from 1 place at a time (Psych Today). The two hemispheres are always working together to retain different kinds of information that the other side specializes in and split-brain patients can be used to show that the connection between these two sides in important.

Brogaard, B. (2012, November 6). Split Brains: Brain's Processing of Information

> Affected by Hemispheric Transfer. Retrieved from Psychology Today website: https://www.psychologytoday.com/us/blog/the-superhuman-mind/201211/split-brains

Q: The article stated that there is little evidence that the right hemisphere contributes to reasoning in situations that lack relevant content. Considering this article is about 20 years old, has there been any further research done into this area?

The original article stated that content dependent reasoning is mediated by the right hemisphere as well as the bilateral ventromedial frontal cortex, although it also stated that reasoning is most likely mediated by not just the right hemisphere, but both hemispheres in normal subjects (Johnson-Laird, 1999). Further research from a review in 2015 found that there is a “hemispheric lateralization in reasoning” in which the left hemisphere of the brain is associated with “drawing inferences or creating explanations” while the right hemisphere of the brain is associated with reducing conflict by “rejecting or refining explanations that are no longer tenable in the face of new evidence.” The review goes on to say that in healthy adults, both hemispheres work together to create normal reasoning ability, and when one hemisphere is compromised reasoning can fail or delusions can occur (Turner, Marinsek, Ryhal, & Miller, 2015).

Content dependent reasoning, which is reasoning that requires context or content, such as a rule or some kind of social context gathered from life experience, and whether or not it is associated with a specific hemisphere of the brain, does not show up in many of the current articles on reasoning in the brain (Johnson-Laird, 1999). However, there was an article on “the effect of social content on deductive reasoning” which seems to be a similar concept. This article illustrated that subjects find it easier to reason with social context, and fMRIs (and random effect-statistical analyses) showed that the Wason selection tasks given in the study “activated the frontal medial cortex and left dorsolateral frontal and parietal regions.” This study was done slightly earlier in 2005 and concluded that the left hemisphere is dominant in deductive reasoning but that the right hemisphere did “mirror” the activated brain regions on the left side of the brain when subjects were doing social-exchange tasks. This affirms the original study’s conclusion that the right hemisphere of the brain is involved in content-dependent reasoning (Canessa et al., 2005).

On a more related note, one article in 2013 actually found that intensive training can alter brain connectivity patterns. Individuals who were studying for the LSAT were observed via resting state fMRI before and after a 70 hour course in reasoning, and it was shown that the reasoning training strengthened frontoparietal and parieto-striatal connections in the brain, providing more evidence that many brain regions work together in the process of reasoning (“Intensive reasoning training alters patterns of brain connectivity at rest. - PubMed - NCBI,” n.d.).

The only article we found that rebutted the claim that both hemispheres work together was an article using a neuropsychoanalytic perspective of regulation theory. The goal was to understand brain structures and unconscious processes, and the article concludes that the “early developing right brain generates the implicit self” and is linked to implicit information processing as opposed to the explicit information processing that is associated with the left hemisphere. A term of note was “implicit cognition.” This can be defined as “unconscious influences such as knowledge, perception, or memory, that influence a person's behavior, even though they themselves have no conscious awareness whatsoever of those influences” otherwise known as the “human unconscious”. Researcher Allan Schore rebuts the belief that the left hemisphere is the dominant one and says in his article that the right hemisphere is dominant because of its “homeostatic survival and communication functions.” The article details how the brain’s implicit cognitive functioning can give insight into the patient’s condition and therefore lead to better treatment options (Ph.D, 2011). However, this was not the most pertinent article to reasoning and therefore I think this researchers claim is probably not as accurate as the many other articles that confirm the conclusions of the original article that we read.

Overall, it would seem that the original articles conclusions still remain accurate, and that both hemispheres work together, and the right hemisphere is more specifically association with content-based reasoning, although current studies look more specifically at certain brain regions instead of just the two hemispheres. Many different areas of the brain seem to play a role in reasoning.

Q: How does this information relate to how left-brained vs. right-brained people perform in academic settings?

RespondLlama: “Direct and inverse tendencies seemed apparent between particular learning styles and academic achievement. In brain dominance, direct and inverse tendencies appeared to exist between certain brain hemispheric modes and academic achievement”

> Carthey, J. H. (1993). *Relationships between Learning Styles and Academic Achievement and Brain Hemispheric Dominance and Academic Performance in Business and Accounting Courses*. Retrieved from https://eric.ed.gov/?id=ED374412

Q: In one of my psych classes the professor talked about how left-handed people are more likely to use both sides of their brain more equally - is this true and if so, how does it apply to the reading?

Ambient Benefit**:** From the American Psychological Association, handedness does relate to brain hemispheres. Right handed people are dominant in the left-hemisphere of the brain, and left handed people are dominant in the right-hemisphere of the brain. However, left handed and ambidextrous people can also have more symmetrical hemispheres. The article I read says right handed people do generally have brains that split tasks more fully, where the left hemisphere is associated with speech/language and the right hemisphere is associated with emotions/image processing_reasoning. It also says that strongly symmetrical brains, like those referenced in the question, may be more efficient because information does not have to cross the corpus callosum, but can also lead to mental disorders.

Q: The article mentions that content-dependent reasoning is mediated by regions in the right hemisphere specifically the bilateral ventromedial frontal cortex. Can we find the bilateral ventromedial frontal cortex in mango?

MileImport:

Yes, the bilateral ventromedial frontal cortex can be seen in this image below_reasoning. We are able to find this location with Mango as well.

Q: Does the damage to a certain brain region greatly affect the problems that would arise in reasoning?

Damage to the Frontal Lobe can result in a disregard of behavioral social rules, a loss of executive function, planning, and abstract reasoning. Other results include decrease in a sustained attention and insight. With damage to the Parietal Lobe comes disorientation and unsequenced long-term memories, as well as confusion and inability to read. When the Temporal Lobe is damaged, there can be difficulty with screening out distractions and with observed problems in reasoning and memory recollection.

- Isotope Nirvana
- Cognitive Skills of the Brain. (n.d.). Retrieved April 2, 2019, from Brain Injury Alliance of Utah website: https://biau.org/about-brain-injuries/cognitive-skills-of-the-brain/

Further Research

Q: The article stated that there is little evidence that the right hemisphere contributes to reasoning in situations that lack relevant content. Considering this article is about 20 years old, has there been any further research done into this area? (Answered above)

Q: This article was published in 1998. What “further investigation… with contemporary neuroimaging” has been done to elaborate on its preliminary conclusions?

This question is extremely similar to the other unanswered question, but we will attempt to find more evidence of the article’s original conclusions, this time focusing on “contemporary neuroimaging”. Neuroimaging has advanced in tremendous ways over the last 20 years, and even within the last decade. Techniques and continued studies have “unlocked” numerous structures and allowed for relationships to be formed and understood.

Regarding neuroimaging, an article on eating disorders detailed how neuroimages from the last decade (2005-2015) targeted brain activities/circuits that were previously unable to be directly analyzed_reasoning. This resulted in the ability to extrapolate on basic research from previous decades, that were then expanded and analyzed for deeper understanding of structures such as the limbic system and its surrounding circuitry (Frank, 2015). Another article from 2008 on the advances of neuroimaging again showed the significant progress that has been made since the original article was published in 1998. Doctors who were previously unable to localize epileptic seizures or intra-axial abnormalities are now able to document their findings and assist other doctors in treating epileptic seizures. This allows for lesion-directed surgeries to take place with far more effectiveness and chance of recovery than was possible in decades past.

A more recent study regarding deductive reasoning from 2018 discussed the evolution of studies on deductive reasoning in psychology over the last century, and how neuroimaging has been able to uncover many previously unanswered or unanswerable questions, such as “the identity of the neurological structures that are core to the deductive process, the source of the hierarchical structures on which deduction depends, whether deduction is a modular or domain general process” and more. This article used three experiments with different neuroimaging techniques. The first was an fMRI study to look at the relationship between language and deduction, which “revealed a new dissociation between deduction and memory.” The second study was a neuromodulation (defined as the alteration of nerve activity by an electrical or chemical stimulus) study that used transcranial magnetic stimulation (TMS) to “establish a causal dissociation between brain areas that support language and those believed to support deduction, specifically with regard to the hierarchical frameworks on which both language and deduction depend” (Coetzee, 2018; Krames, Hunter Peckham, Rezai, & Aboelsaad, 2009). The third study was actually related to social exchange theory research described in the answer to the previous question, and also used the Wason Task. Study 3 concluded that there are association between personality traits and psychopathology (Coetzee, 2018).

Overall, the three studies illustrated that deductive reasoning is associated with frontoparietal regions of the brain, which confirms previous studies mentioned in the answer to the previous question. The second main finding was that core regions commonly associated with deductive inference “cannot be interpreted as merely responding to general (i.e., non-deductive) cognitive load and/or increased working memory demands (Coetzee, 2018).

Bibliography

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