# Neural Reuse and the Evolution of Higher Cognition

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## Abstract

Harvard psychologist Steven Pinker recently examined a problem with understanding human cognition, particularly how the processes of biological evolution could explain the human ability to think abstractly, including the *higher cognitive abilities* for logic and math (hereafter, HCAs). Pinker credits the formulation of the problem of understanding human cognition and the evolutionary development of HCAs to the co-discoverer of evolution by natural selection, Alfred Russell Wallace. Pinker states the following response to the question raised by Wallace:

> …Nonetheless it is appropriate to engage the profound puzzle [Wallace] raised; namely, why do humans have the ability to pursue abstract intellectual feats such as science, mathematics, philosophy, and law, given that opportunities to exercise these talents did not exist in the foraging lifestyle in which humans evolved and would not have parlayed themselves into advantages in survival and reproduction even if they did?

Wallace claimed that while ancestral cognitive operations, such as those operations for perception and motor control, were the product of evolution, he disagreed with Charles Darwin's view that HCAs are the product of evolution by natural selection.

Wallace is not the only one to doubt that HCAs are the product of evolution. Contemporary philosopher Thomas Nagel also rejects the view that HCAs are the product of evolution. Comparable to Wallace, although Nagel accepts that older operations of the brain, such as perception and motor control, are the product of evolution, Nagel denies that higher types of cognitive operations are the product of evolution.

The aim of this dissertation is to argue that HCAs are the product of evolutionary processes, both natural selection and other mechanisms of change. The reason HCAs are the product of evolution is because HCAs are carried out by the neural reuse of older evolved brain regions. Neural reuse is the view that brain regions can be recruited for multiple cognitive uses. Ancestral brain regions, such as regions for perceptual and motor functions, can be reused for carrying out HCAs, such as language, logic, and math.

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# Chapter 1

# Introduction

Harvard psychologist Steven Pinker recently examined a problem with understanding human cognition, particularly how the human ability to think abstractly, including the *higher cognitive abilities* for logic and math (hereafter, HCAs) could be the product of evolution.[1] Pinker credits the formulation of that problem of understanding human cognition and the evolutionary development of HCAs to the co-discoverer of evolution by natural selection, Alfred Russell Wallace. Pinker states the following response to the question raised by Wallace:

> …Nonetheless it is appropriate to engage the profound puzzle [Wallace] raised; namely, why do humans have the ability to pursue abstract intellectual feats such as science, mathematics, philosophy, and law, given that opportunities to exercise these talents did not exist in the foraging lifestyle in which humans evolved and would not have parlayed themselves into advantages in survival and reproduction even if they did?[2]

Wallace claimed that while ancestral cognitive operations, such as those operations for perception and motor control, were the product of evolution, he disagreed with Charles Darwin's view that HCAs are the product of evolution.[3]

To clarify the question about whether or not HCAs are the product of evolution, some terms require definition. Biological evolution is a process of change over time and includes three ideas.[4] The first idea is that evolution refers to descent with modification: all living things are all related and the diversity and relationship of species to one another is the product of a long

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[1] Steven Pinker, "The cognitive niche: Coevolution of intelligence, sociality, and language," accessed November 12, 2016, http://www.pnas.org/content/early/2010/05/04/0914630107.full.pdf.

[2] Ibid., 186-90.

[3] Alfred Russell Wallace, *Darwinism: An Exposition of the Theory of Natural Selection With some of its Applications* (London: MacMillan, 1889), 462-463, accessed November 17, 2016, https://archive.org/details/darwinism00unkngoog.

[4] Ernst Mayr, *What Evolution Is* (New York: Basic Books, 2001), 8; Carl Zimmer and Douglas J. Emlen, *Evolution: Making Sense of* Life (Colorado: Roberts and Company Publishers, 2013), 3-5.

history of change through genetic inheritance.[5] The second idea is that evolution describes the tree of life when species split from various lineages and the changes that took place. The third idea of evolution refers to the mechanisms that may cause evolution, including natural selection, sexual selection, and genetic drift.[6]

Natural selection is an important concept in this project and is a mechanism whereby the differential reproduction of individuals can cause some genetic traits to spread within a population.[7] Traits that increase reproductive success, or fitness, often pass on to future generations. For example, within a herd of zebra, differential reproduction causes differences in the mutations that cause running speed.[8] Some zebra within the population run faster than other zebra because of the mutations they acquired. The mutation responsible for the increase in speed causes fitness-enhancing behavior, meaning that the zebra with increased speed will likely reproduce more offspring than the slower zebra. The implication of this differential reproduction is that over time the mutation causing the increase in speed will dominate the population. The trait that promotes fitness will become an adaptation within that species of zebra.

While natural selection is an important mechanism for causing evolution, biologists discuss other mechanisms that may cause evolution as well. Another form of selection that causes evolution is called sexual selection. Sexual selection refers to the mating competition

[5] Michael Ruse and Joseph Travis, "Introduction" in *Evolution: The First Four Billion Years* (eds. Michael Ruse and Joseph Travis; Cambridge, Mass: Belknap Press, 2009), ix; Ernst Mayr, *What Evolution Is,* 7.

[6] Ibid., ix; Stephen Jay Gould, "The Evolution of Life," *Scientific America* 271, no. 4 (1994): 92. See also Mayr, *What Evolution Is,* 115; Zimmer and Emlen, *Evolution*, 46-7. For differences between natural selection and sexual selection, see Mary-Jane West-Eberhard, "Sexual Selection, Social Competition, and Speciation," *The Quarterly Review of Biology* 58, No. 2 (1983): 155-183; Ernst Mayr, "The Objects of Selection," *Proc. Natl. Acad. Sci.* 94, no. 6 (1997): 2091; Neeltje Boogar et al., "Mate choice for cognitive traits: a review of the evidence in non-human vertebrates," *Behav Ecol* 22, no. 3 (2011): 447-459; Richard Byrne, "The Evolution of Primate Cognition," *Cognitive Science* 24, no. 3 (2000): 543-570).

[7] Zimmer and Emlen, *Evolution*, 6.

[8] Elliott Sober, *Core Questions in Philosophy: A Text With Readings, 6th Edition* (Boston: Pearson, 2013), 71-72.

within a species. Males within a species compete with each other over access to the females.[9] Still other mechanisms that may cause evolution include genetic drift, exaptation, and the influences of culture. Roughly, genetic drift refers to the random influences that cause changes often within smaller populations.[10] Exaptation refers to traits that originally performed one function and then were co-opted for a different function.[11] Some biologists explore the changes that occur because of culture and learning, sometimes called the "Baldwin Effect."[12] And still other biologists discuss traits that are "by-products" of evolution, in that these traits do not exhibit any immediate function.[13] Noting these other mechanisms of evolution besides natural selection is important. As we shall see throughout this project, different approaches for explaining how HCAs are the product of evolution may include these other mechanisms.

Another important term to define is cognition. Defining cognition can be difficult because the term does not have agreed-upon meaning.[14] For our purposes, cognition refers to mental activity which causes behavior, including both ancestral mental activity, such as the activity for motor control and perception, as well as higher mental activity, such as reflection and abstract thinking.[15]

Defining natural selection and higher cognition provides some clarity about the question raised by Pinker and Wallace. Is the human ability to think abstractly the product of evolution

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[9] Zimmer and Emlen, *Evolution*, 46.

[10] Ibid., 160-161.

[11] Ibid., 103.

[12] Keith L. Downing, "Development and the Baldwin Effect," *Artificial Life* 10, no. 1 (2004): 39-63.

[13] Stephen Jay Gould and Richard Lewontin, "The Spandrels of San Marco and the Panglossian Paradigm: A Critique of the Adaptationist Program," *Proceedings of the Royal Society of London* 205, no. 1161 (1979): 581-598.

[14] Peter Godfrey-Smith, "Environmental Complexity and the Evolution of Cognition," in *The Evolution of Intelligence* (eds. R. Sternberg and J. Kaufman; Lawrence Erlbaum Associates, 2001, accessed April 4th, 2016, http://www.its.caltech.edu/~theory/Godfrey-Smith.pdf.

[15] Godfrey-Smith, "Environmental Complexity," accessed April 4th, 2016, http://www.its.caltech.edu/~theory/Godfrey-Smith.pdf.

generally and by natural selection in particular? Wallace is not the only one to doubt that HCAs are the product of natural selection. Contemporary philosopher Thomas Nagel also rejects the idea that HCAs are the product of natural selection. Comparable to Wallace, although Nagel accepts that older cognitive operations are the product of natural selection, Nagel rejects that HCAs are the product of natural selection.[16]

The consequence of their skeptical position about evolution and HCAs is that the evolutionary development of HCAs requires a different type of teleological explanation. For Wallace, the different type of teleological explanation for HCAs may require a designer of sorts.[17] Nagel does not share Wallace's solution about a designer exactly, although Nagel suggests that teleology within science is required.[18] While I examine the views of both Wallace and Nagel in chapter five, for now consider the following analogy to better understand why Wallace and Nagel argue for a teleological account for the development of HCAs.

Imagine walking along the beach and discovering a well-designed sand castle, with towers, a draw-bridge, and elegant writing on the walls. To explain the existence of the sand castle, you contemplate two potential causes. The first potential cause is that the sand castle is the result of buckets, shovels, and a design plan. The second potential cause for explaining the existence of the sand castle is that the sand castle is the result of the wind, waves, erosion, crawling critters, and so on. You conclude that the sand castle is likely the result of the first set of causes, the buckets, shovels, and design plan. Now imagine that you walk farther along the beach and discover a second, less elegant structure resembling the first sand castle. You then consider the same potential causes discussed earlier, the causes involving the shovels, buckets, and design plan, and the causes involving the wind, waves, erosion, and crawling critters. You conclude that this second structure, while exhibiting the appearance of design, is the result of the wind, waves, erosion, and crawling critters, and not the result of the causes involving the

[16] Thomas Nagel, *Mind and Cosmos: Why the Materialist Neo-Darwinian Conception of Nature is Almost Certainly False* (Oxford: Oxford University Press, 2012), 76-78

[17] Alfred Russell Wallace, "Sir Charles Lyell on geological climates and the origin of species," *Reviews of principles of geology*, 10th edition (London: 1869) This quotation was cited from Charles Gross, "Alfred Russell Wallace and the evolution of the human mind," *Neuroscientist* 16, no. 5 (2010): 500.

[18] Nagel, *Mind and Cosmos*, 7, 33.

buckets, shovels, and design plan. The difference between the two structures is that the first structure includes an agent with intentionality and the second structure does not include an agent with intentionality.[19]

In both cases above, the sand castle and the sand castle-like structure, one may discuss the descriptive causes that produced each structure, as well as a broader philosophical explanation about agency and teleology within those causal processes. The descriptive account of the first structure includes tools and a design plan; the descriptive account of the second structure includes the wind, waves, and erosion. One form of the teleological discussion in both cases is that the first sand castle requires an agent as part of the causal process and the second castle-like structure does not require an agent as part of the causal process.[20]

The point of the sand-castle analogy is that a complete explanation of the first structure requires more than the descriptive account. Imbedded in that descriptive account includes broader philosophical questions about teleology. Specifically, a complete explanation of the first sand castle requires the agent, its intentionality, and the design plan. Wallace and Nagel argue that HCAs are analogous to the first sand castle and dis-analogous to the second castle-like structure. Wallace and Nagel claim that HCAs are the type of object that requires broader philosophical explanation, such as teleology and agent causes. The distinction between the descriptive and teleological accounts for HCAs is important because this project focuses mainly on the descriptive account of HCAs and does not include discussing the teleological account of HCAs. I will return to this distinction later in the introduction.

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[19] The first example includes "agent causation." Roughly, agent causation is a controversial idea that intentional agents exhibit causal power independent of prior causes. But that definition is different than how I apply agent causation here. The only claim I wish to make is that some physical objects – such as sand castles and computers – require agents within the causal process. I would suggest that critics such as Wallace and Nagel employ these philosophical concepts of teleology and agent causation (or some variation of agent causation) when considering evolutionary arguments for HCAs. For details on one view of agent causation, see Timothy O'Connor, "Agent Causation," in *Agents, Causes, and Events: Essays on Indeterminism and Free Will* (ed. Timothy O'Connor; New York: Oxford University Press, 1995), 173-200.

[20] This distinction can be a bit misleading because if the Aristotelian view of teleology were correct, then agency would exist as part of the causal process of both structures. I do not consider this view here. Even if the Aristotelian view were correct, one could draw a weaker distinction between the "agency" required for causing the first structure and the lack of "agency" required for causing the second structure.

The aim of this dissertation is to argue that HCAs are the product of evolutionary processes, both from natural selection, and other mechanisms of change. The reason HCAs are the product of evolution is because HCAs are carried out by the neural reuse of older evolved brain regions. Evolution by natural selection produced a brain for performing ancestral operations, such as perception and motor control, and those ancestral operations have been reused for carrying out HCAs.[21] As I will discuss later in this chapter, note that my aim does not commit to natural selection as the necessary and sufficient condition for explaining HCAs. While natural selection may be a necessary condition, my approach is open to including the other mechanisms of change as well.

The idea that the brain reuses its neural capacities for supporting HCAs will be introduced in detail later in this chapter. For now, the main point is that HCAs are not an instance of brain regions specialized for higher abilities. Rather, HCAs are an instance of ancestral brain regions, such as regions for perception and motor control, that have been reused for higher cognitive use. If I am correct, then a gradual process of incremental change from older evolved brain structures and operations to the structures and operations supporting HCAs would likely have occurred, and this gradual development was caused by both natural selection and other mechanisms of change.

My defense of this evolutionary argument for HCAs is not the first attempt. Several evolutionary arguments for HCAs date back to Darwin. In what follows below, I provide a brief introduction to these evolutionary arguments, including arguments from Darwin, Ernst Mayr, Steven Pinker, and Elliott Sober, distill some general features from these arguments, and then introduce in detail my own argument for the evolution of HCAs from neural reuse afterwards.

As briefly noted above, Darwin disagreed with Wallace, and in his book, the *Descent of Man*, Darwin outlines some of his reasons for affirming the evolution of HCAs:

> We have seen in the first chapter that the homological structure of man, his embryological development and the rudiments which he still retains, all declare in the plainest manner that he is descended from some lower form. The possession of exalted mental powers is no insuperable objection to this conclusion. In order that an ape-like creature should have been transformed into man, it is necessary that this early form, as

[21] Michael L. Anderson, *After Phrenology: Neural Reuse and the Interactive Brain* (Cambridge, Mass.: MIT Press, 2014), 5.

> well as many successive links, should all have varied in mind and body. It is impossible to obtain direct evidence on this head; but if it can be [shown] that man now varies – that his variations are induced by the same general causes, and obey the same general laws, as in the case of the lower animals – there can be little doubt that the preceding intermediate links varied in like manner.[22]

Darwin claimed that HCAs – or the "exalted mental powers" – were within the explanatory scope of natural selection as a gradual process. While I argue that HCAs are the result of the gradual process of change, from older functions to higher functions, Darwin alluded to this strategy already. For instance, in a different piece, Darwin claims that:

> Although an organ may not have been originally formed for some special purpose, if it now serves for this end we are justified in saying that it is specially contrived for it. On the same principle, if a man were to make a machine for some special purpose, but were to use old wheels, springs, and pulleys, only slightly altered, the whole machine, with all its parts, might be said to be specially contrived for that purpose. Thus throughout nature almost every part of each living being has probably served, in a slightly modified condition, for diverse purposes, and has acted in the living machinery of many ancient and distinct living forms.[23]

This passage is helpful because Darwin introduces the concept of preadaptation. Preadaptation is the view that traits can adopt new functions by evolution without significant changes to structure.[24] Contemporary evolutionary biologists refer to a preadaptation as an "exaptation."[25] I

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[22] Charles Darwin, *The Descent of Man, and the Selection in Relation to Sex* (1871; repr., New Jersey: Princeton University Press, 1981), 107.

[23] Charles Darwin, *On the various contrivances by which British and foreign orchids are fertilized by insects and on the good effects of intercrossing* (London: John Murray, 1862), 348.

[24] Charles Dawin, *On the Origin of Species by Means of Natural Selection or the Preservation of Favored Races in the Struggle for Life* (1859; repr., New Jersey: Wiley-Blackwell, 2004): 179-186.

[25] Stephen Jay Gould and Elizabeth Vrba, "Exaptation: A Missing Term in the Science Form," *Paleobiology* 8, no. 1 (1982): 4-15; Stephen Jay Gould, "Exaptation: A Crucial Tool for an Evolutionary Psychology," *The Society for the Psychological Study of Social Issues* 47, no. 3 (1991): 58-59; David M Buss, et. al., "Adaptations, Exaptations, and Spandrels," *American Psychologist* 53, no. 5 (1998): 533–548.

briefly introduced the concept of exaptation above as a mechanism that can lead to evolution. Now consider the following example. Birds likely evolved from feathered dinosaurs,[26] and the original adaptive function of those feathers included visual signals for mating and insulation for incubation,[27] and then feathers were later exapted for flight.[28] The function of bird feathers changed over time. Following Darwin's general claim about preadaptation, the development of HCAs resembles the development of every other human feature. Although not stated explicitly, Darwin's view suggests that HCAs were the result of the functions of ancestral brain regions, and, comparable to the changing functions of bird feathers, evolution caused these ancestral brain regions to change their functions without significant re-structuring. Utilizing the concept of exaptation for examining the evolution of HCAs depends on several factors regarding natural selection. I comment more on exaptation and natural selection and how this concept applies to this thesis towards the end of this chapter and in chapter five.

A more recent example of how HCAs are the product of evolution by natural selection is from evolutionary biologist Ernst Mayr. Mayr argues that the human brain of roughly 100,000 years ago is the same brain possessed by humans today but with some relevant differences.[29] According to Mayr, one relevant difference between the ancestral human brain and a current human brain is in its functional operations:

> "The brain of 100,000 years ago is the same brain that is now able to design computers. The highly specialized mental activities we see in humans today seem not to require an ad hoc selected brain structure. All the achievements of the human intellect were reached with brains not specifically selected for these tasks by the Darwinian process."[30]

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[26] Louis M. Chiappe, *Glorified Dinosaurs: The Origin and Early Evolution of Birds* (New Jersey: John Wiley & Sons), 2007.

[27] Mark A. Norell, et. al., "A Nesting Dinosaur," *Nature* 378 (1995): 774-776; Mark A. Norell and X. Xu, "Feathered Dinosaurs," *Annual Review of Earth and Planetary Sciences* 33, no. 1 (2005): 277-99.

[28] K. Dial et. al., "A Fundamental Avian Wing-Stroke Provides a New Perspective on the Evolution of Flight," *Nature* 451 (2008): 985-989.

[29] Ernst Mayr, *This is Biology: The Science of the Living World* (Cambridge, Massachusetts: Belknap Press, 1982), 74.

[30] Ibid., 75.

Mayr describes at least two types of brain regions. The first type of brain region is a primitive type of region, which would have existed early in primate brain development. The operations of these primitive brain regions include fixed reflexes and instincts exhibited by "lower animals."[31] The second type of brain region described by Mayr includes the potential for learning and does not exhibit the rigidity of the first type of ancestral brain region. He argues that this second type of brain region would have enabled organisms to acquire information from the world and this information eventually resulted in the production of HCAs. In contrast to both Wallace and Nagel, Mayr argues that no teleological explanation for HCAs is required, but rather a gradual process of evolution by natural selection. That is, Mayr would likely argue that HCAs are analogous to the second castle-like structure, such that its descriptive account includes non-agent causes. He then concludes: "as a result, not only is [the brain] able to cope with the actual challenges that faced primitive humans, but it also has capabilities, such as those required for playing chess, that were not being called upon at the time when these improvements of the brain were selected."[32]

Mayr's view is instructive for two reasons. First, in this project I reject his sharp distinction between ancestral brain regions and higher brain regions. Recall that I will argue that a sharp distinction is misleading. That is because brain regions supporting older ancestral operations have been reused to support HCAs. Second, I would argue that Mayr's rejection of the teleological explanation is too quick. He has not shown that natural selection excludes a teleological/philosophical account – indeed, he has not even supported the descriptive claim about how HCAs could have resulted from natural selection. I return to the philosophical problem later in this introduction when discussing teleological and descriptive accounts of why HCAs are the product evolution.

A more thorough example of an argument for how HCAs are the product of natural selection is from Pinker.[33] Pinker offers two strategies for responding to Wallace's objection.

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[31] Ibid., 75.

[32] Ibid., 76.

[33] Pinker, "The cognitive niche," accessed November 12, 2016, http://www.pnas.org/content/early/2010/05/04/0914630107.full.pdf. Pinker also defends a different evolutionary argument for human language, and comparable to arguments for HCAs, critics of these evolutionary arguments aim to show that natural selection cannot produce

The first strategy refers to cognitive niche construction. To understand this strategy, consider an ecological niche. An ecological niche is a description of the role an organism occupies in an environment.[34] It is understanding the "way of life" of an organism, particularly the organism's fitness-enhancing qualities, such as its behavior and morphology, relative to its environment.[35] For example, unlike many species of bear, which occupy a general ecological niche, in that they live in diverse environments and eat several different types of food, China's panda bear occupies a precise ecological niche, since its diet consists of mostly bamboo. The panda cannot have a way of life without bamboo.[36] So the panda's ecological niche, which includes bamboo, describes the necessary and sufficient conditions for understanding the life of a panda.[37]

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language. As part of his evolutionary argument for language, Pinker notes that language became a necessary adaptation. Objections against the evolutionary arguments for language closely resemble Noam Chomsky's resistance to a Darwinian explanation of the design and incorporation of language. Here Chomsky argues: "In studying the evolution of mind, we cannot guess to what extent there are physically possible alternatives to, say, transformational generative grammar, for an organism meeting certain other physical conditions characteristic of humans. Conceivably, there are none – or very few – in which case talk about evolution of the language capacity is beside the point." See Noam Chomsky, *Language and Mind* (New York: Harcourt Brace, 1972), 98. Stephen Jay Gould agrees with Chomsky, insisting that the evolution of some language faculty is a by-product of evolution; he states: "…The universals of language are so different from anything else in nature, and so quirky in their structure, that origin as a side consequence of the brain's enhanced capacity, rather than a simple advance in continuity from ancestral grunts and gestures, seems indicated." Naturally, others reject Chomsky and Gould's objections. Pinker and Paul Bloom argue that "Many people have argued that the evolution of the human language faculty cannot be explained by Darwinian natural selection. Chomsky and Gould have suggested that language may have evolved as the by-product of selection for other abilities or as a consequence of as-yet unknown laws of growth and form…We conclude that there is every reason to believe that specialization for grammar evolved by a conventional neo-Darwinian process." See Steven Pinker and Paul Bloom, "Natural Language and Natural Selection," *Behavioural and Brain Sciences* 13, no. 4 (1990): 707.

[34] Richard Lewontin, "Adaptation," *Scientific American* 293 (1978): 215.

[35] Ibid., 215. See also Tyler Miller Jr. and Scott E. Spoolman, *Essentials of Ecology*, 5th edition (Belmont: Brooks/Cole, Cengage Learning, 2009), 91.

[36] Miller and Spoolman, *Essentials*, 91-92.

[37] Kevin N. Laland and Gillian R. Brown, "Niche Construction, Human Behavior, and the Adaptive-Lag Hypothesis," *Evolutionary Anthropology* 15, no. 3 (2006): 95–104; De Cruz, "Evolutionary Approaches," 531; Kim Sterelny, "Externalism, Epistemic Artifacts and the

Pinker argues that the same type of ecological niches observed in nature likely occurred with early humans and the way early humans constructed a cognitive niche. A cognitive niche is a mode of survival and describes the human way of life, whereby humans control their environment through reasoning and social interaction.[38] Just as the Panda occupies a precise ecological niche, so humans occupy a precise cognitive niche. The result of developing a cognitive niche is that selective pressure changes. For example, humans who changed their environment by farming no longer experienced the same selective pressure from hunting predators, but rather experienced pressure from the social factors of living within cooperative groups. The important point for Pinker is that living in a cognitive niche would have enabled humans to develop new types of learning.

Pinker's second strategy includes the human ability to perform "metaphorical abstraction." According to Pinker, cognitive operations necessary for projecting concrete beliefs also perform metaphorical abstractions of those beliefs. For example, the sentences "Rose forced the door open" and "Rose forced Sadie to go" differ in their usage of the verb "force." The first sentence describes a concrete idea, while the second illustrates a metaphorical abstraction. Pinker suggests that grammatical faculties utilize concrete descriptions of "force" to then postulate metaphorical abstractions of the same concept. Pinker's claim is that ancestral brain operations would have utilized concrete descriptions and these same concrete descriptions exhibit the potential to realize metaphorical abstractions, particularly within a cognitive niche. That is, once traditional selective pressures had become dormant, the environment would have enabled humans to produce HCAs by metaphorical abstraction.

Pinker's argument for how HCAs are the product of evolution introduces two related issues. The first issue is whether Pinker's strategy can be supported by evidence.[39] Does there

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Extended Mind," in *The Externalist Challenge. New Studies on Cognition and Intentionality* (ed. by Richard Schantz, New York: de Gruyter, 2003).

[38] Pinker, "The cognitive niche," accessed July 2017, http://www.pnas.org/content/early/2010/05/04/0914630107.full.pdf. Pinker's theory rests on the original thesis by J. Tooby and I. DeVore, "The reconstruction of hominid evolution through strategic modeling," in *The Evolution of Human Behavior: Primate Models* (ed. W. Kinzey, SUNY Press: Albany, 1987).

[39] For a brief analysis with the problems with Pinker's thesis, see Jerry Coyne's post, "Did humans evolve to fill a 'cognitive niche,'" accessed May 4th, 2018,

exist evidence for any theory of cognitive evolution generally and Pinker's view in particular?[40] I will explore this first issue of evidence in more detail in a moment. For now, note the second issue with Pinker's thesis related to the problem of evidence.

A second related issue with the problem of evidence just discussed is whether Pinker's thesis illustrates a "just-so-story." The phrase just-so-story often refers to creative causal accounts of a feature. The phrase just-so-story is ubiquitous, both in evolutionary biology and philosophy.[41] One problem with the phrase just-so-story is that it has become ambiguous. The traditional use of the phrase in evolutionary biology applied to a strict adaptationist account of a biological feature.[42] The term "adaptation" refers to a characteristic well-adapted to the environment, enabling the organism to reproduce more offspring than other members in that species.[43] Recall the example of the zebra above. Zebra with adaptations for increased speed will more likely reproduce and pass on those adaptations to their offspring. An adaptationist account of a biological feature is an account that describes how that feature was selected for by evolution. The adaptationist account is a causal story about why that feature exhibited the type of adaptability required for it to be selected. In that context, the phrase "just-so-story" originally

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https://whyevolutionistrue.wordpress.com/2010/05/31/did-humans-evolve-to-fill-a-cognitive-niche.

[40] Lewontin, C. Richard, "The Evolution of Cognition: Questions We Will Never Answer," in *Thinking: An Invitation to Cognitive Science*, second edition, vol. 4 (eds. Daniel N. Osherson and Edward E. Smith. Cambridge: MIT Press, 1998), 124-125.

[41] For commentaries and criticisms of the phrase, see for example David Barash, "An Unevolved Take on Psychology," *The Chronicle of Higher Education*, accessed August 2018, https://www.chronicle.com/blogs/conversation/2012/09/17/an-unevolved-take-on-psychology-from-the-new-yorker; Ernst Mayr, "How to Carry Out the Adaptationist Program?" *The American Naturalist* 121, no. 3. (1983): 324-334; David C. Queller, "The Spandrels of St. Marx and the Panglossian Paradox: A Critique of a Rhetorical Programme," *Quarterly Review of Biology* 70, no. 4 (1995): 485-48.

[42] Stephen Jay Gould and Richard Lewontin, "The Spandrels of San Marco and the Panglossian Paradigm: A Critique of the Adaptationist Program," *Proceedings of the Royal Society of London* 205, no. 1161 (1979): 581-598.

[43] Joseph Travis and David N. Reznick, "Adaptation," in *Evolution: The First Four Billion Years* (eds. Michael Ruse and Joseph Travis Cambridge, Mass: Belknap Press, 2009), 105.

applied to the strict adaptationist view of evolutionary theory, made popular by Stephen J. Gould and Richard Lewontin.[44]

Gould and Lewontin argued that the strict adaptationist view was false and that a variety of evolved characteristics were not adaptations but rather by-products (or spandrels) of other adaptations. The term by-product or spandrel referred to characteristics that did not exhibit any immediate adaptive function but were the side-effect of some other adaptive trait. In other words, according to Gould and Lewontin, not every trait evolved as an adaptation and some traits, such as by-products or spandrels, were mere side-effects of adaptations.

The phrase just-so-story includes other connotations. At times the phrase describes issues of empirical testability.[45] This means that some evolutionary explanations are speculative and cannot be empirically verified, resembling the problem with evidence described by Pinker's thesis above. Although this second definition may apply to the traditional use of just-so-story used by Gould and Lewontin, this is not always the case.[46] And then in other contexts the phrase means "begging the question."[47] To say that a claim begs the question is to say that the claim affirms the conclusion it is meant to support. In the case of just-so-stories, one affirms a conclusion that such-and-such a trait is an adaptation, and then describes a just-so-story assuming the truth of that conclusion.

One goal of this project is to produce evidence from recent work in cognitive science, and specifically neural reuse, to show how HCAs are the product of evolution. If the phrase just-so-

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[44] George C. Williams, *Adaptations and Natural Selection: A critique of some current evolutionary thought* (New Jersey: Princeton University Press, 1966).

[45] Edward A. Wasserman and Thomas R. Zentall, *Comparative Cognition: Experimental Explorations of Animal Intelligence* (Oxford: Oxford University Press, 2006): 123; Jonathan H. Turner, *On the Origins of Human Emotions: A Sociological Inquiry Into the Evolution of Human Affect* (Stanford, California: Stanford University Press, 2000), 84.

[46] For example, Lewontin never challenges the theories of cognitive evolution as "just-so-stories," although he does call them "inventive stories." He merely states that theories of cognitive evolution cannot be confirmed by evidence; see Richard Lewontin, "The Evolution of Cognition," chapter 3.

[47] Noam Chomsky and James McGilvray, *The Science of Language: Interviews with James McGilvray* (Cambridge: Cambridge University Press, 2012), 172.

story refers to the problem of evidence discussed in response to Pinker's view, then I hope to avoid that evidential problem. In addition to providing evidence, I avoid describing an adaptationist causal story of the evolution of human cognition and HCAs. I concede that one may never know the causal story of human HCAs, either by natural selection or some other biological process. Thus, I avoid the first problem with just-so-stories described above in the context of Gould and Lewontin, in that while natural selection and adaptationism may be necessary for explaining how HCAs are the product of evolution, natural selection and adaptationism may not be sufficient for explaining how HCAs are the product of evolution.

A final example of a contemporary argument supporting the claim that HCAs are the product of evolution by natural selection is from philosopher of biology Elliott Sober. In a piece on evolution and rationality, Sober argues that natural selection is sufficient for explaining HCAs, particularly HCAs required for the scientific method.[48] Sober defends this claim against the following objection: "an evolutionary account of the origins of rationality is impossible because natural selection is too coarse-grained a process to single out the scientific method from innumerable other, less rational, procedures for constructing beliefs out of other beliefs."[49]

According to Sober, this objection to the evolutionary account of HCAs and the rationality required for the scientific method makes two assumptions. The first assumption is that brain operations supporting HCAs and the scientific method do not produce reproductive benefit to practitioners; and the second assumption is that the cognitive operations for supporting HCAs hold equal fitness value to the cognitive operations antithetical for supporting HCAs. Therefore, according to Sober, the critic argues that HCAs are likely not the product of evolution by natural selection.

Here I note Sober's assessment of the second assumption briefly and then return to a more detailed discussion of his response to the first assumption. The reason for examining the assumptions in this order is because Sober's examination of the first assumption is helpful for introducing the details of my own argument afterwards.

According to the second assumption of the critic's objection above, the problem with the

[48] Elliot Sober, "The Evolution of Rationality," *Synthese* 46, no. 1: 95-120.

[49] Sober, "The Evolution," 98.

evolution of brain operations for supporting HCAs and the scientific method is that these operations exhibit equal fitness value to brain operations antithetical to HCAs and the scientific method. So, the critic argues that natural selection would not have discriminated between these two types of operations. The question from the critic is why did natural selection choose brain operations for HCAs over brain operations antithetical to HCAs?

In response to this second assumption, Sober considers different inductive beliefs exhibiting equal truth value, and then compares this belief-forming process to how natural selection may have affected different brain operations. Sober considers the predicates "is green" and "is grue," famously described by Nelson Goodman as part of the new riddle of induction.[50] I do not explore the new riddle, or its implications for induction, prediction, and science, but only briefly consider Sober's application of Goodman's thought experiment for addressing the second assumption above.

The predicate "is grue" refers to the fact that before time *t* all emeralds are green, and after *t* all emeralds are blue. The question for Sober is why does one predicate, "is green," gain acceptance as a convention, and the other predicate, "is grue," become rejected, since both could exhibit equal truth value? Why does one affirm that all emeralds are green rather than grue? Now compare this question with the critic's second assumption above: for what reason did natural selection favor one set of brain operations over another, given that both brain operations carry equal fitness value?

According to Sober, the first predicate, "is green," is chosen over the second predicate, "is grue," because the former is simpler. Sober then applies simplicity to the second assumption above. The reason natural selection would have picked out brain operations for HCAs and the scientific method is because those rational inferential capacities were simpler than the irrational inferential capacities antithetical to HCAs and the scientific method. Brain operations of greater simplicity would have been selected for over brain operations that conflicted with simplicity.[51]

Commenting on Sober's view of simplicity and how natural selection would have affected the evolution of brain operations, philosopher of biology Michael Ruse states:

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[50] Nelson Goodman, *Fact, Fiction, and Forecast* (Cambridge, Mass: Harvard University Press, 1955).

[51] Sober, "The Evolution," 109.

> The Proto-human who sat around worrying about grue may have been the better philosopher but it is doubtful that he or she was fitter in the Darwinian sense than the simple minded proto who was satisfied with thinking green.[52]

Ruse argues that the relevant factor for selection would have been selecting those beliefs and behaviors that promote fitness enhancement (i.e. reproductive success), and the beliefs and behaviors that do promote fitness enhancement are the same beliefs and behaviors that cause HCAs. Similarly, according to Sober, simplicity may explain how ancestral cognitive structures evolved and how HCAs for science are the product of those evolved structures.[53]

I do not consider responses to Sober's analysis of the second assumption above. In my view, the more relevant rebuttal to the critic's objection above is Sober's response to the first assumption. Recall that the first assumption of the objection is that brain operations for the scientific method do not incur reproductive benefit to practitioners. The critic's claim is that if evolution were to select for brain operations for HCAs and the scientific method, then these higher operations would have exhibited reproductive success throughout human evolution. But, according to the critic, brain operations supporting HCAs did not produce reproductive success for much of primate evolution. Thus, the critic concludes that evolution did not select for brain operations supporting HCAs and the scientific method.

Sober thinks that this first assumption of the critic's objection distinguishes between two types of brain regions, comparable to Mayr's assessment earlier: practical/ancestral brain regions for improving reproductive success, and impractical/higher brain regions for supporting HCAs.[54]

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[52] Ruse, *The Philosophy of Human Evolution* (Cambridge: Cambridge University Press, 2012), 142.

[53] Ibid., 141-143. See also Hilary Kornblith, *Inductive Inference and Its Natural Ground: An Essay in Naturalistic Epistemology* (Cambridge, MA: MIT Press, 1993), 91. For details on other types of evolutionary arguments for science and induction, see W.V.O Quine, *Ontological Relativity and Other Essays* (New York: Columbia University Press, 1969), 126-7; W.V.O. Quine, "The nature of natural knowledge," in *Mind and Language: Wolfson College Lectures* (Clarendon Press: Oxford, 1975),70; see also Daniel Dennett makes a similar point, see *Darwin's Dangerous Idea: Evolution and the Meanings of Life* (New York: Simon and Schuster, 1995), 491. Pinker, "How the Mind Works," in *Philosophy after Darwin: Classic and Contemporary Readings*, (ed. Michael Ruse; New Jersey: Princeton, 2009), 281.

[54] Sober, "The Evolution," 99.

Sober provides two responses to that distinction for the first assumption. The first response is that he rejects the consequence of the first assumption and argues that even if the antecedent about the two types of brain operations were true, it would not follow that natural selection failed to select for brain regions for HCAs. His reason for rejecting the consequence includes the concept of pleiotropy. According to pleiotropy, a mutation in a single gene can affect multiple phenotypic expressions.[55] A phenotypic expression refers to the physical features and behaviors that organisms acquire from their genetic blueprint (the genotype). A single gene can be the cause of two different physical features, one of which was selected for because of its *practical* fitness value, and the other *impractical* phenotypic expression gets "carried along for the ride." So, evolutionary processes can accommodate higher brain regions for HCAs, even if these regions remain impractical.

His second response to the assumption is that he rejects the distinction between brain regions altogether. Sober argues that evolution selected for one set of brain regions which carried out both practical behavior and impractical behavior.[56] While most of primate evolution would have favored practical behavior, those same practical brain regions could have supported HCAs.

Notice that Sober's second response resembles my own strategy. Although at the time Sober would have been unaware of the evidence from current cognitive science and how the operations of ancestral brain regions were reused for supporting HCAs, his conceptual analysis appears correct. Part of my strategy then is to develop a conclusion comparable to Sober's second response to the critic's objection but with additional evidence from cognitive science generally and neural reuse in particular.

Let me take a moment to summarize this history of arguments for why HCAs are the product of evolution by natural selection and then re-state the general features for my own strategy. To reiterate the problem: according to Pinker, the problem with explaining human cognition includes the problem of how evolutionary processes – and natural selection in particular – could explain human higher abilities, such as the HCAs for logic and math. When summarizing the history of these arguments, a primary feature included natural selection as the

[55] Zimmer and Emlen, *Evolution*, 170.

[56] Ibid., 100

only mechanism for explaining HCAs. This claim about the sufficiency of natural selection for explaining HCAs now requires additional comment.

Note again that the first problem with just-so-stories included the response by Gould and Lewontin towards the strict adaptationist account of evolutionary theory. If we apply the adaptationist account of evolution to the argument for HCAs, then HCAs are adaptations forged by natural selection and this view is in line with Pinker's argument. As stated in response to Pinker, my primary strategy avoids a strict adaptationist view, since while natural selection may be a necessary condition for the development of HCAs, natural selection may not be sufficient. Perhaps other processes of evolution besides natural selection contributed to the development of HCAs.

Identifying natural selection as a necessary condition for the evolution of HCAs is important because it specifies the scope of natural selection. Specifying the scope of natural selection refers to what extent natural selection contributed to the evolution of higher abilities. Even though my primary strategy does not commit to the view that natural selection is a sufficient condition for the development of HCAs, the strategy from neural reuse may suggest that natural selection is a sufficient condition for HCAs. Throughout this project I will discuss three strategies for understanding the evolution of HCAs and how HCAs align with natural selection.

According to the first strategy, neural reuse is an outcome of evolutionary processes, including but not limited to natural selection. As stated above, the first strategy does not commit to natural selection as a sufficient condition for explaining HCAs but a necessary condition for explaining HCAs and is the primary strategy adopted in this project. According to the second strategy, natural selection is both a necessary and sufficient condition for explaining HCAs in that evolution selected for a brain for reuse. The entire reusable brain is the adaptation. Even though this second strategy is not the primary strategy adopted in this project, I will outline provisional evidence at the end of chapter two supporting this second strategy. The third strategy states a stronger claim than the second one. According to the third strategy, not only was natural selection sufficient for explaining HCAs, but HCAs are adaptations described by evolutionary psychology and modularity theories of the brain. Evolutionary psychology is the view that the mind has been shaped by evolution by natural selection.[57] Moreover, according to some proponents of evolutionary psychology, the mind and brain includes distinct modules for specific functions and these modules are adaptations selected for by evolution.[58] For example, language is instantiated by a language module and that module is an adaptation selected for by evolution.[59] Pinker's thesis adopts this third strategy and it continues to influence arguments attempting to explain evolution and HCAs. Furthermore, as we shall see in chapter five, Nagel assumes that the best candidate for explaining HCAs is the third strategy. The reason I focus on the first strategy only is because unlike strategies two and three, the first one describes an evolutionary account that does not rely on a causal story and is therefore less controversial than the other two strategies.

A second feature of the history of the arguments about evolution and HCAs is exaptation. Recall that exaptations are old traits that may have been selected for by evolution for a new function.[60] The difficulty with describing HCAs as exaptations is that exaptations may be defined as evolved adaptations. That is, according to some biologists and philosophers, exaptations just are adaptations.[61] Thus, if the concept of exaptation falls within the concept of natural selection, such that exaptations just are adaptations, then describing HCAs as exaptations assumes the adaptationist view. If exaptations are not adaptations selected for by evolution, then describing

[57] Although more recent accounts do not commit to natural selection as the only cause. For a recent summary of evolutionary psychology, see Clark Barrett, *The Shape of Thought: How Mental Adaptations Evolve* (Oxford: Oxford University Press, 2015), 13. For objections, see Steven Quartz, "Toward a Developmental Evolutionary Psychology: Genes, Development, and the Evolution of the Human Cognitive Architecture," in *Evolutionary Psychology: Alternative Approaches* (eds. Steven J. Scher and Frederick Rauscher; Dordrecht: Kluwer, 2003), 185–210; for responses see Edouard Machery, "Massive Modularity and Brain Evolution," *Philosophy of Science* 74, no. 5 (2007): 825-838.

[58] For a recent summary of this view, see Leda Cosmides & John Tooby "Evolutionary Psychology: A Primer," accessed November 16, 2018, https://www.cep.ucsb.edu/primer.html.

[59] See footnote 33.

[60] Zimmer and Emlen, *Evolution*, 103.

[61] Daniel Dennett, *Darwin's Dangerous Idea*, 281; Greger. Larson et. al, "Exapting Exaptation," *Trends Ecol. Evol* 28, no. 9 (2013): 497-498; Aditya Barve and Andreas Wagner, "A latent capacity for evolutionary innovation through exaptation in metabolic systems," *Nature* 500 (2013): 203-206.

HCAs as exaptations does not assume the adaptationist view. I avoid using the term exaptation to describe HCAs. The reason is because it remains an open question whether or not exaptation is a category of natural selection and the adaptationist view of evolution, and since my position does not commit to the adaptationist view of evolution.

A third feature from the history of the arguments described above is the distinction between brain regions for ancestral actions and brain regions for HCAs. Here two comments are required, a definition of "brain region" and a comment on the distinction. The term "brain region" is used loosely both in the literature and in this thesis. Brain regions in cases of neural reuse refer to anatomical structures of the brain. Even though brain regions may be designated by their functional description, that functional description does not imply functional individuation of brain regions. In cases of reuse, brain regions are always individuated anatomically. For instance, the brain region called Broca's area (or Broca's region) is a functional description of that region, referring to the function of speech. However, even though the term Broca's area describes function, the actual designation is anatomical, instantiated by Broadmann's areas 44 and 45. Moreover, when I discuss sub-cortical regions of the brain, such as the basal ganglia and the cerebellum, these structures I also refer to as brain regions. So, whenever the term brain region is being used, even if described functionally or as a sub-cortical structure, that description refers to the anatomy of the brain region and not the function of the brain region.

Regarding the distinction between ancestral brain regions and regions for HCAs, as discussed above in response to the views of Mayr and Sober, I deny the sharp distinction between ancestral brain regions and higher brain regions. The brain operations supporting older, ancestral actions such as perception and motor control resemble the brain operations supporting HCAs. By rejecting the relevant distinction between the two types of brain regions and operations, the inference to a gradual process of change between older evolved operations and HCAs becomes more feasible.

A final note on the history of the arguments for HCAs is the lack of evidence supporting these arguments. Recall that the second problem associated with the phrase just-so-stories included the view that just-so-stories lack evidence. Just-so-stories are unsupported stories about such-and-such a feature. This is a relevant criticism of the history of the arguments for the evolution of HCAs. Darwin admits that he lacks evidence for his argument and Mayr offers meager evidence for his view. Pinker's thesis, while thought-provoking, may not be established by evidence.[62] And Sober's analysis appears more conceptual than empirical. What is missing from these accounts is an evidential defense.

A strategy in this project, then, is to add to this historical account of these arguments for the evolution of HCAs, from Darwin and Mayr to Pinker and Sober, and suggest that recent evidence from cognitive science favors the evolutionary view of HCAs. With this history and context in mind, I now introduce my own strategy for defending an argument for the evolution of HCAs, which will then be explicated in later chapters.

The central feature of my argument for the evolution of HCAs is a concept called neural reuse. Neural reuse describes the functional architecture of the brain such that brain regions can be reused for carrying out different operations.[63] A brain region producing one type of operation can be recruited for supporting another type of operation. Aligning with the first strategy of understanding HCAs and natural selection, neural reuse is an outcome of evolution, including but not limited to the process natural selection. That is, evolution by natural selection produced a brain with the capacity for reuse.

To understand neural reuse by analogy, imagine an airline network.[64] Nodes illustrate airports to which the airline connects, and lines between the nodes illustrate the connections between airports. Note two relevant points. The first point is that as the airline develops a larger network between airports, this network enables the airline to carry out more complex routes. An extensive network of airports provides greater potential for realizing complicated routes than a limited network of airports. The second point is that a single airport within a complex network may operate in different ways depending on the features of that airport and the circumstances affecting the airport. Under normal circumstances, certain airports within the network provide the stability for an airline to carry out more complex routes. Under different circumstances, however, those same airports may operate in a variety of ways, for instance, providing emergency landings, fire and rescue, repairs, rentals, housing, connecting with other airline

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[62] See footnote 39 above.

[63] Michael L. Anderson, "Neural Reuse: A fundamental organizational principle of the brain," *Behavioral and Brain Sciences* 33, no. 4 (2010): 245-266.

[64] Michael L. Anderson, *After Phrenology*, 12; Melanie Mitchel, "Complex Systems: Network Thinking," *Artificial Intelligence* 170, no. 18 (2006): 1194–1212.

networks, and so on. The features of an airport and how that airport situates within a broad airline network may determine how that airport functions in different ways and in varying circumstances. Thus, to restate the two main points in the analogy: networks provide greater potential for performing complex tasks, and individual units within the network may contribute in different ways depending on the features of that unit and the circumstances affecting those units.

According to neural reuse, the brain resembles the airline network in that airports represent brain regions and connection lines between airports represent the functional partners between brain regions. Recall the two main points used in the airline analogy. First, as the brain develops more complex neural networks, the brain exhibits greater potential for generating more complex tasks. For instance, language requires an extensive neural network, while more ancestral abilities such as perception may not. Second, individual brain regions may contribute to various operations because of the features of those brain regions and the circumstances affecting those brain regions. A single brain region may contribute to a variety of cognitive abilities by reusing its resources with different regional partners. In short, comparable to the airline, neural reuse is the view that the brain is a dynamic network and regions within the network contribute to many diverse functions in a variety of circumstances.

My argument for the evolution of HCAs includes two steps. The first step is neural reuse. I argue that the operations of ancestral brain regions, such as perception and motor control, have been reused for carrying out HCAs. The second step includes an inference from the reuse of older brain regions for carrying out HCAs to affirming the conclusion that HCAs are the product of evolution. To describe my strategy with a bit more precision, consider the following argument:

1. Brain regions xyz evolved.
2. Brain regions xyz have been reused for carrying out HCAs.
3. So, brain regions xyz evolved and have been reused for carrying out HCAs.
4. If brain regions xyz evolved and have been reused for carrying out HCAs, then HCAs are the product of evolution.
5. So, HCAs are the product of evolution.

Some general points are required here. Throughout the next three chapters I will attempt to defend the main premises of this argument. For instance, in this project I do not defend premise (1) besides pointing out that brain regions xyz refers to brain regions carrying out ancestral operations, such as perception and motor control. The reason I do not address this premise is that Wallace – and Nagel, to some extent – agree with that premise. In chapters two and three, I defend premise (2) by stating and evaluating the evidence for neural reuse. I discuss the fourth premise in chapter four. I defend premise (4) by constructing two sub-arguments, the first utilizing the hypothetico-deductive model of scientific confirmation, and the second utilizing the inference to the best explanation, both of which will be explained in that chapter. In the final chapter, I consider objections by Wallace and Nagel and then offer some responses to those objections.

A quick note on premise (4). Recall that the objection from Wallace and Nagel is that HCAs likely did not result from evolution. One difficulty with this objection is that it is ambiguous and can refer to either a *descriptive* position or a *teleological* position, or a combination of both. This distinction between the descriptive and teleological positions was introduced above using the sand castle analogy. As we shall see in chapter five, Wallace and Nagel often combine (or conflate) the descriptive and teleological views of HCAs and for clarity these two views should be explained in greater detail.

This project focuses on the *descriptive* account of HCAs only and not the *teleological* one. The descriptive objection is that HCAs cannot be the product of evolutionary processes. The current project is an attempt to respond to this descriptive objection. This type of descriptive objection resembles traditional criticisms about the evolution of the vertebrate eye.[65] At one point, the claim was that evolutionary processes generally – and natural selection in particular – could not explain the development of the eye and thus another descriptive process was required, either as a replacement or a supplement to natural selection.[66] According to the critic, the descriptive version of the evolution of HCAs suffers from a similar problem to the evolution of the vertebrate eye.

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[65] Charles Darwin, *The Origin of Species*, 227.

[66] See Richard Dawkins, *The Blind Watchmaker* (London: Penguin Books, 1986), 77-78.

The teleological objection against the evolution of HCAs is different in that even if HCAs are the product of evolution, the descriptive processes of evolution remain insufficient for a complete explanation of HCAs. According to this broader philosophical objection, what is required in addition to the descriptive processes of evolution is another teleological explanation for HCAs. The reason for this teleological objection is because of the nature of HCAs, including mental content, intentionality, consciousness, qualia, and so on. The critic affirming the teleological objection claims that HCAs exhibit unique qualities that cannot be fully understood in descriptive terms. Recall the example of the first sand castle above. Even if one explains the causal processes for creating the first sand castle, such as buckets, shovels, and a design plan, the first castle is the type of thing that requires additional explanation, such as an agent with intentionality. For critics like Wallace and Nagel, HCAs are a type of thing that requires additional teleological consideration. For them, HCAs are analogous to the first type of sand castle and dis-analogous with the second type of castle-like structure.

With this distinction between the descriptive view and the teleological view of HCAs in place, return now to premise (4) above: "*If brain regions xyz evolved and have been reused for HCAs, then HCAs are the product of evolution*." According to the teleological objection, even if the antecedent and consequent were true, that conditional would not fully explain the existence of HCAs. The premise may explain the descriptive claim about HCAs but would fail to explain the broader philosophical issues pertaining to the full realization of HCAs. As stated, I do not consider the force of the teleological objection but focus solely on establishing the descriptive claim about the evolution of HCAs.

Given this strategy of focusing on the descriptive view of HCAs and not the teleological view, for some there may exist additional concerns regarding the project's aim and method. The concern may question whether the current project is overly scientific. I will argue that although I address only the descriptive claims about HCAs, this project remains philosophical for a variety of reasons, including how philosophical analysis clarifies the assumptions about science, in this case both evolutionary biology and cognitive science.

Mayr argues that the tools of philosophy contribute to a more precise understanding of biology and evolutionary theory.[67] In his review of Sober's work, *The Nature of Selection: Evolutionary Theory in Philosophical Focus*, Mayr examines the philosophical rigor required for clarifying terms misunderstood by biologists, such as causation, tautology, chance, explanation, reduction, and correlation.[68] Mayr establishes this point because "hidden assumptions have been the bane of all scientific controversies," and philosophical analysis can uncover and address these hidden assumptions.

Another example illustrating the value of philosophical analysis is with the synthesis of ideas between science and philosophy. For example, philosophers recently developed a distinction between the philosophy of science (and by extension the philosophy of biology) with the philosophy of nature. In his book, *Darwinian Populations and Natural Selection*, Peter Godfrey-Smith highlights this distinction between philosophy of science and the philosophy of nature, suggesting that philosophy of science is about the scientific method, its strategy, assumptions, how it works, and what it aims to achieve, while the philosophy of nature is about humanity's place within nature, and how scientific data can inform a philosophical understanding of human nature.[69]

In a more recent work that captures similar themes to those presented by Godrey-Smith, in the book *The Evolved Apprentice*, philosopher Kim Sterelny draws similar conclusions, arguing that the philosopher's tool kit contributes to the synthesis of several research traditions, by using arguments from both philosophy and science to integrate various ideas.[70] The idea of

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[67] Ernst Mayr, "The Nature of Selection," *Paleobiology* 12, no. 2 (1986): 233-239; Ernst Mayr, "The Autonomy of Biology: The Position of Biology Among the Sciences*," The Quarterly Review of Biology* 71, no. 1 (1996): 97-106.

[68] Mayr, "The Nature of Selection," 233-234.

[69] Peter Godfrey-Smith, *Darwinian Populations and Natural Selection* (Oxford: Oxford University Press, 2009), 2.

[70] Kim Sterelny, *The Evolved Apprentice* (Cambridge, Massachusetts: MIT Press, 2012), xi. The claim more generally that philosophy contributes to science in this way is captured by philosopher Dan Dennett: "There is no such thing as philosophy-free science; there is only science whose philosophical baggage is taken on board without examination." Dennett, *Darwin's Dangerous Idea*, 21.

synthesis is relevant in the current project because, as discussed already, the evolution of HCAs introduces both descriptive and teleological concerns.

This type of philosophical analysis and synthesis also applies to the field of cognitive science. Cognitive science is an interdisciplinary study on the workings of the human mind.[71] Philosophy contributes to cognitive science by both analyzing the general concepts used in cognitive science, many of which remain ambiguous,[72] as well as highlighting the assumptions in cognitive science. According to cognitive scientist Michael Anderson, one of the guiding assumptions within current cognitive science is that the functional architecture of the brain is composed of highly discrete, domain specific, individually functioning parts and this assumption in cognitive science affects empirical studies utilizing fMRI methods.[73] Here Anderson quotes cognitive scientist Russell Poldrack:

> Imagine that fMRI have been invented in the late 1860's rather than the 1990's. Instead of being based on modern cognitive psychology, neuroimaging would instead be based on the faculty psychology of Thomas Reid and Dugald Steward, which provided the "mental faculties" that Gall and the phrenologists attempted to map onto the brain. Researchers would…almost certainly have found brain regions that were reliably engaged when a particular faculty was engaged…and Gall and his contemporaries would have taken these neuroimaging results as evidence for the biological reality of his proposed faculties.[74]

One point in the quote is that past assumptions about the structure and function of the brain – in this case, Reidian faculty psychology – could have been supported by contemporary fMRI. Even though the guiding assumption about Reidian faculty psychology has proven inadequate, this assumption can be empirically verified to a degree with contemporary methods. This suggests that neuroimaging alone remains insufficient for providing an accurate picture of the structure

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71 For an introduction, see Paul Thagard, *Mind: Introduction to Cognitive Science,* 2nd edition (Cambridge, Mass: MIT Press, 2005).

72 Andrew Brook, "Philosophy in and Philosophy of Cognitive Science," *TopiCS in Cognitive Science* 1, no. 2 (2009): 216-230.

73 Michael L. Anderson, *After Phrenology,* xiii-xiv.

74 Russell Poldrack, "Mapping Mental Function to Brain Structure: How Can Cognitive Neuroimaging Succeed?" *Perspect Psychol Sci* 5, no. 5 (2014): 753-761.

and function of the brain.[75] In addition to neuroimaging, one must postulate an assumption about the structure of the brain and the functional architecture of the mind and how those assumptions guide the empirical work.[76] If the guiding assumption were false or inaccurate, then the false assumption would undermine empirical work in cognitive science. Philosophical analysis influences future empirical work by developing and evaluating guiding assumptions and therefore philosophical analysis remains indispensable for contributing to cognitive science.

Consider one example of how philosophical analysis clarifies assumptions utilized in cognitive science. One attempt to describe a guiding assumption in cognitive science includes identifying "cognitive ontologies." Poldrack argues that current "Neuroimaging studies rely upon a theory about the structure of the mind that specifies the component operations that comprise mental function, which I will refer to as a cognitive ontology." This attempt to describe a guiding assumption is confusing because of the term "ontology."

The term "cognitive ontology" refers to classifying mental functions and is often used by cognitive scientists. The problem is that the term "ontology," as it is used by cognitive scientists, differs from the metaphysical definition of "ontology" often used by philosophers, and this difference creates confusion, particularly when discussing concepts within the philosophy of mind. According to the metaphysical view of ontology, ontology denotes being and is the study of what exists.[77] To highlight the confusion of the term "ontology" and offer some brief clarification, I will capitalize the term "Ontology" to denote the metaphysical definition and maintain the lower-case "ontology" to denote the definition from cognitive science.

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[75] In fact, recent studies have challenged the accuracy of neuroimaging studies, particularly how these studies cannot capture the full complex operations of brain activity during cognitive tasks. For this study, see Benjamin Kubit and Anthony I. Jack, "Rethinking the role of the rTPJ in attention and social cognition in light of the opposing domains hypothesis: findings from an ALE-based meta-analysis and resting-state functional connectivity," *Frontiers in Human Neuroscience* 7 (2013), accessed July 2018, https://www.sciencedaily.com/releases/2013/07/130710114221.htm

[76] Anderson, *After Phrenology*, xiv.

[77] Peter van Inwagen and Dean W. Zimmerman, *Metaphysics: the big questions*, 2nd edition (Oxford: Blackwell, 2008), 1-2.

Suppose that one is a physicalist about the mind. This means that mental function supervenes on, or is identical to, physical brain states. The physicalist views the mind such that the deeper Ontological structure of the mind is physical, not mental. The cognitive scientist who also endorses physicalism aims to identify cognitive ontologies about mental function, while also affirming that the Ontological structure of the brain is physical. On the other hand, suppose that one is a non-physicalist about the mind, such that the Ontological structure of the mind is non-physical. The cognitive scientist who embraces a non-physicalist view of the mind will aim to identify cognitive ontologies about mental function, while also affirming to an Ontology of the mind that is non-physical. One way to avoid this confusion about ontology within cognitive science is to adopt a more appropriate term to represent this goal of cognitive science. If cognitive ontology just means cognitive taxonomy, then perhaps cognitive scientists should use the term taxonomy. The project of identifying cognitive ontologies then becomes identifying and constructing cognitive taxonomies. This clarification avoids the metaphysical baggage associated with the traditional usage of Ontology as defined by philosophers.

The main point is that assumptions about the nature of the brain and mind, and how scientists describe those assumptions, may create confusion and influence empirical work. As noted with previous studies,[78] if the assumptions remain unchecked, then neuroimaging may fail to establish the correct results.[79] The tools of philosophical analysis provide clarity about those assumptions and their descriptions. Thus, resembling the philosophy of biology and philosophy of nature, philosophical analysis is indispensable for examining scientific claims in the field of cognitive science.

Another issue that may arise regarding the method and aim of this project is whether a focus on evaluating the theories of human cognitive evolution matters. Why not focus on the brain as it exists currently and ignore the evolutionary development of the brain? In response, I would argue that evaluating the merits of the theories of cognitive evolution and HCAs contributes to a current view of the human brain in two ways: by constraining the guiding

[78] Poldrack, “Mapping Mental,” 753-4.

[79] Anderson, *After Phrenology*, xiv-xxi.

assumption in cognitive science, and by reinforcing the bottom-up approach to studying animal and human cognition.

The first way is that the theories of cognitive evolution may support or undermine the guiding assumption within cognitive science. As just discussed above, the guiding assumption of cognitive science is relevant for the empirical work, often work utilizing neuroimaging studies. One example of a guiding assumption guiding empirical work is massive modularity.[80] Roughly, massive modularity is the view that the anatomical structure of the brain is composed of discrete, domain specific, encapsulated, highly specialized, and dissociable parts.[81] Although the idea of massive modularity will surface throughout, I do not consider the details of the massive modularity thesis, specifically its wide-ranging definitions and objections. The point rather is that proponents of massive anatomical modularity argue that one reason for preferring the modularity theory of the brain is that non-modular brains could not have evolved. So, a theory of cognitive evolution – i.e. that only modular brains could have evolved – supports a guiding assumption within cognitive science influencing empirical work. While I consider the evolution of a non-modular brains in chapter two, a brief note about the evolution of modular and non-modular brains is relevant here.

Peter Carruthers argues that modularity is a "pre-requisite" for evolvability, since the "properties of modules are to some significant degree independent of one another, both they and the developmental pathways that lead to them can have distinctive effects on the overall fitness of the organism."[82] Carruthers's point is important for how an evolutionary development of the brain contributes to the guiding assumption within cognitive science. If Carruthers is right about modularity as a pre-requisite for human cognitive evolution, then human cognitive evolution could not have produced non-modular brains. If the view of the modular brain is correct, researchers should avoid guiding assumptions about non-modular brains. Naturally, the opposite

[80] Max Coltheart, "Assumptions and methods in cognitive neuropsychology," in *The handbook of cognitive psychology* (ed. Brenda Rapp; Oxford: Psychology Press, 2001), 9-10.

[81] For discussion, see Vincent Bergeron, "Anatomical and functional modularity in cognitive science: Shifting the focus," *Philosophical Psychology* 20, no. 2 (2007): 175-195.

[82] Peter Carruthers, *The Architecture of the Mind: Massive Modularity and the Flexibility of Thought* (Oxford: Oxford University Press, 2014), 14.

claim would also apply. In contrast to Carruthers's view of evolution and modularity, suppose that (a) non-modular brains could have evolved, and (b), that modular brains could not have evolved. If both (a) and (b) were supported by evidence, then that evidence would undermine the massive modularity thesis and thus undermine the current guiding assumption within cognitive science influencing empirical work. If the modularity thesis about the anatomical structure of the brain does not align with evolution, then it cannot align with the broader context of human evolution and should be discarded.[83] It could be that the neuroscientific experiments which assume massive modularity fail to provide correct empirical results. Therefore, the first reason cognitive evolution is important for cognitive science is that examining the evolution of human cognition constrains the assumptions guiding cognitive science. The theory of cognitive evolution may support or undermine current neuroimaging studies.

The second reason cognitive evolution contributes to cognitive science is that these theories encourage an emerging method for conducting cognitive science. Specifically, studying the evolution of HCAs may require a bottom-up approach and not a top-down approach to understanding cognition and HCAs. The top-down approach includes describing a higher-cognitive ability, such as the human ability to count, and then examining whether or not other species exhibit that higher ability.[84] The top-down approach distinguishes between humans and other species in that it focuses on the "unique outcome" of a cognitive capacity, while ignoring the similarities between species that gave rise to that outcome. The position ignored in this case includes the bottom-up approach.

According to the bottom-up approach, the focus is on the building blocks of HCAs and less on comparing various cognitive abilities.[85] Consider again the human ability to count. The bottom-up approach does not observe whether other species besides humans exhibit the ability to count, but rather notes the general capacities for counting, and then assesses whether or not other

[83] See Barrett, *The Shape of Thought*, 3-7; Steven Mithen, *The Prehistory of the Mind: The Cognitive Origins of Art, Religion, and Science* (New York: Thames and Hudson, 1996), 7.

[84] Frans de Waal and Pier Francesco Ferrari, "Towards a bottom-up perspective on animal and human cognition," *Trends Cogn Sci* 14, no. 5 (2010):201-7, accessed June 2016, https://www.ncbi.nlm.nih.gov/pubmed/20363178.

[85] Frans de Waal and Pier Francesco Ferrari, "Towards a bottom-up," 21.

species display those general capacities.[86] What this bottom-up approach would show is that a variety of species possess the cognitive infrastructure for counting, and that this infrastructure gave rise to counting within a unique human context. Therefore, while the ability to count may exhibit a unique status amongst humans because of a relevant context, the cognitive machinery responsible for that status is not unique to humans. The bottom-up approach is the method assumed in this project. To say that the operations of ancestral brain regions carry out the operations for higher abilities assumes the bottom-up approach to understanding cognition.

This project includes four additional chapters and one interlude. As discussed above, the chapters address the main issues involving neural reuse and the inferences necessary for affirming the conclusion that HCAs are the product of evolution. In chapters two and three, I defend premise (2) of the argument. In particular, I discuss the theory of neural reuse and how neural reuse establishes the connection between ancestral cognitive operations and higher cognitive operations. Chapter two includes two parts. The first part of chapter two outlines the evidence for neural reuse and one version of reuse called neural recycling. In the second part of chapter two, I explore how reuse aligns with evolution and some of the objections to this view.

In chapter three, I examine additional evidence for neural reuse in support of premise (2). Here I discuss two types of experiments. The first type explores the relations between various ancestral functions with higher functions. The second type of experiments explore sub-cortical regions of the brain, such as the basal ganglia and the cerebellum, which are anatomically distinct from the cortex. I discuss recent evidence that both the basal ganglia and the cerebellum support HCAs.

In chapter four, I outline the reasons for affirming premise (4) of the argument. Here I discuss two models of scientific confirmation and explanation. These models are important for establishing how one infers from the observation of neural reuse to the conclusion that HCAs are the product of evolution. The first model is the hypothetico-deductive model of confirmation. According to this model, one generates a hypothesis which entails an observation. If one can test the observation successfully, then this test confirms the hypothesis. I will show how neural reuse confirms the hypothesis that HCAs are the product of evolution. The second model is called

[86] A. Nieder and S. Dehaene, "Representation of number in the brain," *Annu. Rev. Neurosci* 32 (2009): 185-208.

Inference to the Best Explanation. According to this model of explanation, confirmation obtains in a different way. One starts with a set of observations, and then infers which hypothesis, if true, would best explain those observations. I argue that evolution, if true, would best explain the observation of neural reuse recruiting older evolved brain structures for higher cognitive use.

In chapter five, I briefly review the main premises of my argument for the evolution of HCAs and then assess broader objections by Wallace and Nagel. I will argue that these critics make two crucial moves. First, they distinguish between older brain regions for ancestral actions and higher brain regions for HCAs, comparable to Mayr's distinction above. As I have suggested, there is no relevant distinction between these two types of brain regions and therefore this objection fails. Second, critics affirm the broad scope of natural selection, such that natural selection is a sufficient mechanism for explaining HCAs. I argue that while this assumption about the sufficiency of natural selection applies to other types of strategies, such as strategies two and three, the critic's assumption about natural selection does not apply to the first strategy that I adopt in this project.

The interlude includes background content that, while not necessary for understanding the main project, briefly introduces additional philosophical issues relevant to the topic. Recall the difference between the teleological objection and the descriptive objection to explaining the development of HCAs. As stated, this project focuses on providing an argument of the descriptive variety and not the teleological variety. The Interlude is meant to delineate a philosophical perspective. The example I provide is from Alvin Plantinga's Evolutionary Argument Against Naturalism. I use this example for two reasons. The first reason for outlining this argument is because critics of Plantinga's argument often assume that it represents a descriptive objection when it represents a teleological objection. This confusion illustrates how often theorists conflate the descriptive and teleological views of cognitive theories of evolution. A second reason for introducing this argument is that neural reuse may challenge the first premise of Plantinga's argument. This second reason is interesting because neural reuse may address a variety of philosophical problems pertinent within the philosophy of mind that often assume the third method of understanding HCAs and natural selection.

# Chapter Two

## Neural Reuse: Defense of Premise (2)

As stated in the introduction, one problem with understanding human cognition is noting how human higher abilities could have been the product of evolution. In this chapter and the next, I examine the theory of neural reuse to better understand how higher cognitive abilities (HCAs) are the product of evolution. Neural reuse is important for supporting the evolutionary view of HCAs because reuse would demonstrate how HCAs could have been realized by the operations of more ancestral brain regions. In the first section, I describe neural reuse and one version of reuse called neural recycling. The purpose of this section is to introduce reuse, its predictions, and the evidence supporting these predictions. In the second section, I explore how neural reuse aligns with evolution. Aligning neural reuse within evolution is important because if reuse were in conflict with the theory of evolution, then that conflict would undermine neural reuse.

### I. Neural Reuse: Predictions and Evidence

Neural reuse is the idea that the brain is a network that uses the same brain regions within that network for contributing to different cognitive functions in varying circumstances.[87] Recall the analogy in the introduction describing an airline network.[88] The brain resembles the airline network in that airports represent brain regions and connection lines between airports represent the functional partners between brain regions. Note the two relevant points used in the airline analogy. First, as the brain develops more complex neural networks, the brain exhibits potential for producing more complex functions. Second, individual brain regions may contribute to various cognitive functions because of the features and circumstances affecting those brain regions. Thus, neural reuse is the view that the brain is a dynamic (i.e. changing) network and regions within the network contribute to many diverse functions.

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[87] Michael L. Anderson, *After Phrenology: Neural Reuse and the Interactive Brain* (Cambridge, Mass.: MIT Press, 2014), 5.

[88] Anderson, *After Phrenology*, 12; Melanie Mitchel, "Complex Systems: Network Thinking," 1194–1212.

One example of neural reuse is the brain region called Broca's area.[89] While one view of the function of Broca's area is that it contributes to language and speech,[90] more recent evidence suggests that Broca's area contributes to a broader neural network, participating more often in non-language abilities, including movement preparation.[91] Utilizing the two points made from the airline analogy above, Broca's area is a region that (i) exists within a larger neural network that enables the brain to carry out more complex behaviors; and (ii), Broca's area is a brain region that under varying circumstances contributes to different cognitive functions, from movement preparation to linguistic ability.

It is important to note how reuse functions in the case of Broca's area. The claim is that Broca's area already performed operations for movement preparation and then was later coopted to include operations for language. That is, movement preparation, as well as other sensorimotor functions produced by Broca's area, were the precursors for language to develop. In addition to this first instance of reuse for language, other studies indicate that Broca's area contributes to musical abilities.[92] Accordingly, while it is possible that music is the result of reusing sensorimotor capacities within Broca's area, it is also possible that music is the result of the linguistic capacities that were first reused by Broca's area.[93] According to this latter view of neural reuse, Broca's area initially functioned for movement preparation, was then reused for linguistic ability, and then these linguistic abilities were reused again for musical abilities.

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[89] Michael L. Anderson and Luiz Pessoa, "Quantifying the diversity of neural activations in individual brain regions," *Proceedings of the 33rd Annual Conference of the Cognitive Science Society* 33 (2011): 2421-2426.

[90] Daniel L. Schacter, Daniel T. Gilbert, Daniel M. Wegner, Matthew K. Nock, Ingrid Johnsrude, *Psychology, 3rd Canadian Edition* (New York: Worth Publishers, 2014), 362.

[91] Russell Poldrack, "Can cognitive processes be inferred from neuroimaging data?" *Trends in Cognitive Science* 10, no. 2 (2006): 59-63; see also Y. Grodzinsky and A. Santi, "The battle for Broca's region," *Trends in Cognitive Sciences* 12, no. 12 (2008): 474-480; P. Hagoort, "On Broca, brain and binding," *Trends in Cognitive Sciences* 9, no. 9 (2005): 416-423; M. Tettamanti and D. Weniger, "Broca's area: a supramodal hierarchical processor?" *Cortex* 42, no. 4 (2006): 491-494.

[92] B. Maess, S. Koelsch, T.C Gunter, and A.D Friederici, "Musical syntax is processed in Broca's area: An MEG study," *Nature Neuroscience* 4, no. 5 (2001): 540-545.

[93] Anderson, *After Phrenology*, 27-28.

The example of Broca's area illustrates neural reuse. If neural reuse were true, then one would predict the following three things.[94] The first thing is that brain structures would be used and reused for a variety of cognitive functions and not exhibit limited specialization. The second prediction is that a given brain region being reused will partner with different regions for carrying out different functions. The third prediction is that more recent cognitive abilities would be supported from other brain regions more broadly. Recent evidence from cognitive science supports these three predictions.

Evidence for the first prediction includes examining reuse at various levels of the brain, such as the cortex, basal ganglia, and cerebellum.[95] Recent studies examined 78 regions of the brain to determine their selectivity (i.e. specificity) by observing over one-thousand experimental tasks in 11 cognitive domains.[96] An experimental task is a test whereby participants engage in cognitive activities, such as responding to visual cues and pushing buttons, and then experimenters collect data, often using neuroimaging techniques (e.g. fMRI). Neuroimaging techniques involve assessing neuronal activity in various regions of the brain. This neuronal assessment includes imaging blood flow and electrical activity within the selected brain regions, which in some cases is triggered by the metabolic increase within an active brain region.[97] One then compares this data of blood flow and electrical activity with other data of the same brain region when that region remains inactive. Cognitive domains, such as reasoning, memory, and emotion represent the functional tendencies of brain regions. The result of these experiments was that few regions of the brain display selectivity and most regions of the brain perform diverse functions within varying cognitive domains, ranging from memory to mathematics.[98]

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[94] Anderson, *After Phrenology*, 7-16.

[95] For discussion on how to identify these regions, see Schacter et. al. *Psychology*, 96-97.

[96] Anderson and Pessoa, "Quantifying the diversity of neural activations," 2421-2426; M. L., Kinnison and L. Pessoa, "Describing functional diversity of brain regions and brain networks," *NeuroImage* 73, no. 50 (2013):50–58.

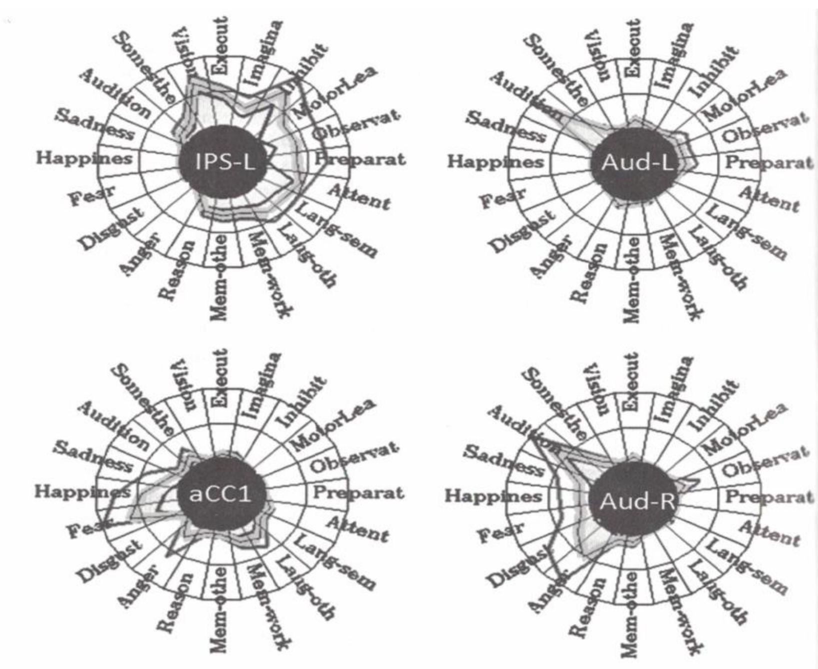
[97] Bruce Crossan et. al., "Functional Imaging and Related Techniques: An Introduction for Rehabilitation Researchers," *J Rehabil Res Dev* 47, no. 2 (2011): vii-xxiv.

[98]Anderson, *After Phrenology*, 9-11.

The range of the varying domains is important, since then reuse cannot be explained away by drawing similarities between the task domains. If experiments were to focus on similar task domains, such as motor control and perception, support for reuse would be weaker than focusing on different task domains, such as motor control and mathematics. This difference between task domains shows that neural reuse does not occur only within regions contributing to similar functions, but brain regions performing diverse functions.[99]

Figure 1 below illustrates neural reuse applied to four brain regions activated by a variety of different tasks.[100] Each graph describes a brain region and the relative degree of activity of the regions under 20 task domains.

Figure 1




For example, the graph on the top right represents the activity of the left auditory cortex. This region of the brain exhibits limited reuse and more functional specificity. The other regions however illustrate greater functional diversity in that those regions activate in a variety of cognitive domains.

[99] For details, see Anderson, *After Phrenology*, 10.

[100] Taken from Michael Anderson, *After Phrenology*, 118.

Additional evidence supporting the first prediction includes reuse at the cellular level. This evidence is important because even if neuroimaging techniques failed to support neural reuse, since these techniques operate at a low resolution and can be difficult to interpret, cellular reuse avoids the low-resolution problem.[101] Consider two types of evidence for cellular reuse.

Regarding the first piece of evidence for cellular reuse, recent studies show that single neurons may contribute to a variety of functions.[102] One example of this observation is with monkeys. During one experiment, when monkeys pressed a lever in response to visual stimuli, one set of neurons performed both the decision-making procedure to press the lever as well as the action of execution.[103] In this case, the same neuron performed two functions, the first for decision-making and the second for executing the movement. Another instance of cellular reuse comparable to the monkey example is the c. elegans worm.[104] There exist roughly three different types of neurons within c. elegans, a third of the neurons are for sensory functions, a third for motor functions, and a third for integration. The integrating neurons may exhibit a type of reuse because of how they participate in a variety of functions, both forward locomotion and backward locomotion. The conclusion drawn from the study of c. elegans is that the integrating neurons cannot be assigned to a single class of neurons but can be reused to carry out different functions.[105]

A second piece of evidence for cellular reuse is neuromodulation. Neuromodulation is the process by which external conditions cause a chemical reaction within the cellular network and

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[101] For these objections against reuse, see the open commentary in Anderson, "Neural Reuse," 266-304.

[102] Paul Cisek and F. Kalaska, "Neural Mechanisms for Interacting with a World Full of Action Choices," *Annu. Rev. Neurosci* 33 (2010): 269-98; J.I Gold and M.N Shadlen, "The neural basis of decision making," *Annu. Rev. Neurosci* 30 (2007): 538.

[103] Paul Cisek and F. Kalaska, "Neural Mechanisms," 274.

[104] Z.F Altun and D.H Hall, "Nervous system, general description," (eds. Z.F Altun, L.A Herndon, C. Crocker, R. Lints, and D.H. Hall; *WormAtlas* (2002-2010), accessed August 2018, http://www.wormatlas.org/hermaphrodite/nervous/mainframe.htm.

[105] See Cornelia I. Bargmann, "Beyond the connectome: How neuromodulators shape neural circuits," *Bioessays* 34, no. 6 (2012): 460. For a more detailed discussion, see Anderson, *After Phrenology*, 31-35.

this reaction influences the functions of a group of cells. The result of the chemical reaction is neurons performing different functions. For example, an anti-depressant drug is a neuromodulator because it causes a chemical reaction within a cellular network. Or consider again the c. elegans worm.[106] Depending on external conditions such as food intake, the neural circuitry of c. elegans may change and perform different functions. A worm suffering from starvation compared to a worm with a full stomach produces different neuromodulatory states and therefore the same neurons may perform different functions under those various conditions.[107] Neuromodulation is important not only for supporting cellular reuse but also for assessing the alignment between evolution and reuse. I explore the implications of neuromodulation for aligning reuse with evolution in section II. The main point for now is that there exists both anatomical and cellular evidence for the first prediction of neural reuse.

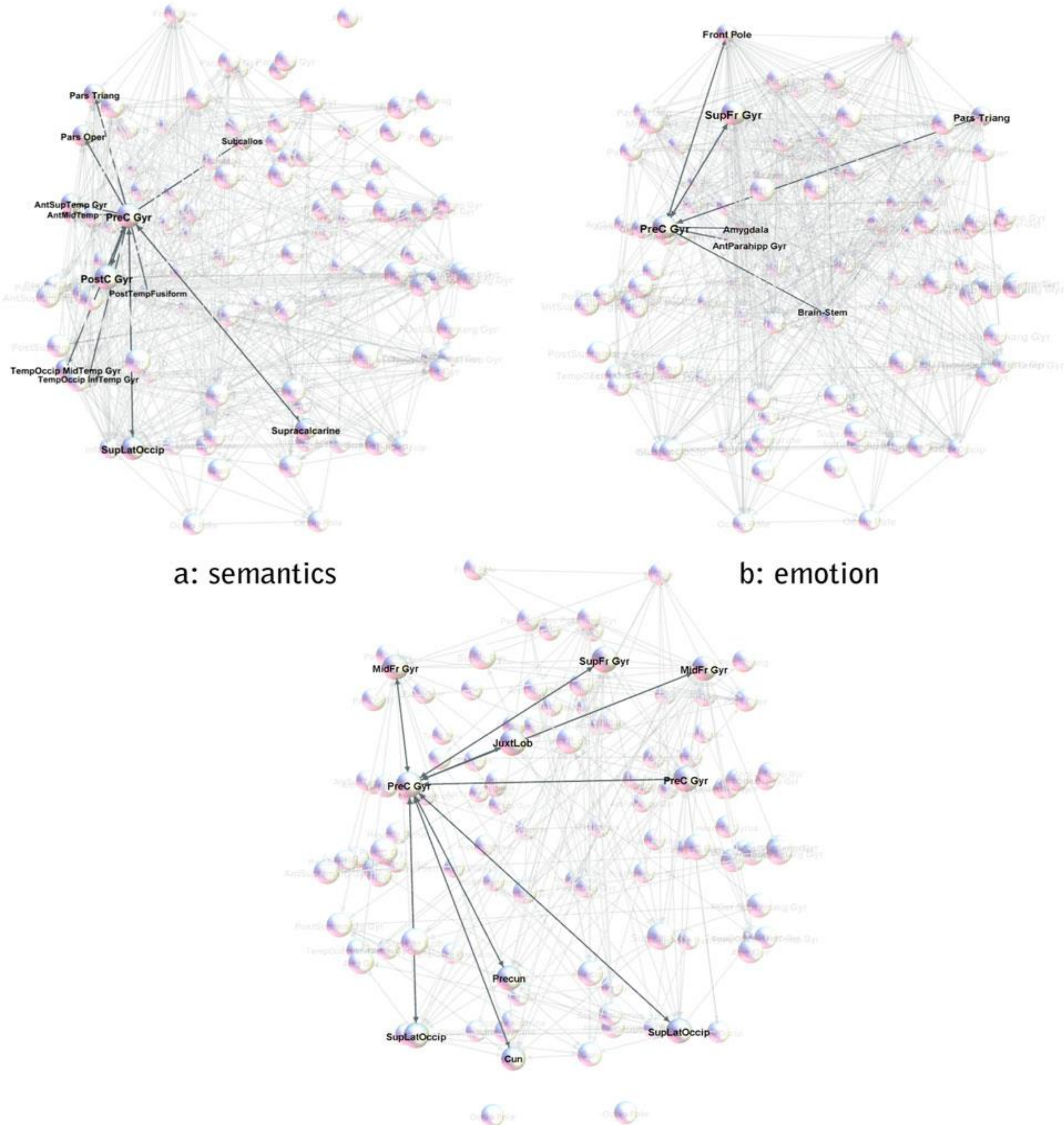
The second prediction implied by neural reuse is the functional partners with which a region will network when performing a cognitive task. Recall the airline analogy in the introduction. A network of units can perform more complex tasks than units operating on their own. Neural reuse predicts that brain regions will connect with each other differently depending on the cognitive task. The neural network configuration predicted by reuse includes high node overlap and low connection overlap. High node overlap means that the same brain region participates in different cognitive functions (as already discussed with the first prediction above). Low connection overlap means that the brain region does not use the same functional partners (i.e. the connection lines between nodes) when contributing to various cognitive functions. That is, the brain region being reused networks with different brain areas to accomplish different functional tasks.[108]

Figure 2

[106] M. de Bono and A.V Maricq, "Neuronal substrates of complex behaviors in C elegans," *Annu Rev Neurosci* 28 (2005): 451–501.

[107] Cornelia I. Bargmann, "Beyond the connectome," 460-461.

[108] Anderson, *After Phrenology*, 12-14.



c: attention

The evidence described by Figure 2 above supports the second prediction.[109] Figure 2 describes the left precentral gyrus functioning under three different cognitive domains, such as semantics, emotion, and attention domains.[110] The left precentral gyrus is the node in the top left region of each graph from which various connection lines originate. This network configuration supports

[109] This graph is taken from Michael Anderson, "Précis of After Phrenology," 2-3.

[110] Anderson, *After Phrenology*, 12-13.

the second prediction because the left precentral gyrus displays high node overlap, since it is being reused in the three task domains, semantics, emotion, and attention, and low connection overlap, in that the region utilizes different functional partners while performing the cognitive tasks. For instance, when performing a semantics task, the precentral gyrus networks with the post central gyrus and not with the amygdala. When performing an emotion task, the precentral gyrus networks with the amygdala and not with the post central gyrus. When performing an attention task, the precentral gyrus networks with neither the post central gyrus nor the amygdala, but with other regions entirely. The functional analysis illustrated by figure 2 shows that there exists functional connectivity between brain regions when performing different cognitive operations and this supports the second prediction.[111]

The third prediction states that more recent cognitive abilities will be supported more broadly across brain regions, since older brain regions have existed longer and therefore possess greater potential for reuse.[112] This prediction can be supported by observing language. A recent study by Anderson compiled fMRI data of 665 experiments in 18 task domains within the cortex. Out of the 665 experiments, 135 experiments focused on regions within the cortex in four task domains (attention, visual perception, mental imagery, and language). The aim of the study was to identify which domains scattered more broadly across brain regions. The result was that language constituted the most widely scattered domain across brain regions, followed by reasoning and memory, down to perception and attention.[113] This observation supports the view that older abilities such as vision and attention activate fewer regions than language. That is because vision and attention abilities would have developed earlier when there existed simpler brain regions for reuse, while language developed more recently and would have been grounded by a more complex neural network.

The third prediction elucidates another doctrine of neural reuse: brain regions cannot be reused for just any cognitive action. While the capacity for language requires a more extensive

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[111] Ibid., 12.

[112] Michael L. Anderson, "Evolution of cognitive function via redeployment of brain areas," *Neuroscientist* 13, no. 1 (2007): 13-21.

[113] Michael L. Anderson, "Circuit sharing and the implementation of intelligent systems," *Connection Science* 20, no. 4 (2008): 244.

neural network than the capacity for vision, it is false to suggest that just any brain region can accommodate language. The reason that only some brain regions accommodate language is that brain regions possess invariant structures for certain cognitive abilities.[114] An invariant structure is a rigid neural structure that remains relatively fixed and thus often produces invariant functions. This view of the invariant structures of the brain is important not only for understanding the limits of neural reuse but for aligning reuse with evolution. I consider reuse and evolution in section II below. Still, for now it is instructive to examine two different types of cognitive functions, "cognitive workings" and "cognitive uses," to better understand neural reuse and invariant structures.

Cognitive workings describe the functional tendencies of that region in virtue of the invariant structure of the region.[115] I provide an analogy in a moment. Unlike cognitive workings, the cognitive uses of a brain region describe the many types of operations brain regions may contribute to. Cognitive uses represent the flexibility of a region to carry out other types of cognitive actions in concert with other regions. For instance, while Broca's area includes an invariant structure for contributing to specific intrinsic workings, its structure can be reused for different types of cognitive uses.

To understand the distinction between cognitive workings and cognitive uses and how this distinction applies to neural reuse, first imagine a pair of scissors. The invariant structure of the scissors includes two blades swiveling on a pivot point. The two blades swiveling on the pivot point constitute the workings of the scissors. Moreover, the scissors can contribute to a variety of uses, including cutting, stabbing, jamming, and so on. The workings of the scissors remain fixed, while the uses of the scissors accommodate a variety of functions. Brain regions resemble the scissors in that while brain regions possess fixed, invariant workings, they also contribute to a variety of cognitive uses. Broca's area may exhibit a fixed working in that it

[114] Anderson, *After Phrenology*, 15.

[115] Vincent Bergeron, "Anatomical and functional modularity in cognitive science: Shifting the focus," *Philosophical Psychology* 20, no. 2 (2007): 175-195; see Anderson, *After Phrenology*, 15.

operates as a pattern processor,[116] but Broca's area also may contribute to multiple cognitive uses such as language.

The implication of the distinction between cognitive workings and cognitive uses for neural reuse is that brain regions cannot perform just any cognitive operation but remain fixed because of their invariant structures. Structures can be reused only according to their structure's potential. This view will become important in section II when aligning reuse with evolution.

To summarize so far: the first prediction for neural reuse is that brain regions will redeploy their resources and contribute to a variety of cognitive functions. The second prediction is that when brain regions redeploy their neural resources, they network with different regional partners for carrying out the varying cognitive functions. The third prediction is that more recent cognitive functions will be instantiated by a broader neural network, as opposed to more ancestral cognitive functions. The third prediction raises new questions about the definition of "cognitive function" and particularly the distinction between cognitive workings and cognitive uses. Each of these predictions can be supported by recent evidence in cognitive science. What is important for now is that the brain is a dynamic (i.e. changing) network with both invariant and flexible neural structures, such that those structures can accommodate a variety of cognitive functions, both ancestral abilities, such as perception and motor control, and higher abilities, such as language, math, and logic. In the next section I examine one theory of reuse called the neural recycling hypothesis.

### A. Neural Reuse: The Neural Recycling Hypothesis

The neural recycling hypothesis is a version of neural reuse and refers to when a cultural object, such as reading or arithmetic, "invades" a pre-existing brain system, in that the cultural object utilizes the cognitive circuitry of a brain region.[117] This hypothesis includes three postulates. The first postulate is that brain regions consist of stringent anatomical and functional constraints

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[116] Ricardo I. Schubotz and Christian J. Fiebach, "Integrative Models of Broca's Area and the Ventral Premotor Cortex," *Cortex* 42, no. 4 (2006): 461-463.

[117] Stanislas Dehaene, "Cultural Recycling of Cortical Maps," *Neuron* 56, no. 2 (2007): 384.

because of evolution.[118] This first postulate resembles the discussion above regarding cognitive workings and cognitive uses. Invariant constraints suggest that brain regions cannot perform just any cognitive task but remain limited in the type of operations they can perform. This view of the brain is different than a view of the brain that displays universal plasticity, such as a holistic view of the brain.[119] According to the neural recycling hypothesis and reuse, the brain exhibits degrees of plasticity according to the invariant structures developed by evolution.

The second postulate is that cultural objects such as reading encroach on a "neural niche."[120] Recall from the introduction the concept of an ecological niche. An ecological niche is the role an organism occupies in an environment.[121] China's panda bear lives in a precise ecological niche, since its diet consists of mostly bamboo. Comparable to how an ecological niche is the way of life of an organism, a neural niche is a metaphor for describing the role a cognitive operation occupies within a neural environment. A neural niche is the way of life of the neural operation within a neural network. This view of a neural niche is different than Pinker's view of a cognitive niche. A neural niche is the role a cognitive operation plays within a neural environment, while a cognitive niche is the role humans play within a natural environment.

The third postulate explicates the second one in greater detail. As a new cultural operation invades an older brain region, the organization of that region does not reconfigure, but continues to influence the new operation.[122] This organization of a brain region suggests that other species – particularly non-human primates – with the same invariant structures may display similar potential for learning. In other words, if both human and non-human primates possess

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[118] Ibid., 384.

[119] Dehaene, Stanislas, Jean-Rene Duhamel, Marc D. Hauser, and Giacomo Rizza latti, *From Monkey Brain* to *Human Brain: A Fyssen Foundation Symposium* (Cambridge: MIT Press, 2010), 133-134.

[120] Dehaene, "Cultural Recycling," 384-385.

[121] Richard Lewontin, "Adaption," *Scientific American* 293 (1978): 215.

[122] Dehaene, "Cultural Recycling," 384-385.

brain region X, and X was coopted in humans for higher capacity Y, then, to some degree, one should be able to test the potential for Y to obtain in other non-human primates.[123]

The three postulates for supporting the neural recycling hypothesis lead to several predictions and implications. Here I discuss only one prediction and one implication. The prediction implied by the neural recycling hypothesis is that one would expect limited variability within primate brain structures in general and human brain structures in particular. For instance, brain structures that have been recycled for producing language would look similar not only across human cultures but among non-human primates.[124] One of the implications of the neural recycling hypothesis includes understanding the precursors of human learning through tool use. The same brain regions implicated in human tool use are roughly homologous to the brain regions in some non-human primates.[125] I discuss both of these points below.

Regarding the prediction, recent evidence for the development of reading shows that (i) the visual word form area (VWFA) is implicated in processing written words across a variety of cultures, and (ii), that the precursors of the VWFA exist amongst non-human primates.[126] Recent studies have located the VWFA within the occipito-temporal cortex.[127] The occipito-temporal cortex possesses the appropriate neural environment for the VWFA to occupy a neural niche. For example, the shapes used for writing letters, including intersecting symbols such as "T" and "Y," exist both within most writing traditions across cultures, and, more importantly, resemble primitive visual tasks in many primates contributed by the occipito-temporal cortex for object and scene recognition.[128] This observation supports the view that the occipito-temporal cortex

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[123] Anderson, *After Phrenology*, 101-102.

[124]Dehaene, "Cultural Recycling," 385.

[125] Anderson, *After Phrenology*, 99-100

[126] For objections, see C.J. Price and J.T. Devlin, "The myth of the visual word form area," *Neuroimage* 19, no. 3 (2002): 473-481.

[127] G. Kayaert, I. Biederman, and R. Vogels, "Representation of regular and irregular shapes in macaque inferotemporal cortex," *Cereb Cortex* 15, no. 9 (2005): 1308–1321.

[128] Dehaene, "Cultural recycling," 389. For example, the primitive ability to decipher physical objects, their shape and properties, may have been recycled by the VWFA for writing.

did not evolve to include the VWFA for reading, but rather that the ancestral neural mechanisms of the occipito-temporal cortex were reused (or recycled) for reading.[129]

The example of the occipito-temporal cortex supports the first prediction for the recycling hypothesis. The brain structures of the occipito-temporal cortex remain relatively fixed across primates and human cultures and those structures were sufficient for incorporating the neural niche for the VWFA to emerge. Whatever cultural phenomena occurred to cause the emergence of writing across a range of writing traditions may remain unknown. The point is that the ability to write likely recycled the neural hardware located within the occipito-temporal cortex.

One objection to the example above is that if the VWFA were to activate during any visual exercise, then the observation would become trivial. That is, the VWFA would activate regardless of whether it associated with language or not.[130] The truth of that objection would undermine the specific function of the VWFA as a region contributing to reading. There are two responses to this objection.

One response to the objection is that additional evidence shows that the VWFA specializes in orthographic processing.[131] Orthography refers to the social conventions used for writing, such as letter order and punctuation. Orthographic processing is the cognitive ability to recognize and master these linguistic conventions. Recent experiments demonstrate that when subjects identify a familiar script, the VWFA activates more strongly than when the script remains foreign to participants.[132] This evidence suggests that the VWFA does not participate in just any visual exercise.

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[129] Dehaene, *From Monkey Brain*, 147; Dehaene, "Cultural recycling," 389. A similar claim above was already made about Broca's area. The sensorimotor functions of Broca's area could accommodate language.

[130] Dehaene, "Cultural Recycling," 386.

[131] L. Cohen and S. Dehaene, "Specialization within the ventral stream: the case for the visual word form area," *Neuroimaging* 22, no. 1 (2004): 466-476.

[132] Chris Baker, Jia Liu, Lawrence Wald, Kenneth Kwong, Thomas Benner and Nancy Kanwisher, "Visual word processing and experimental origins of functional selectivity in human extrastriate cortex," *PNAS* 104, no. 21 (2007): 9087-9092.

A second response to the objection is that when subjects observe a familiar script, there is a stronger response from the VWFA when participants read actual words and not consonants strung together, upper versus lower case, and so on. This second observation suggests that the VWFA includes finely-tuned orthographic regularities within a specific language.[133] That means that the VWFA activates when participants perform highly specific language tasks involving grammar and syntax. Therefore, there exists evidence that the VWFA area does not respond to just any visual stimuli, but specific forms of linguistic stimuli.

Regarding the implication for the neural recycling hypothesis, the invariant structure of brain regions may describe the potential for learning, particularly with other non-human primates that possess the same invariant structures. Recent experiments describe the neurophysiological changes in Japanese macaque monkeys before and after receiving formal training in tool use.[134] One example of basic tool use is the simple act of manipulating an object by using something else, for instance, bending a branch to retrieve food. While this type of monkey behavior is the exception and not the rule, the ability to retrieve food with tools may exhibit a primitive form of tool use relevant to the development of tool use in the great apes and humans.[135] This is relevant especially if those basic skills can be enhanced and the same brain regions display modification.

The experiment included two parts. The first part of the experiment was training the monkey for novel tool use; these abilities are considered novel because they would have been unnecessary for Japanese macaques in their natural environment. The second part of the assessment was whether or not the artificially-induced ability for novel tool use could explain some of the evolutionary precursors of human tool use. These two pieces of evidence would show how an invariant structure possessed by both humans and monkeys can be reused for the same cognitive ability required for tool use.

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[133] Dehaene, "Cultural Recycling," 386.

[134] Atsuchi Iriki and Osamu Saruka, "The neuroscience of primate intellectual evolution: natural selection and passive and intentional niche construction," *Phil. Trans. R. Soc. B* 363, no. 1500 (2008): 2229–2241, accessed Sept 2017, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2394573/

[135] Ibid., 2230.

According to the first part of the study, experimenters provided the monkey with a long-handled spoon with food at the end of the spoon and observed how monkeys retrieved the food. As expected, monkeys would pull the spoon towards them to retrieve the food. This primitive practice reflects the exceptional cases in the wild whereby monkeys retrieve food with branches. Next experimenters utilized a rake-shaped instrument with a longer shaft and handle, with food placed on the rake. As expected, the monkeys would retrieve the food in the same way as with the spoon. A third type of experiment included placing the food next to the rake and teaching the monkeys to manipulate the rake around the food to pull it back for retrieval. Gradually experimenters would create a more difficult path for retrieval, and the monkeys had to maneuver the rake accordingly to retrieve the food. The final set of experiments was the most difficult to teach. Experimenters placed the food farther away to the right of the rake with various obstacles in between. Monkeys would then use the rake to navigate the obstacles to place the rake above the food and then pull the food back towards them. In the early stages of the experiment, testers could successfully train monkeys for more novel tool use within a few months. Experimenters have reduced this time frame within two weeks, as the experiment has become more finely-tuned.[136]

The point is that a brain area in the monkey may have been recycled for human tool use. If humans practice tool use because of how certain invariant brain structures operated and were recycled during human evolution, then, to some extent, other non-human primates with the same invariant structure may demonstrate the potential to learn similar skills. This is what the experiment above supports and provides an example of the implication for the neural recycling hypothesis.[137]

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[136] Ibid., 2238

[137] An additional implication of the experiment above for the evolutionary argument for HCAs could be how tools apply to the evolution of human higher abilities. The cognitive flexibility required for tool use has long been regarded as a prior condition for intelligence, and the neuronal activity responsible for this flexibility is stored in an older brain region, the intraparietal cortical area. In this area the sensory motor systems (systems required for tactile, muscular, and joint sensations) merge with visual systems. If tool use were necessary for the advancement of human higher abilities, then there would exist evidence for older ancestral brain regions contributing to that advancement. For a classic position, see H. Head, and G. Holmes, "Sensory disturbances from cerebral lesions," *Brain* 34, no. 2-3 (1911): 102–254; Ibid., 2231; Jody C. Culham and Kenneth F. Valyear, "The Parietal Cortex in action," *Current Opinion in Neurobiology* 2, no. 16, (2006): 205-212; L. G. Ungerleider and M. Mishkin, "Two cortical

With these details about neural reuse and the recycling hypothesis in place, recall the second premise of the argument that HCAs are the product of evolution: *Brain regions xyz have been reused for carrying out HCAs*. Although I state more evidence for affirming this premise in chapter three, for now recognize that the neural recycling hypothesis provides initial support for this premise. According to the first prediction of the neural recycling hypothesis, which aims to explain how invariant structures contribute to higher cognitive use, the occipito-temporal cortex represents an ancestral brain region reused for reading. The neural circuitry of the occipito-temporal cortex was coopted for contributing to reading. The trigger of the event for reuse is not important. We may never know the full causal story for what caused this cognitive recruitment to take place. What is relevant is that the occipito-temporal cortex is the type of neural object that can in principle accommodate HCAs. Indeed, even if it were true that other neural pathways contributed to language,[138] or future human evolution coopted other brain regions for linguistic ability, the occipito-temporal cortex is an example of an ancestral brain region being reused for higher cognitive use.

The second piece of evidence for supporting the recycling hypothesis and premise (2) is the implication of the recycling hypothesis, in that both human and non-human primates possess similar invariant structures for learning tool use. Experimenters have been able to show how some non-human primates can learn basic skills in tool use by formal training. While this example does not show an ancestral brain region being reused for higher cognitive use, the example of training monkeys for tool use does illustrate the ability for non-human primates to learn new skills that may have contributed to human higher cognition. The example shows in part that the cognitive infrastructure for HCAs may exist within ancestral brain regions.

visual systems," in *Analysis of visual behavior* (ed. D. J. Ingle; Cambridge, MA: MIT Press, 1982), 549–586.

[138] Mohamed L. Seghier et. al., "Reading without the left ventral occipito-temporal cortex," *Neuropsychologia* 50, no. 14 (2012): 3621–3635.

## II. Neural Reuse: Evolution

In this section I digress to examine various considerations when aligning evolution with reuse and include three parts. The first part examines one strategy for how reuse may align with evolution by describing cognitive homologies. The second part examines an objection against reuse such that only modular brains could have evolved. The third part focuses on the three strategies for understanding the evolution of HCAs and how those strategies align with natural selection. These three strategies were briefly discussed in the introduction. The first strategy is that natural selection is necessary but not sufficient for understanding how HCAs are the product of evolution. The second strategy is that natural selection is both necessary and sufficient for understanding how HCAs are the product of evolution. The third strategy is that natural selection is both necessary and sufficient for understanding HCAs and HCAs are adaptations described by evolutionary psychology.

### A. Cognitive Homologies

One attempt to align reuse with evolution is by showing how homologous structures resemble cognitive structures.[139] The term homology is ambiguous. Two common definitions of homology include structural homology and behavioral homology and discussing the differences between these views is relevant for defining and assessing the term cognitive homology.

Structural homology refers to different species sharing the same structural traits inherited from a common ancestor.[140] For instance, human arms include the same bones as seal flippers.

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[139] Vincent Bergeron, "Neural Reuse and cognitive homology," commentary in Michael Anderson, "Neural reuse: A fundamental organization principle of the brain," *Behavioral and Brain Sciences* 33, no. 4 (2010): 268-269; Michael Anderson and Marcie Penner-Wilger, "Neural Reuse in the Evolution and Development of the Brain Evidence for Developmental Homology?" *Developmental Psychobiology* 55, no. 1 (2012): 48; David S. Moore and Chris Moore, "Neural Reuse as a source of development homology," commentary in Michael Anderson, "Neural reuse: A fundamental organization principle of the brain," *Behavioral and Brain Sciences* 33, no. 4 (2010): 284.

[140] Originally coined by Richard Owen in 1843. See Al Panchen, "Homology – a history," *Novartis Found Symp,* 222 (1999): 5-18; B.K. Hall "Homology, homoplasy, novelty, and behavior," *Dev Psychobiol* 55, no. 1 (2013): 4-12.

The bones of each species are homologous because both humans and seals acquired these bones from a common ancestor.[141]

Unlike homologous traits, some species show similar traits not acquired from a common ancestor. This second type of trait is called analogous. Analogous traits refer to physical features that appear similar and may exhibit the same function, but those traits were inherited from different ancestors. For example, marsupial moles and placental moles diverged from a common ancestor roughly 130 million years ago. However, they both evolved within the same ecological niche – a niche that required the adaptive behavior for burrowing – and therefore both species of mole appear and function physically similar because of that ecological niche.[142] Structural homology focuses solely on structure and ignores function.

Behavioral homology is different than structural homology. Behaviors are homologous if they were inherited from a common ancestor regardless of whether or not the structures causing those behaviors were inherited from a common ancestor.[143] Thus, behavioral homology focuses on function and less on structure. One example of a behavioral homology is the grasshopper's song.[144] While one species of grasshopper performs their song by rubbing its forewings with its legs, a second species of grasshopper produces the same song by rubbing the legs with the mandibles. While early proponents of behavioral homology were hesitant to describe behavioral homologies without structure, more recent proponents of behavioral homology draw a distinction

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[141] Zimmer and Emlen, *Evolution*, 44.

[142] Ibid., 321; N. Shubin, C. Tabin. And S. Carroll, "Fossils, Genes, and the Evolution of Animal Limbs," *Nature* 388 (1997): 639-48; N. Shubin, C. Tabin, and Sean Carroll, "Deep homology and the origins of evolutionary novelty," *Nature* 457, no. 7231 (2009): 818-823.

[143] J.W Wenzel, "Behavioral homology and phylogeny," *Annual Review of Ecology and Systematics* 23 (1992): 361-381; G. Lauder, "Homology, form, and function," in *Homology: The Hierarchical basis of comparable biology* (ed. Brian K. Hall; San Diego, Academic Press, 1994), 151-196; for discussion, see also R. Richards, *Darwin and the Emergence of the Evolutionary Theories of Mind and Behavior* (Chicago: Chicago University Press, 1984); P. Bateson, "The promise of behavioral homology," *Journal of Biosciences* 65 (2003): 3-10.

[144] G.F Streidter and R.G Northcutt, "Biological hierarchies and the concept of homology," *Brain, Behavior, and Evolution* 38, no. 4-5 (1991): 177-189. For details see Marc Ereshefsky, "Psychological categories as homologies," *Philosophy and Biology* 22, no. 5 (2007): 660.

between structural and behavioral homologies.[145] The reason for the hesitancy with abandoning structure was because behaviors – and particularly psychological behaviors – often change without any difference to physical structure and changes without physical differences can be difficult to identify.[146]

Cognitive homology resembles structural homology more than behavioral homology. A cognitive homology is a cognitive working performed by a homologous brain structure.[147] Note again the distinction above between cognitive workings and cognitive uses. The invariant workings of the scissors were two blades on a pivot point and the scissors could be employed for multiple uses, cutting, stabbing, etc. Cognitive homologies can be understood by focusing on cognitive workings and not cognitive uses: a cognitive homology describes the invariant workings of the homologous brain structure, and these invariant workings can be traced back to a common ancestor. So, cognitive homologies are not defined by the many cognitive uses of a cognitive structure but rather according to the stable cognitive workings inherited from a common ancestor. The term cognitive homology agrees with the standard structural view of homology in the attempt to ground certain types of cognitive operations on to physical structures.[148]

One example of a cognitive homology could be the workings of Broca's area. Suppose that Broca's area's cognitive working was a rule-based pattern processor, and that this processor inherited from a common ancestor.[149] The pattern processor is an example showing how a cognitive working inherited from a common ancestor (i.e. a cognitive homology) could have

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145 Ereshefsky, "Psychological categories as homologies," 660.

146 Alan C. Love, "Functional homology and homology of function: biological concepts and philosophical consequences," *Philosophy and Biology* 22, no. 5 (2007): 691-708; E. Abouheif et. al. "Homology and developmental genes," *Trends Genet* 13, no. 11 (1997): 433.

147 Bergeron, "Neural Reuse," 269.

148 There is a further subtlety here. There may be a difference between an anatomical brain homologue and a cognitive homologue. Clearly humans possess brain regions with physical traits such that those traits can be derived from a common ancestor. But this anatomical homology does not mean that those homologues possess the same functions. The notion of cognitive working is meant to try and solve this functional problem.

149 Ibid., 269.

been reused for higher cognitive use. That is, there exists an evolutionary history of neural reuse: stable cognitive workings inherited from a common ancestor were reused for other cognitive uses.

One problem with aligning reuse with evolution by identifying cognitive homologies is whether one can in fact identify cognitive homologies. Biologist Richard Lewontin argues that the test of identifying a cognitive trait as analogous or homologous remains formidable. For example, gorillas and dolphins both display degrees of communication and yet these species likely acquired these communication traits from different common ancestors. This example of an analogous trait resembles the examples of analogous traits with moles discussed above. The implication of these examples for understanding homologies is that just because the gorilla and dolphin both possess the cognitive capacity for communication does not suggest that cognitive capacity for communication in these species are homologous structures. Organisms may display similar cognitive structures and functions, but those structures and functions may have arisen from different ancestors. According to Lewontin, identifying homologous structures for communication requires reconstructing the appropriate regions for communication within related species back to a common ancestor, and then comparing that reconstruction with analogous structures in other organisms and lineages.

Applying Lewontin's problem of identifying homologous and analogous structures in human cognition requires identifying the cognitive functions of a wide range of species within the human lineage, and then showing how the structures of those functions trace back to a common ancestor. Here it is worth quoting Lewontin at length:

> The problem of analogy versus homology is particularly serious for cognition. What are we to take as the comparable characteristics in different species? What, indeed, is the mark of cognition, and how are we to tell homology from analogy? On the one hand, if we are extremely loose in our definition of cognition, too many utterly unrelated organisms will appear to possess the trait…in contrast, we might define cognition in an extremely restrictive way, as the ability to communicate the difference between past and future…These, however, are so human-centered that, in fact, no other species possesses them in even a rudimentary form, so that no evolutionary inferences are possible.[150]

[150] Richard C. Lewontin, "The Evolution of Cognition," 124-125.

Lewontin argues that one problem with distinguishing between a cognitive homology and a cognitive analogy is identifying a well-defined “mark of cognition” and then observing the development of that mark throughout the ancestral past. The mark of cognition should be something traceable, comparable to how biologists trace structural homologies. For Lewontin, since one cannot establish a precise mark of cognition that is neither overly general nor too specific, he finds the problem of identifying cognitive homologies difficult to overcome.

Proponents of cognitive homology respond to the mark of cognition objection by utilizing the distinction between cognitive workings and cognitive uses. Recall that a cognitive working remains relatively fixed in the operations that it performs, while cognitive uses change often in operation. The response to Lewontin’s objection is whether the cognitive mark denotes a cognitive use or a cognitive working. If the cognitive mark denotes a cognitive use, then Lewontin’s objections hold. Cognitive uses change often and those uses undermine the potential for describing the mark of cognition. However, according to proponents of cognitive homology, if the cognitive mark denotes a cognitive working, then his objection becomes misplaced. As we have seen, cognitive workings, such as the rule-based pattern processor of Broca’s area, remain relatively fixed in their operations and can be traced back to a common ancestor. The response of utilizing cognitive workings is meant to resolve Lewontin’s mark of cognition objection: the quantitative data that describes the mark of cognition is a cognitive working and this working can be traced back to a common ancestor. The idea is that by focusing on cognitive workings and their stability, one can describe the mark of cognition with greater precision.

There is a rebuttal to that response from the proponent of cognitive workings. Even with the distinction between cognitive workings and cognitive uses in place as a response to Lewontin’s objection, one problem with the cognitive mark denoting a cognitive working is that it remains unclear whether the stability of a cognitive working is sufficient for describing the mark of cognition.

To appreciate the problem of whether the cognitive working successfully describes the mark of cognition, consider another distinction between different types of cognitive workings. One way to understand a cognitive working is a brain region constituted by only one mechanism and that mechanism can be redeployed for additional cognitive uses. A second way to understand a cognitive working is that the brain region includes more than one mechanism and those mechanisms can be reused for other cognitive uses. The first type of working has its own set of cognitive uses and would be analogous to a steak knife. The invariant structure of the steak knife is a handle with a blade. Naturally, the blade can also be redeployed for other uses, such as cutting, prying open a can, stabbing a potato, and so on. The second type of cognitive working resembles a swiss army knife. Unlike the steak knife, the many mechanisms of the swiss army knife include blades, saws, screw drivers, and tooth picks. Each of these mechanisms performs a variety of uses within the workings of the swiss army knife. The mechanisms of the swiss army knife each exhibit their own invariant structures that can be reused for other uses.[151]

If by cognitive working one refers to the second type of cognitive structure, then tracking stable cognitive workings appears more difficult than identifying the first type of cognitive structure. Therefore, if cognitive workings are understood in the second way (i.e. the swiss army knife), then establishing a stable mark of cognition throughout evolutionary history becomes more difficult.

To further detail this rebuttal against proponents of cognitive workings as describing the mark of cognition, consider two pieces of evidence that illustrate the structural instability of cognitive workings. The first is evidence about structural homologies and how homologous bone structures can change and contribute to widely different workings. The second piece of evidence is neuromodulation and how cellular structures may change and carry out different workings. Both pieces of evidence call into question the stability of cognitive workings.

The first piece of evidence from structural homology is the mammalian ear bones and the bones of the reptilian jaw. These two sets of bones are homologous even though they exhibit widely different structural configurations and possess different mechanisms. The mammalian ear bones and the bones from a reptilian jaw both evolved from an earlier reptilian ancestor.[152] This example shows that standard homologous structures may not always have structural stability. Over the course of evolution, even homologous bone structures display physical changes throughout evolution and perform different mechanisms.

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[151] This section relies on personal correspondence with Vincent Bergeron on the competing views of cognitive workings.

[152] Neal Anthwal, Leena Joshi, Abigail S. Tucker "Evolution of the mammalian ear and jaw: adaptations and novel structures," *J ANAT* 222, no. 1 (2013): 147-160.

According to this first piece of evidence against the response that cognitive workings are sufficiently stable for identifying a mark of cognition, the problem with identifying a mark of cognition by way of workings is that cognitive workings appear more amenable to physical changes than bone structures. That is, prima facie, cognitive structures exhibit greater potential for physical restructuring than bone structures. And since homologous bone structures change throughout evolutionary history and realize different types of operations, cognitive structures would also likely change throughout the history of evolution. To successfully respond to Lewontin's mark of cognition objection, the burden is on the proponent of cognitive workings to describe the sufficient stability of those workings for denoting a stable mark of cognition. If bone structures can change, then cognitive workings can change. This undermines the claim that cognitive workings remain stable for describing the mark of cognition.

However, there is a response to this first rebuttal. The rebuttal from noting the changes in homologous bone structures above assumes that deep homology undermines identifying the mark of cognition. The idea of deep homology is a second level of identifying homologous structures. Underneath analogous evolution – i.e. similar traits across different species not inherited from a common ancestor – there exists homologous traits inherited farther back to a common ancestor.[153] For example, bird wings and bat wings are analogous in that they evolved independently in different lineages within similar environments. However, at a deeper level tracing back to tetrapods, bird and bat wings are homologous as forelimbs, derived from a distant common ancestor.[154]

To make sense of how a deep homology affects the position that cognitive workings denote the mark of cognition, suppose that the cognitive workings of Broca's area were traced farther back to a distant common ancestor, such that those same cognitive workings displayed different neural structures and thus performed different workings (resembling the bones of reptiles and mammals). The critic of cognitive homologies may question whether or not a deep homology of cognitive workings undermines the stability of identifying the mark of cognition? That is, comparable to the deep homology of human bone structures and the reptilian jaw, does

[153] Shubin, et. al. "Fossils, Genes, and the Evolution of Animal Limbs," 639-648.

[154] Ibid., 639-648.

the fact of a deep homology of human cognitive workings undermine the stability of human cognitive workings?

In response to this line of questioning, the proponent who identifies the mark of cognition by way of cognitive workings can say that deep homologies are irrelevant. Accordingly, cognitive homologies and the mark of cognition are meant to elucidate how human evolution reused stable cognitive workings for different cognitive uses. The rebuttal from deep homology only describes the cognitive workings of other non-human species and not the cognitive workings of humans.[155] Put differently, even if deep homologous structures were to undermine the stability of cognitive workings and the mark of cognition, this deep homologous structure would not undermine the cognitive homologies which humans share with their more recent ancestors. Those deep homologies would not describe the relevant structures for understanding human cognitive workings.

The second piece of evidence that may undermine the stability of cognitive workings is neuromodulation. Recall that neuromodulation is the process by which a group of cells is affected by external conditions and these conditions cause a chemical reaction within the cellular cognitive network. Above I gave the example of the c. elegans worm. A worm suffering from starvation compared to a worm with a full stomach may allow for different neuromodulatory states and therefore the same neurons may perform different operations under various conditions.[156] The neural structure of c. elegans contains the potential for revised neuronal configurations, depending on the neuromodulatory contexts that may obtain, many of which remain unknown. That is because "there is no reliable way to assess the complete modulatory state within any animal, including c. elegans – it is the dark energy of the nervous system, inferred but not measured."[157] If experimenters cannot reliably describe the neuromodulatory states of c. elegens, which consists of only 302 neurons, then what potential is there for currently

[155] My thanks to Vincent Bergeron for clarifying this section, especially the many mechanisms of cognitive workings and the debate surrounding cognitive homologies.

[156] Cornelia I. Bargmann, "Beyond the connectome," 458-465.

[157] Ibid., 462.

describing the neuromodulatory states of the human brain, which consists of  roughly 100 billion neurons?

The objection from neuromodulation is that cognitive workings may undergo neuromodulatory changes and thus identifying stable cognitive workings throughout evolutionary history becomes more difficult. The implication of this objection for identifying the mark of cognition is that such identification remains formidable, since even cognitive workings can display a variety of different operations under neuromodulatory states and therefore become difficult to track throughout human evolution.

One response to the objection from neuromodulation includes the ceteris paribus clause. That is, all things being equal, the human brain exhibits such-and-such cognitive workings, and it is these workings that we aim to understand. The objection from neuromodulation does not undermine the goal of understanding the stability of the human brain, all things being equal. The proponent of identifying the mark of cognition by way of cognitive workings does not argue that one must identify every neuromodulatory state of those workings. Rather one aims to identity human cognitive workings as functions of homologous structures under normal conditions.

The first attempt to align reuse with evolution includes studying cognitive homologies. While this attempt to align reuse with evolution offers a principled explanation for how evolution and reuse coincide, in that just as structural homologies can be traced throughout evolution, so cognitive structures (by way of workings) can be traced throughout human evolution, it remains an open question whether cognitive homologies exhibit sufficient stability for supporting that principled explanation. A more serious problem for aligning reuse with evolution is whether a brain exhibiting reuse can evolve in the first place. I turn to this evolvability problem of neural reuse aligning with evolution in the next section.

**B. The Evolvability Problem**

A broader objection against aligning reuse with evolution is called the evolvability problem.[158] The evolvability problem states that the brain must have evolved gradually and therefore any

[158] Peter Carruthers, *The architecture of the mind: Massive modularity and the flexibility of thought* (Gloucestershire: Clarendon Press, 2006), 13, 25; Anderson, *After Phrenology*, 38.

theory about the anatomical structure of the brain must also evolve gradually. If neural reuse describes the brain in a way that conflicts with the gradual processes of evolution, then that conflict may undermine neural reuse.

The evolvability problem was introduced in defense of the massive modularity thesis of the mind.[159] Carruthers describes the evolvability problem in the following way:

> One watchmaker assembles one watch at a time, attempting to construct the whole finished product at once from a given set of micro components. This makes it easy for him to forget the proper ordering of parts, and if he is interrupted he may have to start again from the beginning. The second watchmaker first builds a set of subcomponents out of given micro component parts and then combines those into larger subcomponent assemblies, until eventually the watches are complete. [This view] predicts that, in general, each element added incrementally to the design should be realized in a functionally distinct subsystem, whose properties can be varied independently of the others (to a significant degree, modulated by the extent to which component parts are shared between them). It should be possible for these elements to be added to the design without necessitating changes within the other systems, and their functionality might be lost altogether without destroying the functioning of the whole arrangement.[160]

Carruthers promotes the view that the mind is massively modular. As briefly discussed in the introduction, this means that the anatomical structure of the brain is composed of discrete, domain specific, highly specialized, and dissociable parts.[161] One of the reasons why Carruthers supports the massive modularity thesis is because that thesis can solve the evolvability problem. I do not consider Carruthers's view here but rather evaluate whether neural reuse can resolve the evolvability problem. Can a brain composed of reusable structures align with a gradualist view of evolution?

The theory of neural reuse can solve the evolvability problem because reuse predicts that evolution would have worked on older brain structures already in existence.[162] The neural

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159 Carruthers, *The architecture of the mind*, 13, 25.

160 Carruthers, *The architecture of the mind*, 13, 25. This passage resembles the work of Herbert A. Simon in "The architecture of complexity*," Proceedings in the American Philosophical Association* 106, no. 6 (1962): 467-482.

161 Vincent Bergeron, "Anatomical and Functional Modularity," 175–195.

162 Anderson, *After Phrenology*, 38.

components available for evolutionary processes may include unknown functions that could be used in the future. Imagine a software engineer who develops an email program. The developer writes the software with precise rules of functionality to create an efficient email program, but with sufficient flexibility to accommodate unknown operations in the future. Suppose the engineer wishes to coopt a calendar operation into the existing email program. To coopt the calendar operation, the programmer must utilize the initial rules of functionality and their flexibility to introduce the calendar operation.

The point of the software analogy is to show how neural reuse avoids the evolvability problem. The software engineer does not imagine in advance the more novel operations that could be integrated into the existing program. Engineers may have no idea what those operations will include. Rather engineers incorporate new operations on what rules of functionality already exist. Similarly, natural selection developed a brain with sufficient capacities for promoting fitness at one point, while blind to how those capacities could be reused for new actions in the future.[163] Thus, theory of neural reuse does not conflict with the gradual assumption of evolutionary theory.

**C. Neural Reuse and Natural Selection: Three Strategies**

In the introduction I suggested that my argument for the evolution of HCAs from neural reuse situates within a set of broader strategies for understanding how HCAs align with natural selection. I then introduced three strategies. The first strategy was that natural selection was necessary but not sufficient for understanding how HCAs are the product of evolution. This first strategy suggests that natural selection operates with limited scope. Other mechanisms of evolution and perhaps social and cultural processes were also necessary for the development of HCAs. According to the second strategy, natural selection was both necessary and sufficient for producing a brain for reuse. According to this strategy, the entire reusable brain is the adaptation. The third strategy was evolutionary psychology and, in some cases, modular theories of the brain. My thesis does not commit to the second or third strategies. If this project focused on

[163] Francois Jacob, "Evolution and Tinkering," *Science* 196, no. 4295 (1977): 1161-1666; Michael Anderson, *After Phrenology*, 36-38.

either the second or third strategies, then the argument for the evolution of HCAs from neural reuse would require reconstructing the causal history of human cognitive evolution and establishing either how a brain for reuse was an adaptation or how evolutionary psychology correctly describes HCAs. The problem with the causal story is that such stories may succumb to the just-so-story objection, either by way of a strict adaptationist account, or as an account that lacks evidence.

While the second strategy is not the primary one used here, it is worth considering briefly. Anderson introduces a type of neural plasticity called neural search.[164] Neural search is the view that the brain actively seeks neural configurations for successful action. For example, individuals who lose their sight may gain new sensory abilities that compensate for the lost vision.[165] In other words, in varying circumstances, the brain rapidly searches for ways to perform necessary actions. Once the new action develops into a skill, the neural search no longer continues.

The background context to neural search includes theories about the functional development of the brain, such as views that focus on nativism and the genetic fate of cognitive behavior, versus views centering on experience, and how brain regions respond to skill-learning and practice.[166] Between these views of brain development is the Interactive Specialization view.[167] According to the Interactive Specialization view, early on in postnatal brain development some cortical regions of the brain exhibit poorly defined function and are activated in a wide range of circumstances. Over time these poorly defined regions become more rigid as they respond to consecutive actions.[168]

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[164] Anderson, *After Phrenology*, 50-51.

[165] Ibid., 54-56.

[166] For a summary, see Anderson, *After Phrenology*, 50; see also Nancy Kanwisher, “Functional specificity in the human brain: A window into the functional architecture of the mind,” *Proceedings of the National Academy of Sciences of the United States of America* 107, no. 25 (2010): 11163-11170.

[167] M. H. Johnson, “Interactive Specialization: A domain-general framework for human functional development? *Development Cognitive Neuroscience* 1, no. 1 (2011): 475-483.

[168] Anderson, *After Phrenology*, 50-51.

According to Anderson, neural search is a view that aligns closely with Interactive Specialization in one sense but differs in another. Neural search resembles Interactive Specialization in that the brain searches for efficient networks for causing action and over time these networks achieve relative stability for causing those actions. Neural search differs from Interactive Specialization in that neural search suggests that brain regions do not exhibit specialized rigidity over time but under varying circumstances can be redeployed for other types of cognitive uses. The brain regions that model relative stability may operate with certain propensities towards an action, but, according to neural search and reuse, those regions are not fixed to those propensities and can be reused.

Regarding the second strategy of understanding HCAs and natural selection, consider again blind individuals who have acquired the ability to track their environment by tactile recognition. Experiments on sensory substitution – i.e. experiments showing how the human brain adjusts for visual impairment – demonstrate that brain regions search for novel ways to track the environment without vision. Patients suffering from blindness can track their environment using tactile abilities comparable to if they possessed perception through the retina. Prima facie, this type of cognitive plasticity appears relevant for survival and reproductive success. A brain capable of adjusting and adopting new functions on the fly appears more amenable to evolution than a brain that cannot adjust quickly to changing environments and circumstances. Although I do not consider this strategy, there may exist evidence that a brain for reuse is an adaptation selected for by evolution as indicated by the function of neural search.

Aligning reuse with evolution introduces the considerations discussed above, including identifying cognitive homologies and the mark of cognition, the evolvability problem, and figuring how natural selection aligns with reuse, in this case either by affirming the first strategy or the second strategy. These issues are important because any theory of brain development and its functional architecture must align with evolution more generally. So how exactly does reuse align with evolution? A thorough response to that question will not be answered until the end of chapter four. For now, what is clear is that Darwin's view that the processes of evolution utilize older structures for new functions resembles the principles of reuse. This principle of reuse does not succumb to the evolvability problem because a brain exhibiting reuse must not be created all at once. Moreover, perhaps new evidence will support the stability of cognitive workings for establishing cognitive homologies or that evidence may show that natural selection produced a brain for reuse.

### III. General Objections and Responses

The central claim so far is that neural reuse is a hypothesis about the functional architecture of the brain and this hypothesis is meant to support premise (2) of my argument for the evolution of HCAs. The reason for thinking that HCAs are the product of evolution is that ancestral brain regions have been reused for higher cognitive use.

A general problem with this strategy of deploying reuse for defending my argument is that it may assume that other functional architectures of the brain are less effective at explaining the evolution of HCAs. Specifically, the third strategy and proponents of evolutionary psychology, some of whom affirm modular theories of the brain, also explain how HCAs are the product of evolution.[169] Why should we prefer the solution from neural reuse and not evolutionary psychology and massive modularity?

I would argue that evolutionary psychology and massive modularity requires an inference that is more difficult to defend than the inference from neural reuse. The inference from neural reuse for supporting an argument for the evolution of HCAs is that from the observation of older brain regions carrying out HCAs, one infers that HCAs are the product of evolution. The inference from evolutionary psychology and massive modularity is that specific modules were selected for their higher-level abilities, such a language, and over time these modules constitute HCAs.[170] The advantage of utilizing neural reuse over evolutionary psychology is that one does not require a causal story or the strict adaptationist view (both of which become a just-so-story in

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[169] Clark Barrett, *The Shape of Thought*, 4, 298; Peter Carruthers, *The architecture of the mind*, 13, 25.

[170] Steven Pinker and P. Bloom, "Natural Language and Natural Selection," 707-784; Pinker, *How the mind*, chapter 3; Steven Pinker, "Evolutionary Psychology: An Exchange," *The New York Review*, October 9, (1997): 55-6; David Queller, "The Spandrels of St. Marx and the Panglossian Paradox: A Critique of a Rhetorical Programme," *Quarterly Review of Biology*, Vol. 70 (1995): 485-48. See Gould's response to Pinker's criticisms, S.J Gould, "Evolutionary Psychology: An Exchange," *The New York Review*, October 9, (1997); Michael Balter, "How Human Intelligence Evolved – Is it Science or 'Paleofantasy'?" *Science* 319, no. 5866: 1028, accessed October 27, 2016, http://www.sciencemag.org/cgi/content/full/319/5866/1028a.

both senses of the term, strict adaptationism and a lack of evidence).[171] It is for these reasons that one should develop an argument for the evolution of HCAs from neural reuse that does not rely on the third strategy, evolutionary psychology.

## IV. Conclusions

Recall my argument for the evolution of HCAs from neural reuse outlined in the introduction:

1. Brain regions xyz evolved.
2. Brain regions xyz have been reused for carrying out HCAs.
3. So, brain regions xyz evolved and have been reused for carrying out HCAs.
4. If brain regions xyz evolved and have been reused for carrying out HCAs, then HCAs are the product of evolution.
5. So, HCAs are the product of evolution.

This chapter was an attempt to defend premise (2). Although a complete defense of premise (2) requires additional evidence found in the next chapter, chapter two provides initial background knowledge about reuse. Neural reuse is the view that the functional architecture of the brain is such that brain regions redeploy their neural resources to contribute to multiple cognitive uses. This view of the functional architecture of the brain can be aligned with evolutionary theory more generally and provides provisional support for an argument for the evolution of HCAs.

[171] This resembles how Nagel describes the problem. Nagel's main criticisms aim at evolutionary psychology and natural selection as a sufficient condition. See Nagel, *Mind and Cosmos*, 76-77. I explore these views in detail in chapter five.

## Chapter Three

## More on Neural Reuse: Defense of Premise (2)

In chapter two I introduced the theory of neural reuse. The claim in that chapter was that the functional architecture of the brain is such that ancestral brain regions redeploy their resources for carrying out higher cognitive abilities (HCAs). My aim in chapter three is to examine additional evidence for neural reuse in defense of premise (2): *Brain regions xyz have been reused for carrying out HCAs*. In the first section of chapter three, I briefly outline embodied cognitive science (hereafter, ECS). While ECS is unnecessary for evaluating reuse, ECS is a theory about how higher cognition may ground within older brain structures, and therefore represents an important development within cognitive science. In the second section, I discuss three pieces of evidence connecting HCAs with sensorimotor and perceptual systems. The first piece of evidence discusses the functional relations between perceptual/bodily functions with HCAs. The second and third pieces of evidence explore the contributions of sub-cortical structures, such as the basal ganglia and the cerebellum, for carrying out HCAs.

### I. Traditional Cognitive Science and Embodied Cognitive Science

Describing ECS and how ECS relates to the experimental data in section II requires a brief introduction to some general ideas in cognitive science.[172] Two ideas in cognitive science include mental representations and mental computations.[173] A non-mental representation is an object with semantic content, such as words on a page and pictures on a map. Thus, a *mental* representation is a mental object with semantic content, including thoughts, feelings,

[172] For an excellent introduction, see Andy Clark, *mindware: an introduction to the philosophy of cognitive science*, 2nd edition (Oxford: Oxford University Press, 2014).

[173] See Paul Thagard, *Mind: Introduction to Cognitive Science*, second edition (Cambridge, Massachusetts; MIT Press, 2005), 4; David, Pitt, “Mental Representation,” *The Stanford Encyclopedia of Philosophy*, accessed July 2017, <https://plato.stanford.edu/archives/spr2017/entries/mental-representation/>.

impressions, and logical rules.[174] This idea of a mental representation remains ambiguous and contested.[175] Still, the important point for comparing more general ideas of cognitive science with ECS includes describing the physical properties that instantiate these mental representations. According to one view in cognitive science, the physical properties that instantiate mental representations are neural networks within the brain. This is called the connectionist view of mental representation.[176]

The second relevant idea in cognitive science is the computations (or procedures) acting on the mental representations described above. For example, a software program includes symbols and syntax that follow an algorithm, a step-by-step procedure. This procedure computes the content instantiated by the symbols and syntax within the program. The computational view in cognitive science suggests that the brain operates as the center for these computations of mental representations and these computations of mental representation produce human thought and behavior.[177]

ECS diverges from the computational view of mental representation and computation. According to ECS, the body as well as the brain contributes to cognitive processing, both the acquisition of the semantic content required for constructing mental representations, as well as the computations that act upon that semantic content.[178] While this view of ECS lacks precision,[179] it remains helpful for understanding the experiments outlined in section II. As we

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[174] Pitt, "Mental Representation," accessed July 2017, *The Stanford Encyclopedia of Philosophy*, accessed July 2017, <https://plato.stanford.edu/archives/spr2017/entries/mental-representation/>.

[175] Personal correspondence with Vincent Bergeron.

[176] See Clark, *mindware*, chapter 4.

[177] Paul Thagard, *Mind: An Introduction to Cognitive Science* (Cambridge, Massachusetts: MIT Press, 2005), 5; Pitt, David, "Mental Representation," accessed July 2017, *The Stanford Encyclopedia of Philosophy*, accessed July 2017, <https://plato.stanford.edu/archives/spr2017/entries/mental-representation/>.

[178] Robert A. Wilson and Lucia Foglia, "Embodied Cognition," *The Stanford Encyclopedia of Philosophy*, accessed December 2017, https://plato.stanford.edu/archives/spr2017/entries/embodied-cognition/.

[179] Alvin Goldman offers some refinements here; see Alvin Goldman, *Joint Ventures* (Oxford: Oxford University Press, 2013), 233-235.

shall see below, both human and non-human animals exhibit additional types of non-cognitive computing methods for producing beliefs and behavior. This observation is important for supporting the evolution of HCAs because ECS provides a broader theory about how the brain and body works towards contributing to cognitive processing and may demonstrate how more ancestral cognitive/bodily systems carry out higher abilities. Below I briefly note two ways that the body may contribute to cognitive processes. The first way is that the body constrains the types of cognitive processes that can occur. The second way is that the body distributes the cognitive load. According to proponents of ECS, in both cases, the body plays a non-trivial role in cognitive processing.

**A. Embodied Cognitive Science: Body as Constraint**

According to the first way that the body may contribute to cognitive processing, the body constrains the types of cognitive processes that occur.[180] Consider language as an example. George Lakoff and Mark Johnson argue that metaphors, such as "more is up," do not exist as abstractions, but describe the neural-physiological connections within the brain. Experiencing an increase in quantity often includes an increase in height and this experience forges the neural network.[181] For instance, everyday a child observes a cup being filled with liquid. Two regions of the brain activate during this experience, one for quantity and the other for verticality. Over time the two regions strengthen, and the synapses between both regions eventually connect, forming a neural circuit.[182] In this case, the metaphor "more is up" becomes instantiated by a specific neuronal network.

[180] See Lawrence Shapiro, *Embodied Cognition* (New York: Routledge, 2011), 70. He argues that this approach to ECS does not draw any relevant distinctions between ECS and traditional cognitive science.

[181] George Lakoff and Mark Johnson, "The Metaphorical Structure of the Human Conceptual System," *COGNITIVE SCIENCE* 4, no. 2 (1980): 195-208.

[182] For an explanation, see George Lakoff, "Natural Social Science," in *Handbook of Neurosociology* (eds. David D. Franks and Jonathan H. Turner; New York: Springer, 2003), 18.

A similar example is the metaphor "affection is warmth."[183] An infant regularly experiences warmth when comforted by a parent. These bodily experiences forge the type of neural-physiological connections that obtain. Brain regions activated by affection and temperature continue to strengthen until both connect and form a neural circuit, and therefore the metaphor "affection is warmth" becomes instantiated by the neural circuit. But the development of the neural circuit is the result of bodily input. The body constrains the neural connections that represent metaphors because of bodily human experience.

Other examples supporting the constraint thesis of ECS includes Glenberg's Indexical Hypothesis.[184] According to Glenberg's Indexical Hypothesis, bodily action grounds some linguistic meaning; that means that some linguistic meaning is not arbitrary but rather generated by the affordances of objects. An affordance is a potential set of interactions that could obtain between the body and the object. A chair affords different meanings depending on how individuals relate with the object. A human interacts with a chair differently than a mouse because the chair offers different affordances in each case. Humans interact with the chair in a specific way, and, according to the Indexical Hypothesis, this interaction is relevant for how humans abstract linguistic meaning from the chair.

One implication of Glenberg's Indexical Hypothesis for linguistic meaning is noting how affordances contribute to linguistic statements. The phrase "hang the coat on the grass" is more difficult to understand and apply because grass does not include the affordances for hanging coats. On the other hand, the phrase "hang the coat on the doorknob" is easier to understand and apply because of the possible affordances those objects include. According to some versions of ECS, the meaning and application of sentences depend on the physical affordances that occur in relation to bodily action.[185]

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[183] For discussion, see Lakoff, "Natural Social Science," 18-20.

[184] Arthur M. Glenberg, et. al., "Episodic affordances contribute to language comprehension," *Language and Cognition* 1, no. 1 (2009): 113–135; Arthur M. Glenberg and Michael P. Kaschak, "Grounding language in action," *Psychonomic Bulletin & Review* 9, no. 3 (2002): 558-565.

[185] Glenberg and Kaschack, "Grounding Language in action," 558.

**B. Embodied Cognitive Science: Body as Distributor**

According to the second way that the body may contribute to cognitive processing, the body distributes the cognitive load when processing thoughts and actions.[186] One example of the body as distributor is within the field neuroethology. Neuroethology is the study of situated nervous systems.[187] The study of situated nervous systems focus on how an organism, its brain, body, and the environment, causally contribute to the adaptive behavior of the organism.[188] One development in neuroethology is morphological computation. Morphological computation means that the shape of the body contributes to the cognitive process. Stated differently, the algorithmic procedures that generate thoughts and actions do not remain fixed to the brain but extend to the physical shape (or morphology) of the organism.[189]

One example of morphological computation is the bat's sonar ability. Compared to other animals, a bat's body and ears afford from experience of the world through echolocation.[190] Bats use acoustic impulses produced by the mouth and nose to navigate in the dark to catch prey, at high speeds, and with great precision. An important procedure for performing this hunting action is the bat's ability to map its horizontal and vertical space, by analyzing the sounds reverberating off its environment. The reason the bat can process this information – the intensity and frequency of the echoes for determining the nature of its environment – is because of skin tissue within and surrounding the ears. The morphological structure of the ear is part of the cognitive process that constitutes the bat's navigation, such that the structure of the ear has become finely-tuned to sound waves.

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[186] Wilson and Lucia, "Embodied Cognition," accessed December 2017, https://plato.stanford.edu/archives/spr2017/entries/embodied-cognition/. See also Shapiro, *Embodied Cognition*, 114.

[187] Malcom A. McIver, "From Morphological Computation to Planning," in *The Cambridge Companion to Situated Cognition* (eds., P. Robbins and M. Aydede; New York: Cambridge University Press, 2009), 480-504; Goldman, *Joint Ventures*, 219.

[188] McIver, "From Morphological Computation to Planning," 481.

[189] Ibid., 487.

[190] Ibid., 487-488; Goldman, *Joint Ventures*, 219.

The claim according to morphological computation is that the bat's morphology contributes to the relevant computation, in that the structure of the ear discriminates between the various acoustic sounds, and the bat listens to the sounds to guide its path.[191] More generally, in this case the shape of relevant body parts and how they interact with the environment may distribute the cognitive load.

The function of the distribution of cognitive load may also extend beyond the body. Recent work on the "extended mind hypothesis" (EMH) describes a function of distribution.[192] According to EMH, cognition exists beyond the constraints of the brain and body. For instance, consider three Tetris-style illustrations developed by Andy Clark. (1) "A person sits in front of a computer screen which displays images of various two-dimensional geometric shapes and is asked to answer questions concerning the potential fit of such shapes into depicted 'sockets.' To assess fit, the person must mentally rotate the shapes to align them with the sockets." In this first case, imagine playing Tetris without a controller but where one must mentally picture how the relevant shapes fit appropriately. (2) "A person sits in front of a similar computer screen, but this time can choose either to physically rotate the image on the screen by pressing a rotate button, or to mentally rotate the image as before." This example includes the option for standard Tetris, in which one uses a controller to manipulate the objects on the screen. (3) "Sometime in the cyberpunk future, a person sits in front of a similar computer screen. This agent, however, has the benefit of a neural implant which can perform the rotation operation as fast as the computer in the previous example. The agent must still choose which internal resource to use (the implant or the mental rotation…)"[193] According to this third scenario, the participant possesses a "controller" of sorts within their neuro-physiological structure and can choose if they wish to utilize this controller to rotate shapes.

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[191] McIver, "From Morphological Computation to Planning," 488; See also Cynthia F. Moss and Shiva R. Sinha, "Neurobiology of echolocation in bats," *Current Opinion in Neurobiology* 13, no. 6 (2003):751–758.

[192] Wilson and Lucia, "Embodied Cognition," accessed December 2017, https://plato.stanford.edu/archives/spr2017/entries/embodied-cognition/

[193] Andy Clark and David Chalmers, "The Extended Mind," cited from Andy Clark, *Supersizing the Mind* (Oxford: Oxford University Press, 2008), 221.

According to Clark, examples (1) and (3) appear similar in that the neural implant acts the same as the agent's mental mechanism. Moreover, example (2) resembles example (3) in that both display the same computational structure. The only difference between (2) and (3) is that in example (3) the computational structure occurs within the internal organization of the brain, while in example (2) the computational structure includes a computer controller. If (3) passes as cognition, then, Clark asks, for what reason does (2) fail to classify as cognition?[194]

My aim is not to consider the EMH in detail or objections that have arisen in response. Rather, the point is that while this view of extended cognition is interesting for work in ECS, it is unclear how EMH as described by Clark supports the evolutionary view of HCAs. The reason for this is that the EMH described by Clark already assumes that humans possess the cognitive infrastructure for building cognitive technologies, and therefore also assumes that humans already exhibit the mechanisms for HCAs. Here it is worth quoting Clark at length:

> The most obvious problem, for any attempt to explain our distinctive smartness by appeal to a kind of symbiosis of brain and technology, lies in the threat of circularity. Surely, the worry goes, only intrinsically smart brain could have the knowledge and wherewithal to create such cognitive technologies in the first place. All that wideware cannot come from nowhere. This is what I shall call the paradox of active stupidity. There is sure something to the worry. If humans are (as I have claimed) the only animal species to make such widespread an interactive use of cognitive technologies, it seems likely that the explanation of this capacity turns, in some way, on distinctive features of the human brain. Let us be clear, then, that the conjecture scouted in the present chapter is not meant as a denial of the existence of certain crucial neural and/or bodily difference. Rather, my goal is to depict any such differences as the see, rather than the full explanation, of our cognitive capabilities. The idea is that some relatively small neural difference was the spark that lit a kind of intellectual forest fire.[195]

Clark then explains why language remains crucial for bridging the ancestral brain with a brain for technological advancement. But the question under analysis is if HCAs aligns with evolutionary processes in the first place. More precisely, what are the antecedent conditions

[194] Ibid., 221.

[195] Andy Clark, *mindware*, 179. Recent attempts to use EMH to explain the evolution of HCAs include Mark Rowlands's, *The Body In Mind: Understanding Cognitive Processes* (Cambridge: Cambridge University Press, 1999), chapter 4. One challenge with Rowlands's account may be whether of not his explanation can be supported by testable evidence.

required for achieving the technological advancements described by Clark? He does not answer this question and it remains unclear why the answer must adopt a type of circularity, vicious or benign, or even amount to a "paradox," as he describes it. That is because the human brain, while not "intrinsically" unique for technological advancement, evolved over time with the infrastructure for realizing technological advancement, or so the claim from reuse suggests.

Notwithstanding developments in the extending mind, work in ECS remains helpful for understanding the experimental findings for reuse discussed in the next section. I will explore various experiments that show a relation between older cognitive functions and HCAs. The implicit assumption will be that older functions, such as perception and sensorimotor functions, are constituted by older parts of the brain, towards the rear of the cortex. If that assumption is true, then the relation between these older functions and HCAs supports the reuse of ancestral brain regions for HCAs.

## II. Neural Reuse and Higher Cognitive Abilities

In this section I examine three pieces of evidence that support reuse and how the functional capacities of ancestral brain regions were recruited for HCAs. The first piece of evidence shows how older cognitive functions are implicated in cases of higher cognition. This evidence outlines a relation between sensorimotor functions and language, as well as perceptual functions with logic and math. The second and third pieces of evidence include the reuse of older brain structures such as the basal ganglia and cerebellum for HCAs. The evidence from the basal ganglia and cerebellum is important because they are older structures distinct from the cortex.

### A. Neural Reuse and Language

Recent experiments supporting reuse include the relationship between language and bodily action. These experiments elucidate a debate between language as symbolic manipulation (a classical view of language), with language grounded in bodily activity (the embodied view of language). Roughly, according to the classical view of language, language produces meaning by using abstract, amodal, and arbitrary words. Words are abstract in that the same word refers to different token instances of that word: the word "chair" can refer to both large chairs and small chairs.[196] Words are amodal (i.e. multi-modal) in that the same word can be both spoken about or written regardless of perceptual modalities. This means that language bears no intrinsic relationship to perceptual states.[197] And words are arbitrary in that the intrinsic properties of a word, such as the phonemic qualities of the word (i.e. the sounds of the word) bear no relationship to the functional and physical properties of the referent.[198]

According to proponents of the embodied view of language, language and the meaning of some words derive from bodily and perceptual systems, such that those systems ground features of the word and the possible affordances that occur between the referent and the person interacting with the referent.[199] In other words, some types of linguistic meaning depend on or are constituted by bodily and sensorimotor systems.[200] Proponents of the embodied view of language include the following experiments in support of their claim.

According to one experiment supporting the indexical hypothesis, subjects were given a series of phrases and asked to respond yes or no to whether the phrase they heard was sensible or nonsense. For example, if the participant heard the phrase "Charlie ran away," then they would press the button indicating yes, since the phrase would have been considered sensible. If they heard the phrase "Joe boiled the air," then they would press the button indicating no, since the phrase is nonsense. In addition, two independent variables were included in the experiment.

The first independent variable unknown to participants was that each sensible phrase implied a direction, toward the body or away from the body. The sentence "close the drawer" implies an away sentence, and the phrase "open the drawer" implies a toward sentence. In some

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[196] Glenberg and Kacshack, "Grounding language in action," 558.

[197] Sabrina Haimovici, "The Modal—Amodal Distinction in the Debate on Conceptual Format," *Philosophies* 3, no. 7 (2018): 2-13.

[198] For the classical view, see Steven Pinker, *The language instinct* (New York: HarperCollins, 1994); Noam Chomsky, *Rules and representations* (New York: Columbia University Press, 1980). It remains unclear to me exactly how the grounded approach to language resolves the arbitrariness of words.

[199] Glenberg and Kacshack, "Grounding language in action," 558.

[200] Ibid., 558-559. One could argue that the embodied view contains arbitrariness of sorts but perhaps not to the same degree as the classical view of language.

cases, pressing the button for affirming yes would require movement away from the body, while pressing the button for affirming no would require movement toward the body, and vice-versa. Nonsense phrases, such as "boil the air," did not imply direction towards or away from the body.[201]

The second independent variable in the experiment included different sentence types: imperatives, such as "hang up the coat;" concrete transfer sentences, which describe a physical action between the participant and another person, such as "Courtney handed you the notebook;" and then abstract sentences, such as "Liz told you the story," implying no direction at all.

Experimenters tested whether responses to these sentence types required neural regions for planning and guiding real action, such as regions for movement.[202] The prediction was that participants would experience cognitive interference when responding with physical actions to all three types of sentences, even the abstract sentences which did not imply physical direction. This final prediction about abstract sentence types is relevant because it may demonstrate that even abstract language may be affected by bodily and sensorimotor systems.

The experiment tracked the participant's response times when they attempted to understand a sentence by responding with relevant bodily movement. The results of the experiment confirmed the prediction outlined above. Response times to sentences that implied a direction created a cognitive interference depending on the direction of the buttons for responding yes or no. For example, the phrase "Andy delivered the pizza to you" implies a towards action and is sensible. Therefore, answering correctly required pressing the yes button. But if pressing the yes button required movement away from the body, which is not implied by the sentence, then a temporary lapse in judgement occurred. The same observation occurred with pressing the button for indicating no. Participants found that their responses to the questions were easier to make when the buttons indicating yes and no followed the implied direction of the sentence. Pressing a button located opposite to the implied direction of the sentence generated a cognitive interference, and thus pressing the button delayed the participant's response times between understanding a sentence and responding with a physical action.[203]

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[201] Ibid., 559.

[202] Ibid., 559.

[203] Ibid., 559-560.

The traditional view of language requires the manipulation of abstract symbols and then computations operating on those symbols for causing actions.[204] According to the experiment above supporting the embodied view of language, while one could argue that the traditional view of language correctly aligns with the first two types of sentences, imperatives and concrete-transfer sentences, such that understanding these phrases included the manipulation of symbols into an action-based program, the same operation does not apply to abstract sentences, such as "Liz told the story to you." According to proponents of the embodied view, the reason abstract sentences do not apply in the same way is because abstract sentences do not imply movement. Therefore, proponents of the embodied view argue that abstract sentences would fail to manipulate abstract symbols into an action-based program.[205] But their studies show the opposite. The fact that abstract sentence types created cognitive delay suggest that abstract language exploits more basic cognitive capacities for physical action. In other words, brain regions for bodily action contribute to both linguistic meaning related with physical movement and linguistic meaning unrelated with physical movement. According to proponents of the embodied view of language, the experiment above aims to show that bodily actions systems are implicated during some linguistic tasks.

A second experiment following the one above utilized the same method but changed the mechanism by which the participants responded. Instead of pressing a button by moving towards or away from the body, participants used their index finger over a stationary button, one for indicating yes and one for indicating no. The only movement required in this case was pressing a button and not moving toward or away from the body.

One of the purposes with this second experiment was to test whether eliminating extensive movement as a response to linguistic meaning improved performance. The prediction turned out correct. No cognitive interference occurred when participants responded yes or no to various sentences with implied directions, since no relevant bodily movement was required for performing the response.[206] This experiment corroborates with the first experiment in that

[204] Ibid., 560.

[205] Ibid., 561.

[206] Ibid., 561-564.

physical responses to cognitive tasks impact how participants reason about those tasks. According to proponents of the embodied view of language, these first two experiments demonstrate the functional relationship between older functions and higher functions and that some types of linguistic abilities appear grounded in action-based systems responsible for motor control, specifically guiding and planning bodily actions.[207]

A possible objection to applying reuse to language as a higher ability is that language is not a higher ability, since other non-human species, such as monkeys, birds, and whales, display "linguistic ability" or the ability to communicate. This objection raises an important question. What relevant distinction exists between the "linguistic ability" of non-human animals and human language? If there were no relevant distinction between human language and the linguistic ability of non-human animals, then human language would not constitute a case of human HCAs but rather an evolved feature exhibited by other species.

There are at least two responses to the objection that language is not an HCA. The first response includes differentiating between human and non-human linguistic ability.[208] For instance, while some ethologists argue that some monkey calls include a form of reference, such that these calls pick out specific objects in the world,[209] this type of reference requires a stable and on-going correlation between the call and the referred object. A troop of monkeys utilize various calls to pick out different types of predators, but if the environment no longer includes those specific predators, then the call corresponding to those predators would no longer apply and vanish from future generations. If this is correct, then the linguistic ability of monkeys requires an on-going *physical* relation with the referred object.

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[207] Arthur M. Glenberg, M. Brown, and J.R. Levin, "Enhancing comprehension in small reading groups using a manipulation strategy," *Contemporary Educational Psychology* 32, no. 3 (2007): 389-399; see Friedemann Pulvermuller et. al. "Functional links between motor and language systems," *European Journal of Neuroscience* 21, no. 3 (2005): 793–797.

[208] Terrence W. Deacon, *The Symbolic Species: the co-evolution of language and the brain* (New York: W.W Norton & Company, 1997), 30-31.

[209] Robert Seyfarth, Dorothy Cheney, and Peter Marler, "Monkey responses to three different alarm calls: Evidence of predator classification and semantic communication," *Science* 210, no. 4471 (1980): 801-803.

Human language appears different than monkey communication. One difference is that while human language often requires an association with the world, it does not require an on-going *physical* association with the world.[210] Human language includes inventing words to refer to non-existing objects, possibilities, and impossibilities. The notion of inventing words in these abstract categories of possibility and impossibility further suggests that human language displays both ambiguity and more complicated syntax and these properties may distinguish human language from more general linguistic abilities of non-human animals.[211] Thus, the fact that non-human animals communicate by using linguistic abilities that require an on-going physical association with the world establishes a relevant distinction between animal communication the highly abstract and ambiguous nature of human language.

The second response to the objection is that even if human language does not constitute a higher ability and resembles the linguistic abilities of other non-human animals, human language may operate as a prior condition for achieving higher abilities.[212] Recent evidence shows that human language appeared between 70,000 and 100,000 years ago.[213] It is around this time that humans experienced massive change, including technological advancement, population change, and the development of new cultural artifacts.[214] Human language exhibits unique qualities compared with the linguistic abilities of non-human animals and therefore human language provided the foundation for humans to produce higher abilities.[215]

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[210] Deacon, *The Symbolic Species*, 66-67.

[211] Marc D. Hauser, Noam Chomsky, and W. Tecumseh Fitch, "The Faculty of Language: What is it, Who has it, and how did it evolve?" *Science* 298, no. 22 (2002): 1569-1578.

[212] Clark, *mindware*, 179; Jared Diamond, *The Third Chimpanzee: The Evolution and Future of the Human Animal* (New York: HarperCollins, 1992), 141.

[213] Johan J. Bolhuis, Iam Tattersall, Noam Chomsky, Robert C. Berwick, "How Could Language Have Evolved?" *PLOS Biology* 12, no. 8 (2014): 1. Deacon dates this much earlier, up to 2 million years ago; Deacon, *The Symbolic Species*, 23, 53.

[214] Deacon, *The Symbolic Species*, 36.

[215] Ibid., 84; see also Philip Lieberman, *Human Language and Our Reptilian Brain: The Subcortical Bases of Speech, Syntax, and Thought* (Boston, Massachusetts: Harvard University Press, 2000).

The first example of reuse and HCAs above aimed to show that human language may be the result of a more primitive cognitive infrastructure. Cognitive systems for bodily movement appear implicated in some types of language tasks, even abstract language. If human language were a prior condition for realizing HCAs, then connecting an older cognitive architecture with HCAs becomes more realistic. Language is one example of how ancestral brain regions were reused for higher use. In the next section, I evaluate the functional relationships between ancestral operations such as perception to the practice of mathematics.

## B. Neural Reuse and Mathematics

A classical view of abstract reasoning suggests that such reasoning, including math and formal logic, occurs solely within the mind, according to specific rules of inference, and not according to external conditions affecting the body.[216] This view of abstract reasoning occurring solely within the mind has been recently challenged by proponents of ECS.[217] Proponents of ECS aim to show that abstract reasoning utilizes bodily systems such as those systems for perception and motor control.

One study showed that students naturally order equations according to the order of operations, for example, applying multiplication before addition. Students were asked to write and solve an equation written in English with an order of operation, and in most cases, students would group numerals and operators for multiplication closer together and numerals and operators for addition farther apart. The test included two different types of equations: a sensitive set, meaning that incorrectly applying the order of operation would result in an invalid

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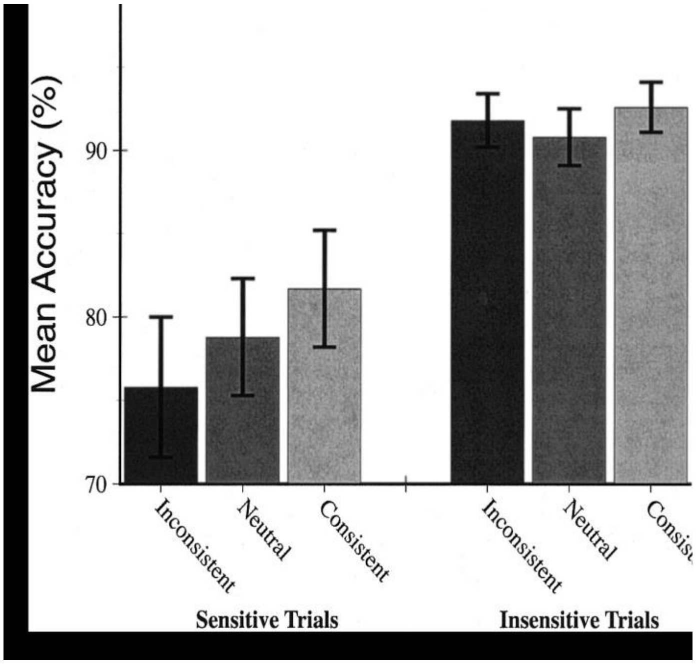
[216] S. Harnad, "The symbol grounding problem," *Physica* 42, no. 1-3 (1999) 335–346.

[217] David Landy and Robert L. Goldstone, "How Abstract is Symbolic Thought?" *Journal of Experimental Psychology: Learning, Memory, and Cognition* 33, no. 4 (2007): 722; Miriam Bassok, "Two types of reliance on correlations between content and structure in reasoning about word problems," in *Mathematical Reasoning: Analogies, metaphors, and images* (ed. L. English; Hillsdale, New Jersey: Erlbaum Press, 1997), 221-246; Miriam Bassok, "Semantic alignments in mathematical word problems," in *The analogical mind: Perspectives from cognitive science* (eds. D. Genter, K.J. Holyoak, and B.N. Kokinov; Cambridge: MIT Press, 2001): 401-433; Miriam Bassok, V.M. Chase, and S.A. Martin, "Adding apples and oranges: Alignment of semantic and formal knowledge," *Cognitive Psychology* 35, no. 2 (1998): 99-134.

conclusion; and an insensitive set, meaning that the order of operation did not affect validity.[218] The results of this study can be observed in figure 3 below.[219]

Figure 3




Experimenters predicted that spacing would be relevant only within the sensitive trials, as indicated on the left side of the graph. That is because the sensitive trials require the correct order of operations and the insensitive trials do not require the correct order of operations. Furthermore, within the sensitive trials, spacing consistent with the order of operations contributed more often to valid judgements, and spacing inconsistent with the order of operations impaired valid judgements. That data supports the view that cognitive functions for spatial awareness have been exploited for carrying out higher abilities in abstract domains.

In addition to the initial findings above, after each trial students were given feedback about the spatial techniques and how those techniques influenced mathematical ability. A surprising observation following rounds of feedback was that participants continued to commit

[218] Landy and Goldstone, "How Abstract is Symbolic Thought?" 722.

[219] Ibid., 730.

errors even after receiving insight about their spatial biases.[220] Therefore, according to experimenters, "learning the practice of mathematical proof is a matter, then, of learning physical constraints on the way parts of an equation can move and transform, akin to learning physical constraints on the motions of real objects."[221] Abstract reasoning of this type may not occur solely within the internal rules of the mind, but may utilize other mechanisms required for more mundane operations, such as spatial distancing.

One objection to the experiment above involving spatial bias is that the symbols for the equation may require spacing for different reasons. Perhaps a memory bias influences the patterns of spacing according to the order of operations. According to this objection, grouped numerals and operators are more easily recalled from memory and are therefore written closer together, while numerals and operators between groups require more time to recall from memory and thereby display greater distance.[222]

This objection provoked a second study to try to confirm the results of the first study by altering the field from mathematics to formal logic. [223] In this second experiment students were required to translate an English sentence into logical notation using logical variables. A relevant difference between the two tests is that the test in formal logic utilized a computer interface for students to respond with and did not require writing, thereby eliminating any additional idiosyncrasies that may have affected the conclusions of the first experiment. For example, where the variables M, J, and B denote each of the following subjects and their predicates, respectively, the sentence "If Mary will dance although John is not happy, Bill will dance" can be symbolized in the following way: $[(M \bullet {\sim}J) \supset B)]$. Experimenters predicted that consistent

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[220] David Landy and Robert L. Goldstone, "Formal notations are diagrams: Evidence from a production task," *Memory and Cognition* 35, no. 8 (2007): 2034

[221] David Landy and Robert L. Goldstone, "How much symbolic manipulation is just symbol pushing?" in *Proceedings of the 31st Annual Conference of the Cognitive Science Society* (eds., N.A. Taatgen and H. van Rijn Austin; TX: Cognitive Science Society, 2010), 1073.

[222] P. Cheng and H. Rojas-Anaya, "A temporal signal reveals chunk structure in the writing of word phrases," in *Proceedings of the 28th Annual Conference of the Cognitive Science Society* (eds., R. Sun and N. Miyake, Mahwah, NJ: Erlbaum, 2006), 160-165.

[223] Landy and Gladstone, "Formal Notations," 2033-2035.

spacing would occur when students answered questions about formal logic, since, according to the claim above, spatial biases contribute to formal reasoning.

The experiment included a default spacing pattern between variables and connectives (i.e. consistent and even spacing between conjunctive, disjunctive, conditional, and biconditional connectives and spacing only to the left of a negation sign but not to the right of a negation sign). Experimenters predicted that at least some participants would use spatial biases when writing out their notations. Second, experimenters predicted that participants who use consistent spacing between operators would experience greater success than inconsistent spacing techniques or no spacing techniques.[224] Third, experimenters predicted that individuals with extensive experience in symbolic logic would require less spacing maneuvers than novice participants.

Regarding the first prediction, almost 11% of all submissions included spatial techniques, both consistent and inconsistent. Out of this percentage, 82% of all spaced equations were spaced consistently. Regarding the second prediction, the most interesting result was that consistently spaced notations were more correct 53% of the time, while the inconsistently spaced notations were correct 37% of the time. The non-spaced notations were correct 50% of the time. With respect to this data, in every type of formal notation, both propositional logic and first-order predicate logic, consistent spacing always contributed to greater success than failure. Out of the sample of individuals who used consistent spacing, there were always more successes than failures, compared to inconsistent spacing and no spacing techniques.[225]

Note that while the success rates between the spaced and non-spaced equations were roughly the same (i.e. 53% and 50%, respectively), this observation need not conflict with the general view that spatial biases are implicated in abstract reasoning tasks. Even if a significant percentage of participants no longer utilize spatial biases to execute abstract reasoning, that claim does not undermine the fact that both in current experiments and perhaps in the ancestral past spatial biases contributed to the rise of abstract reasoning.

That second experiment involving the spatial manipulation of logical variables and connectives corroborates with the original experiment involving mathematics above. These

[224] Ibid., 2037.

[225] Ibid., 2037.

details show that spatial biases contribute to formal reasoning and the objection leveled against the first experiment seems inadequate.

Another experiment focusing on mathematics and perception examined how motion may contribute to mathematical ability. Consider the following equation: y*3+2=8. One way to solve for "y" is to move digits 2 and 3 across the equal sign and inverse their operators. Solving for "y" in the equation y*3+2=8 requires (i) moving and inverting +2, which gives y*3=8-2; and (ii), moving and inverting *3, which gives y=8-2/3.

Experimenters tested subjects to see whether background motion congruent with the direction of movement in the equation impaired or enhanced mathematical ability. The test identified the first set of equations as "sensitive," since these equations were non-communitive operations, such as subtraction and division. These equations are sensitive because when moving a digit and inverting an operator, one must consider order: 8-2 is non-communitive because it is not equal to 2-8. Incorrectly applying order in this case would result in an invalid conclusion. The second set of equations, communitive operations, such as addition and multiplication, were identified as "insensitive," since their order after inversion remains irrelevant: 8+2 or 2+8 both generate the same valid conclusions.

Experimenters predicted that background motion congruent with the sensitive set would enhance computational ability, and background motion incongruent with the sensitive set would impair computational ability. To understand the results of this study, consider again the equation y*3+2=8. This equation qualifies as sensitive because +2 requires inverting the operator to subtraction and then locating the 2 following the digit 8 and not preceding the digit 8. Participants succeeded at correctly locating the 2 more often when the background motion moved congruent with the movement of the digit crossing the equal sign and failed more often when the background motion moved incongruent with the location of the digit crossing the equal sign.[226] That is, when the background motion moved from right to left, participants more often located the 2 on the left side of the digit 8. When the background motion moved from left to right, participants more often located the digit 2 to the right of the digit 8. Thus, background motion affected the validity of the operations. One conclusion drawn from the study was that

[226] Ibid., 1074-1077.

reasoners utilize imagery of motion to enhance computational strategies and that imagery of motion may undermine computational strategies.[227]

The study above involving motion and mathematics was corroborated by another similar study examining the impact of visual distance on mathematical ability.[228] Consider the following two illustrations:[229]

Figure 4


Figure 5


According to this experiment, theorists predicted that equations with an order of operations would appear different to participants depending on which operation required precedence. For

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[227] Ibid., 1077.

[228] David Landy and Sally Linkenauger, "Arithmetic notation…now in 3D!" in *Proceedings of the 32nd Annual Conference of the Cognitive Science Society* (eds. S. Ohlsson and R. Catrambone; Austin, Tx: Cognitive Science Society, 2010): 2164-2169.

[229] Taken from Anderson, *After Phrenology*, 237.

example, according to experimenters, the equation 3+4*5=23 would produce a visual such that the multiplication would appear larger than the addition because the multiplication affords immediate action. In the examples above illustrating the baseballs, students were asked to solve the equation and then half of the students were asked to judge which baseball appeared closer and the other half of the students were asked to judge which baseball appeared farther. The result: the higher precedence operator (multiplication) appeared closer to the perceiver and the lower precedence operator (addition) appeared farther to perceivers.

One implication of this study for understanding how older cognitive functions contribute to higher abilities is that "abstract mathematics is generally possible for us not in spite of the fact but because we have affordance-exploiting perception-action processors that can be used to interact with objects of various types – even abstract objects as algebraic equations."[230] Even if individuals through formal practice no longer depend on natural biases of spacing and movement to solve abstract problems, this observation does not discount the fact that such natural biases from more ancestral operations contribute to abstract reasoning.

The evidence above provides support for premise (2) because that evidence shows the functional relationship between ancestral operations and higher operations. Indeed, the stronger claim is that not only did HCAs result from the reuse of older brain regions, but that these older brain regions continue to influence HCAs.

### C. Neural Reuse and Sub-Cortical Structures

The evidence described above focused on the relations between ancestral abilities, such as spatial distancing and motor control, with language and abstract reasoning. In this next section, I discuss the evidence that sub-cortical structures, such as the basal ganglia and the cerebellum, contribute to HCAs. Traditionally, theorists have focused on cortical structures of the brain to better understand human cognition. As we shall see, theorists are now focusing on sub-cortical structures of the brain to understand human cognition.[231]

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[230] Anderson, *After Phrenology,* 237.

[231] D.T Stuss and D.F Benson, *The frontal lobes* (New York: Raven Press, 1986), 161; See also Robert A. Barton, "Embodied Cognitive Evolution and the Cerebellum," *Phil. Trans. R. Soc. B* 367, no. 1599 (2012): 2097; Andrea C. Bostan, Richard P. Dum, and Peter L. Strick,

One reason these sub-cortical regions are relevant for the evolution of HCAs is the location of the basal ganglia and especially the cerebellum. For instance, the cerebellum is located towards the back of the brain underneath the rear of the cortex next to the brainstem.[232] An oversimplification of brain anatomy is that the older parts of the brain locate towards the back of the brain, [233] and therefore the reuse of these sub-cortical structures would support the view that the functional capacities of ancestral brain structures contributed to the development of HCAs.

First consider the basal ganglia. A dominant function of the basal ganglia includes regulating motor control.[234] One way to demonstrate the link between the basal ganglia and language is by observing the effects of aphasia. Aphasia is a speech/language impairment. While damage to Broca's area remains a primary contributor to aphasia, additional evidence suggests that the basal ganglia may also contribute to aphasia, from mild disorders to global aphasia.[235] In 19 cases of aphasia with language deficit, all cases included lesions in the basal ganglia, and other severe cases included sub-cortical damage generally.[236]

Another observation with the same patients analyzed above is that they suffered from paralysis in the dominant right hand or exhibited difficulty exercising fine-motor skills. This is relevant because difficulty executing hand motor skills for precision is often associated with

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"Cerebellar networks with the cerebral cortex and basal ganglia," *Trends Cogni Sci* 17, no. 5 (2013): 241-254.

[232] V. Smetacek, "Balance: Mind-grasping gravity," *Nature* 415, no. 481 (2002): 481.

[233] Anderson, "Neural Reuse," 246.

[234] Philip Liebermann, "On the Nature and Evolution of the Neural Bases of Human Language," *American Journal of Physical Anthropology* 35 (2002): 36-62.

[235] M.P Alexander, M.A Naeser, and C.L Palumba, "Correlations of subcortical CT lesion sites and aphasia profiles," *Brains* 110, no. 4 (1987): 961-991.

[236] Lieberman, *Human Language*, 101.

aphasia.[237] These additional studies corroborate the view that sub-cortical brain structures causing motor control affect language abilities.[238]

Additional examples describing the implications of sub-cortical impairment of the basal ganglia for higher cognitive function include neurodegenerative diseases, such as Parkinson's Disease.[239] While the primary deficits of Parkinson's Disease include motoric disabilities, some extreme cases have included cognitive and linguistic deficits, such as the inability to detect syntax.[240] During one experiment, patients were asked to utter a numeral to indicate which listed option best represented the meaning of the sentence that they heard. Nine out of 40 patients suffering from Parkinson's Disease displayed a deficit with sentence comprehension.[241]

Obviously, these studies do not show that the basal ganglia are necessary or sufficient for linguistic and fine-tuned motor control abilities. Rather these studies demonstrate that the basal ganglia contribute to linguistic ability in a relevant way. The basal ganglia are implicated in language tasks that may suggest neural reuse. Comparable to the recycling hypothesis in the previous chapter, language abilities may have encroached on the neural circuitry of the basal ganglia. Similar observations to those found with the basal ganglia have been made regarding the operations of the cerebellum.

Theorists began assessing how the cerebellum contributed to higher abilities because of the observation that the cerebellum expanded in concert with the cortex in both human and non-human primates throughout evolutionary history. This phenomenon of the cerebellum expanding

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[237] Ibid., 100.

[238] M. Kimura, T. Aosaki, and A. Graybiel, "Role of basal ganglia in the acquisition and initiation of learned movement," *in Role of the cerebellum and basal ganglia in voluntary movements* (eds., N. Mano, I. Hamada, and M.R. DeLong; Amsterdam: Elsevier Press, 1993), 71-74.

[239] K. Jellinger, "New Developments in the pathology of Parkinson's disease," in *Advances in neurology, vol. 53: Anatomy, pathology, and therapy* (eds., M.B. Streifler, A.D. Korezyn, J. Melamed, and M.B.H Youdim; New York: Raven Press, 1990), 1-15.

[240] Lieberman, *Human Language*, 103.

[241] Ibid., 121-122.

in line with the cortex is not often found in other species.[242] Further motivation for studying the human cerebellum was additional confirmation by fMRI showing that the cerebellum included an anatomical substrate for contributions to cognition.[243] According to this view, the cerebellum directly causes cognitive abilities, including language, problem solving, and the ability to streamline learning techniques.[244]

Here I present two claims about how for brief periods of time in individual learning the cerebellum has been reused for HCAs. The first claim is about how the cerebellum, and not only the cortex, may have contributed to working memory.[245] Working memory stores information in the mind for future manipulation, such as planning, reasoning, and problem solving, and is often associated with higher abilities. For instance, unlike long-term memory, working memory enables a person to recall the steps of the recipe for baking a cake or writing a coherent sentence.[246] A result of this first claim may suggest that the cerebellum, by contributing to the operations of working memory, also played a role in developing the cognitive infrastructure for human culture.[247] The second claim about how the cerebellum has been reused for HCAs includes recent evidence from cerebellar tumors and how these tumors have affected the production of higher abilities, especially linguistic abilities.[248] This second claim will introduce

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[242] H.C. Leiner, "Solving the mystery of the human cerebellum,*" Neuropsychol*. *Rev.* 20, no. 3 (2010): 229–235.

[243] Buckner, "The Cerebellum," 809.

[244] For contributions to language, see Lieberman, *Human Language,* 119-123.

[245] Larry Vandervert, "the prominent role of the cerebellum in the learning, origin, and advancement of culture," *Cerebellum Ataxias* 3, no. 10 (2016): 3-13.

[246] Nelson Cowan, "Working memory underpins cognitive development, learning, and education," *Educ Psychol Rev*. 26, no. 22 (2014): 197–223; P. Goldman-Rakic. "Regional and cellular fractionation of working memory," *Proc Natl Acad* Sci 93, no. 24 (1996): 13473–80; J.D Schmahmann and D. Caplan, "Cognition, emotion, and the cerebellum," *Brain* 122 (2006): 291.

[247] Vandervert, "The prominent role of the cerebellum," 4-6.

[248] Daria Riva and Cesare Giorgi, "The cerebellum contributes to higher functions during development: Evidence from a series of children surgically treated for posterior fossa tumors," *Brain,* 123, no. 5 (2000): 1051–1061.

new problems with evolutionary by-products and just-so-stories that will be explored towards the end of this chapter.

In support of the first claim, the cerebellum may have contributed to human culture by supporting working memory. Some examples of how the cerebellum supports working memory involve activities of higher learning. The cerebellum supports these higher skills by operating as a predictive mechanism tracing repetitive patterns, such as patterns for problem solving, perception, and motor actions, and then constructs models for streamlining these repetitive actions in the future.[249] More generally, a central function of the cerebellum is to anticipate future events and then correct behavior accordingly. This internal predictive mechanism enables the cerebellum to anticipate future actions, whether those actions include higher abilities or motor control, such as those required for learning music or for conducting science.[250]

Consider learning music as an example of the predictive mechanism of the cerebellum. The skill of learning an instrument becomes easier over time because the cerebellum records and produces more efficient processes for conducting the skill. So, the cerebellum contributes to working memory in that it stores and processes more efficient methods of learning – such as music. The claim is that this contribution to working memory supported the cognitive infrastructure for developing human culture.

Some examples of human culture include the shared beliefs required for spreading common knowledge, skills, and language.[251] Human culture requires learning beliefs and behaviors within a society and passing those beliefs and behaviors on to future generations. While the cortex performs immediate and context-specific actions, managing survival and fitness-enhancing behavior, occupied by roughly 16 billion neurons, the cerebellum performs context-independent actions. As described above, the cerebellum includes a predictive modeling

[249] M, Leggio and M. Molinari, "Cerebellar sequencing: a trick for predicting the future," *Cerebellum* 14, no. 1 (2015): 36.

[250] Vandervert, "The prominent role of the cerebellum," 3; this cerebellar activity may have been relevant for adaptive success; see S.P Tomlinson, et al. "Cerebellar contributions to verbal working memory," *Cerebellum* 13, no. 3 (2014): 354-61; for important considerations about the accuracy of these experiments, see Schmahamnn and Caplan, "Cognition, emotion, and the cerebellum," 291.

[251] Vandervert., 6.

system for learning, occupied by roughly 69 billion neurons, just over four times the number of neurons within the cortex.[252]

The predictive mechanism of the cerebellum applies to the shared knowledge, skills, and language required for the development of human culture passed on to future generations. Indeed, unlike the cortex, perhaps the emergence of human culture explains why the human cerebellum has grown considerably in neuronal activity in recent human history.[253] The cerebellum performed the heavy lifting for generating human culture because it enabled humans to unconsciously learn shared social behaviors with others in that culture, recalling the methods of tool construction, art, customs, hunting strategies, language, and so on.

While the evidence regarding the cerebellum and its contributions to higher learning and culture requires additional investigation, if true, the evidence illustrates the gradual process of HCAs. The cerebellum is an old, evolved brain structure possessed by all vertebrates, including reptiles, birds, fish, and both human and non-human primates.[254] The established mechanism of the cerebellum is for motor control and balance, a prime candidate for fitness-enhancing capabilities. Even if the evolutionary story of how human culture developed remained unknown, including the causes of human shared beliefs, skills, and language, the inference from the predictive mechanism of the cerebellum to HCAs seems promising, especially if recent data establishing the link between cerebellar operations and higher abilities continue to develop. Comparable to reuse and language, while human culture does not represent an HCA exactly, human culture may have operated as a condition for realizing higher abilities.

Another claim that may support the connection between cerebellar operations and higher abilities is the impact that cerebellar tumors have on cognitive functions, both with the right and

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[252] R. Lent, F.C. Azevedo, C.H. Andrade-Moraes, A.V. Pinto, “How many neurons do you have? Some dogmas of quantitative neuroscience under revision,” *Euro J Neurosci* 35, no. 1 (2012):1–9.

[253] Vandervert, “The prominent role of the cerebellum,” 3-6.

[254] William Hodos, *Encyclopedia of Neuroscience*, 1st edition., s.v. “Evolution of Cerebellum,” (ed. Larry R. Squire; Cambridge, Massachusetts: Academic Press, 2009), 1242.

left hemispheres of the cerebellum.[255] Some tumors were correlated with a deficiency in social and language tasks. Regarding language and the right hemisphere of the cerebellum, most deficiencies were not with simple language tasks, such as naming or comprehension, but with syntax and the formulation of sentences. On the other hand, damage to the left hemisphere of the cerebellum showed a deficiency with naming and comprehension and not with syntax and sentence formulation.[256] What these deficiencies may indicate is that there exists a relevant connection between both hemispheres of the cerebellum and linguistic ability within the cortex.

One important objection to the impact of cerebellar tumors is that while the evidence supports a correlation between the cerebellum and cortical operations for language, the impact of the cerebellar lesions on cognitive function remains controversial. Specifically, in other cases of cerebellar damage no deficiencies were found and testing for on-going deficiencies continues to be subtle.[257] According to the objection, if the relationship between the cerebellum and the cortex is so strong, then how come cerebellar damage does not cause cortical impairment more broadly?

There are at least two responses to this objection. The first response is that if the cerebellum is a device for learning, such that it acts as a predictive mechanism for streamlining future actions, then damage to cerebellar regions may not always display a relation to the cortex. That is because on this view the cortex now performs the relevant task, while the cerebellum contributed to learning the action and not execution of the action. A more appropriate test for assessing the contribution of the cerebellum would include examining patients with a damaged cerebellum, to observe whether they lack skills or experience deficiencies in learning new abilities which would normally require cerebellar contribution. Thus, a more precise question is whether or not a damaged cerebellum impairs a person's ability to learn a skill which under normal conditions would have required a proper functioning cerebellum?

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[255] Daria Riva and Cesare Giorgi, "The cerebellum contributes to higher functions during development: Evidence from a series of children surgically treated for posterior fossa tumors," *Brain* 123, no. 5 (2000): 1051–1061.

[256] Ibid., 1056-1059.

[257] L.L Helmuth, R.B Ivry, and N. Shimizu, "Preserved Performance by cerebellar patients on tests of word generation, discrimination learning, and attention," *Learn. Mem*. 3, no. 6 (1997): 456-474; Buckner, "The Cerebellum," 812-813.

A second response to the objection addressing the inconsistency with the cerebellum and cortical function for language is that the contributions of the cerebellum may exist as a by-product of evolution.[258] Recall that a by-product of evolution is a trait that is a consequence of another adaptive feature. The by-product does not perform any adaptive function and may or may not be coopted for some future use. According to this response, the cerebellum contributes to motor control and balance and the consequence of the cerebellum functioning as such includes a by-product coopted for language. In line with neural reuse, perhaps the more appropriate response is that the cerebellum was reused for language, regardless of whether the cerebellum exhibited by-products. I return to the by-product response in the next section because it applies to the evolutionary argument for HCAs more generally.

To summarize so far: I outlined three pieces of evidence showing how the reuse of older brain regions may be involved in HCAs. The first piece of evidence examined the functional relation between language and ancestral abilities, such as bodily movement. According to this evidence, proponents of ECS argue that linguistic meaning grounds in sensorimotor and bodily systems. Cognitive interference occurred when participants responded to linguistic tests using relevant bodily movements. Conversely, cognitive interference would not occur when participants responded to linguistic tests with no relevant bodily movements. Even if language does not constitute a higher ability, language may have been required for realizing higher abilities; without language humans would not have achieved the types of higher abilities currently observed.

The second piece of evidence focused on the relation between abstract reasoning in logic and math with perceptual systems. In these cases, perceptual mechanisms for spatial awareness and movement display a correlation with doing mathematics and logic. Participants exhibited greater success in mathematics and formal logic by spacing symbols into appropriate groups and by observing background movement for making valid judgements.

Note that the implicit assumption for that first piece of evidence is that these older operations are constituted by older brain regions and those older regions have been reused for

[258] Buckner, "The Cerebellum," 813; Frederick M. Menger, *The Thin Bone Vault: The Origin of Human Intelligence* (London: Imperial College Press, 2009), 204-205.

HCAs. One reason for thinking that this implicit assumption is true is that these older functions occur within older parts of the parietal cortex.[259]

The last piece of evidence included anatomically distinct structures of the brain, the basal ganglia and the cerebellum. The basal ganglia appear implicated in cases of aphasia as well as other neurodegenerative diseases where speech deficits occur. The human cerebellum is unique in that it has evolved in concert with the cortex for contributing to working memory. The result is that the cerebellum operates as a predictive mechanism relevant for learning new types of skills. Accordingly, some theorists argue that this predictive process was relevant in conjunction with the cortex in developing the skills for human culture.

In all of the cases above, the evidence is meant to support premise (2): brain regions xyz have been reused for HCAs. The evidence from ECS points to a relation between higher types of cognitive activities with lower types of perceptual and bodily activities. The evidence from sub-cortical structures such as the basal ganglia and cerebellum may indicate that the neural circuitry of older brain structures was reused for HCAs.

### III. General Objections and Responses

Some additional objections deserve attention. First, the experimental data in this chapter displayed a close relationship with embodied cognitive science (ECS). But what if ECS fails to explain human cognition and its capacities? Would this failure of ECS undermine the experimental data outlined above? I would argue that even if ECS fails, that failure would not undermine the experimental data for at least two reasons. The first reason is that, according to some theorists, the relationship between traditional cognitive science and ECS is not exactly clear.[260] Perhaps the experimental data outlined above also aligns with traditional cognitive science and does not require ECS. Moreover, regardless of the discussion regarding traditional cognitive science and ECS, the experimental data above supports the evolution of HCAs regardless. The evidence supports the argument for the evolution of HCAs irrespective of the theory of cognition conjoined with that evidence.

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[259] My thanks to Andrew Sneddon and Vincent Bergeron for clarifying this point.

[260] See footnote 179.

A more powerful objection is that motoric brain areas do not provide the bedrock of all other cognitive activity.[261] But in response to this objection, while the focus so far has been on experiments of this type, motor areas capture only a small sample of the evidence available for ECS and how higher abilities may be the product of bodily action.[262] The central claim about ECS is not that all cognition is embodied but only that some non-trivial types of cognition are embodied, and these types of experiments support the evolutionary view of HCAs.

A second objection is the by-product objection. The final example of evidence described above included the cerebellum as a contributor to linguistic ability. One response to an objection in that section included identifying cerebellar contributions to language as by-products of evolution. While this response may explain the fact that cerebellar connections within the cortex continue to be subtle, it raises additional concerns for an argument for the evolution of HCAs more generally. While postulating higher abilities as a by-product does not undermine the evolution of HCAs by neural reuse, since by-products are a relevant factor resulting from evolution, arguing that HCAs are by-products may fuel further objections.[263] At the end of the first chapter, I briefly compared the inference from neural reuse to the evolutionary view of HCAs with the inference from evolutionary psychology (and massive modularity). I argued that the inference from neural reuse was superior to the inference from evolutionary psychology (and massive modularity) because the former is not susceptible to the evolutionary story. One problem with the view that HCAs constitute by-products is that this view may provoke critics. Specifically, what evidence exists to show that HCAs are by-products? In this project I avoid this question because then the answer would require reconstructing the causal history of HCAs and it remains controversial whether or not this reconstruction can be supported by evidence. The problem then with identifying HCAs as by-products is that they invite skepticism about how

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[261] P. Jacob and M. Jeannerod, "The motor theory of social cognition: A critique," *Trends in Cognitive Science* 9, no. 1 (2006): 21-25.

[262] See Goldman, *Joint Ventures*, 245.

[263] This assumes that HCAs can be adequately defended as a by-product. For details, see Michael Ruse, *Darwin and Design: Does Evolution have a Purpose?* (Cambridge, Massachusetts: Harvard University Press, 2003), 235-236; for other details, see Maria Brinker, "Sensorimotor grounding and reused cognitive domains," *Behavioral and Brain* Science 33, no. 4 (2010): 270.

human cognition and HCAs evolved,[264] and this skepticism may fuel unnecessary objections about whether or not HCAs are the product of evolution. According to the critic, the by-product response is too easy to make without evidence, and thus other explanations for the evolution of HCAs besides by-product explanations should be considered first.

One example of suggesting that HCAs may constitute by-products is Lewontin's view. Recall in chapter two that Lewontin remains skeptical that one can describe the evolution of human cognition. He remains confident, however, that evolutionary processes produced HCAs, either by way of natural selection or more likely as by-products. Indeed, for Lewontin, in either case the evolution of HCAs remains trivially true.

There are problems with Lewontin's confidence, especially if Lewontin thinks that HCAs are mere by-products of evolution, and these problems may incite the critic's objection that a by-product response is too cheap. First, the fact of cognitive evolution and the existence of HCAs is not "trivially true." A trivial truth is such that if q is true, then $p \supset q$ is also true. Thus, by "trivial" Lewontin more likely refers to an uncontroversial claim about cognitive evolution and higher abilities. But he offers almost no argument in support of this claim.[265]

Second, a charitable reading would suggest that Lewontin compares HCAs with every other human feature that has evolved over time.[266] As discussed in the introduction, however, comparing the evolution of HCAs with other evolved traits is a central issue under examination. A primary goal is to provide an argument in response to critics who think that HCAs do no resemble other human traits. So, for Lewontin to assert that evolutionary processes produced every human trait, including HCAs, begs the question in favor of the evolutionary view of HCAs. Critics such as Wallace and Nagel would likely reject Lewontin's confidence, especially if that confidence requires stipulating by-product explanations. Thus, a more principled response seems in order.

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[264] Stephen Jay Gould, "The exaptive excellence of spandrels as a term and phenotype," *Proc. Natl. Acad.* Sci 94, no. 20 (1997): 10755.

[265] Another example of mere assertion is from Robert C. Richardson, *Evolutionary Psychology as Maladapted* Psychology (Cambridge, Massachusetts: MIT Press, 2007), 94.

[266] Lewontin, *The Evolution of Cognition,* 108.

## IV. Conclusions

In this chapter I outlined additional evidence that the operations of ancestral brain regions were reused for carrying out HCAs. At this point, recall the argument under consideration and how the previous two chapters support premise (2):

1. Brain regions xyz evolved.
2. Brain regions xyz have been reused for carrying out HCAs.
3. So, brain regions xyz evolved and have been reused for carrying out HCAs.
4. If brain regions xyz evolved and have been reused for carrying out HCAs, then HCAs are the product of evolution.
5. So, HCAs are the product of evolution.

In this chapter, I presented three pieces of evidence for the reuse of older evolved brain regions for carrying out HCAs. The first piece of evidence was the functional relations between perceptual and sensorimotor functions with HCAs. The implicit assumption in that section was that the relation between those older functions and HCAs is instantiated by older brain regions contributing to HCAs. The second and third pieces of evidence examined anatomically distinct brain structures, the basal ganglia and the cerebellum, and showed that these older structures contributed to HCAs. These three pieces of evidence support the truth of premise (2): brain regions xyz have been reused for carrying out HCAs. Throughout the previous two chapters we have avoided some broader philosophical questions about HCAs. This is intentional, since this project focuses on the descriptive question of HCAs and not the teleological question of HCAs. Still, before analyzing the inference from neural reuse to the evolutionary view of HCAs in support of premise (4), in the following Interlude I outline and briefly consider a popular argument that highlights some of the philosophical problems with discussing the evolution of HCAs and then apply the theory of neural reuse to this problem.

## Interlude

Alvin Plantinga's Evolutionary Argument Against Naturalism (EAAN) claims that one cannot rationally affirm both metaphysical naturalism and evolution in conjunction. According to Plantinga, if there were no God and evolution were true, then one would not be able to trust the reliability of their belief-forming faculties. If one cannot trust the reliability of their belief-forming faculties, then one cannot rationally affirm the beliefs produced by those faculties, including metaphysical naturalism and evolution.[267] A popular objection against the first premise of the EAAN includes the reliability of common-sense faculties. According to this common-sense objection, evolution would likely have selected for reliable common-sense faculties because true common-sense beliefs would likely have promoted fitness-enhancing behavior. Plantinga's response to the common-sense objection is that even if the objection holds, it does not explain the reliability of our faculties for metaphysics, such as those faculties required for HCAs. In response to Plantinga, what if our common-sense faculties were reused for metaphysical beliefs? What if there is no relevant distinction between the two types of faculties Plantinga has in mind? The theory of neural reuse may undermine Plantinga's distinction and thus challenge his response to the common-sense objection.

Plantinga's recent version of the EAAN is the following, where (P) is "the conditional probability," (R) is "our cognitive faculties are reliable," (N) is "naturalism," and (E) is "evolutionary theory."

1. P(R/N&E) is low.
2. Anyone who believes N&E and sees that P(R/N&E) is low has a defeater for R.
3. Anyone who has a defeater for R has a defeater for any other belief she thinks she has, including N&E.
4. If anyone who accepts N&E thereby acquires a defeater for N&E, N&E will be self-defeating and can't rationally be accepted.
5. Therefore, N&E can't rationally be accepted.

267 Alvin Plantinga, *Where the Conflict Really Lies* (Oxford: Oxford University Press, 2011), 308-309.

Before summarizing each premise of this argument, some brief definitions are required. According to Plantinga, the term reliability refers to how often a belief-forming faculty produces true beliefs, and the term faculty denotes a brain architecture for producing beliefs. Thus, a reliable belief-forming faculty is a brain architecture that will produce mostly true beliefs and an unreliable belief-forming faculty is a brain architecture that will produce mostly false beliefs.

Plantinga defines naturalism in two ways. The first definition of naturalism is that there is no God. This definition of naturalism is important for Plantinga because the fact that there is no God implies that there is no ultimate source guiding the processes of evolution. So, if there were no God, then the processes of evolution would be "unguided."

The second way that Plantinga defines naturalism is materialism. Materialism is a branch of naturalism stating that only material things exist. For instance, some naturalists may believe that some objects are immaterial, such as persons, numbers, and so on. According to Plantinga, materialistic naturalism is stronger than general naturalism because materialistic naturalism claims that only material objects exist and not immaterial objects.

Materialism is important for the EAAN because the materialist affirms a position about the nature of belief and its propositional content. Plantinga claims that the materialist view of belief includes two features. The first feature of belief according to materialism is the neurophysiological properties (hereafter, NP properties) that determine beliefs. The second feature of belief according to materialism is the propositional content associated with belief. Beliefs are about propositional content that is either true or false.

By the term evolution, Plantinga includes the doctrines of the neo-Darwinian thesis: heritability, random genetic mutation, and natural selection. Heritability and random genetic mutation refer to the differential reproduction that occurs within species and how offspring inherit slightly different traits from their forebears. Traits that promote fitness (i.e. reproductive success) tend to pass on to future generations by natural selection, and this heritability causes change both within a population and creates new species.[268]

Finally, the term "probability" refers to conditional probability. This means the one assesses the chances of p given the prior truth of q. To use Plantinga's example, what is the probability that Mr. A will live to one-hundred, given that he is a heavy smoker, eats unhealthily,

[268] Ibid., 320-324.

and refuses to exercise? To answer this question, one must figure how heavy smoking, bad diet, and lack of exercise count against the chances of aging to one-hundred.

According to premise (1), the probability that human belief-forming facilities are reliable, given both naturalism and evolution, is low. This probability claim resembles the example above regarding the chances of Mr. A living to one-hundred. The question is what are the chances that human belief-forming faculties are reliable, given the prior claim that both naturalism and evolution are true?

Premise (1) includes two steps. The first step is to assess the chances, given N&E, that the propositional content produced by human belief-forming faculties is true. Plantinga thinks that the chances are 50%. Given naturalism and evolution, the chances that a belief-forming faculty produces true belief is equal to the chances that the faculty produces a false belief. I discuss his reasons for defending this claim in a moment.

The second step includes applying the chances outlined in the first step (i.e. 50% chance that a belief is true) to the overall reliability of a belief-forming faculty. That is, how many true beliefs must a cognitive faculty generate for that faculty to satisfy reliability? Here Plantinga is intentionally vague. For argument's sake, he suggests that a reliable cognitive faculty will produce true beliefs roughly 75% of the time out of all its generated beliefs. A belief-forming faculty that produces true beliefs 25% of the time out of all its generated beliefs is an unreliable belief-forming faculty.

For example, suppose that faculty f produces memory beliefs that are true 50% of the time. What are the chances that f will achieve reliability, given that the chances f produces a true memory belief are 50%? Recall that a reliable belief-forming faculty produces true beliefs 75% of the time. Thus, what are the chances that f will produce true memory beliefs 75% of the time, given that the prior chances that a belief is true is 50%? Or a different example. You flip a fair coin one-hundred times. What are the chances of flipping heads seventy-five times out of the one-hundred tosses, given the prior claim that the chances of flipping heads is 50%? I suspect the chances are low. Similarly, according to Plantinga, if the chances that a belief-forming faculty produces true beliefs is 50%, then the chances that the faculty will generate true beliefs 75% of the time is low.[269]

[269] Ibid., 330-333.

The question is why does Plantinga think that the first premise is true? Why does he think that the conjunction of believing both naturalism and evolution implies a low probability? Recall the two features of belief according to Plantingian-style materialism. The first feature of a materialistic belief was the NP properties that determine beliefs. The second feature of materialistic belief was that beliefs exhibit propositional content and that propositional content is either true or false. The problem for Plantinga is that when these features of materialistic belief conjoin with unguided evolution, the result is that the NP properties produced by evolution generate beliefs arbitrarily: the beliefs may be true, or the beliefs may be false. Naturalistic (unguided) evolution generates NP properties for adaptive behavior – to promote the fitness (i.e. reproductive success) of the organism – not NP properties that produce true beliefs. True belief is causally irrelevant to adaptive behavior. This is the central claim supporting premise (1) and requires additional consideration.[270]

The critic may argue that a process of evolution that does not produce true belief would undermine fitness. For instance, organisms with NP properties that generate the belief that all water is poisonous would likely not survive and reproduce as many offspring as conspecifics that did not believe as such. So, the critic argues that true belief is causally relevant to adaptive behavior and is thus not produced arbitrarily. According to Plantinga, however, the problem with the critic's response above about true adaptive beliefs is that true adaptive beliefs do not accurately reflect beliefs at all. Plantinga refers to these types of examples described by the critic as instances of "cognitive indication."

To understand the distinction between beliefs and cognitive indication Plantinga provides an example of a frog. The frog possesses adaptive NP properties that produce behavior in response to incoming prey. These NP properties include indicators that respond to various stimuli, which then produce adaptive behavior. These indicators enable the frog to detect insects, the distance of the insect, its speed, weight, and so on. When the relevant indicators trigger in response to incoming prey, the frog shoots out its tongue. Even if the frog could produce beliefs in this moment, those beliefs remain causally irrelevant to adaptive behavior. The indicators cause the adaptive behavior; the corresponding beliefs – if frog's exhibit belief at all – remain causally irrelevant to adaptive action. For Plantinga, indication is one thing and belief content is

[270] Ibid., 328-329.

something different. To use the poisonous water example, organisms that exhibited indicators for detecting poisonous water would likely have survived and reproduced and organisms lacking those indicators for detecting poisonous water would likely have died and not reproduced. Belief-formation is causally irrelevant in this case.

More instructive examples about indicators given by Plantinga include indicators in the human body: indicators for temperature, blood pressure, insulin, and so on, and these indicators respond to stimuli and produce adaptive behavior. The human body responds to temperature regardless of the belief content produced in the instance where temperature applies. A human need not produce a belief about overheating for the body to register and trigger cooling action. The belief is causally irrelevant to adaptive action in this case. Even if a person produces the belief that they are overheating, this belief is causally irrelevant to the triggered indicators for cooling the human body.

The problem with Plantinga's examples above for explicating belief and indication is that they fail to describe human cognition and the complexity therein. Perhaps I can provide a more helpful example to illuminate the distinction between belief and indication. Consider the hyper-agency-detection-device (HADD).[271] HADD is a mechanism for detecting hostile agents. You walk down a dark alley and hear a noise from behind. In this case HADD triggers fear, causing you to either fight or flee. Thus, HADD is a cognitive mechanism useful for survival and reproductive success and is therefore under the power of selection. HADD also generates false positives in that the false detection of hostile agents triggers the same reflex of fear: the noise in the dark alley is the wind and not a hostile agent and HADD triggers fear nonetheless. HADD's trigger does not depend on or produce the truth of the propositional content. Rather, HADD's action operates adaptively according to the NP properties triggering the correct response in the appropriate instance. It does not matter if the content of the belief produced by the HADD refers to the wind or the predator. HADD generates propositional content about the belief of hostile agents regardless of whether hostile agents exist. HADD's adaptive function remains insensitive to the truth of the belief content. HADD both causes adaptive behavior via indication and

[271] For discussion, see Justin Barrett, *Why Would Anyone Believe in God*? (Walnut Creek, California: AltaMira Press, 2006); Daniel Dennett, *Breaking the Spell: Religion as a Natural Phenomenon* (New York: Penguin Books, 2006).

generates beliefs arbitrarily in that those beliefs may be true or may be false. The HADD example is different than Plantinga's previous examples because it captures both cognitive indication and arbitrary belief-formation in one action. The hope is that the example utilizing HADD is more intuitive for understanding the first premise.

With these details in mind, according to premise (1), given the prior truths of both N&E, the HADD scenario resembles human belief-forming faculties more generally. Given the truths of both N&E, the relevant factor for the construction of human belief-forming faculties is that those faculties trigger appropriate fitness-enhancing behavior and not that they produce true belief. The adaptive behavior of those faculties obtains regardless of the propositional content that is produced by those faculties. In other words, given N&E, our entire cognitive infrastructure would be unreliable, comparable to the unreliability of the HADD. I respond to this premise shortly.

According to premise (2), anyone who believes the first premise must then accept that their belief-forming faculties are unreliable. By analogy, Plantinga describes a substance called XX which causes cognitive unreliability when ingested. Now imagine Lucy realizes that she consumed XX. This realization gives Lucy reason to doubt the reliability of her belief-forming faculties. Suppose Lucy believes that she is currently sitting at home. How can she trust that this belief is true, given the prior belief that she consumed XX? Her doubt about the belief that she is currently sitting at home originates from the prior belief that she consumed XX and the fact that XX produces cognitive unreliability. She cannot trust her cognitive faculties in conjunction with affirming the belief that she consumed XX. According to Plantinga, Lucy's epistemic position after consuming XX resembles the person who affirms both naturalism and evolution. Affirming both naturalism and evolution in conjunction is analogous to ingesting XX. Affirming both naturalism and evolution in conjunction entails that one cannot trust the reliability of their belief-forming faculties.

According to premise (3), if one accepts that their belief-forming faculties are unreliable, then that person must doubt the beliefs produced by those faculties, including the beliefs about naturalism and evolution. If the cognitive infrastructure producing beliefs cannot be trusted, then one cannot affirm the truth of those beliefs produced by that infrastructure. And Premise (4) states that believing both naturalism and evolution is self-defeating. Affirming naturalism and evolution produces a defeater for believing the truth of both naturalism and evolution. A defeater is a belief or fact that undermines the truth of another belief. Thus, says Plantinga, it is irrational to believe both naturalism and evolution.

A popular response to the EAAN – and premise (1) specifically – is that evolution would have likely selected for common-sense faculties that produced common-sense beliefs.[272] The common-sense strategy aims to show how common-sense faculties are reliable and then demonstrate how that reliability undermines the first premise.

Common-sense beliefs refer to ordinary beliefs that guide every-day actions, such as perception, memory, sensation, and so on. For example, organisms with faculties generating the belief that they can pass through solid objects would not have reproduced as many offspring as conspecifics that did not possess those faculties. The common-sense response to the EAAN resembles the types of scenarios described above. Consider again the HADD example. Even if the belief about a hostile agent were false, HADD would have functioned reliably in a different way. HADD (in conjunction with other belief-forming faculties) produced true common-sense beliefs in a non-arbitrary way about the environment – noises, wind, and colliding objects. According to the common-sense response to the EAAN, basic common-sense mechanisms would have been selected for by evolution and would produce true beliefs in a non-arbitrary way.

Plantinga seems willing to concede the common-sense objection against the first premise and then he develops a weaker version for the EAAN.[273] The weaker version of the EAAN affirms that some common-sense NP properties produce true common-sense beliefs in a non-arbitrary way. But, says Plantinga, the reliability of common-sense faculties does not resolve the conflict. The reason is because the belief in naturalism and evolution is the product of "metaphysical faculties," or "higher" faculties, and not "common-sense" faculties. Plantinga then re-states the first premise of the weaker version of the EAAN: P (MR/N&E) is low. This means that the probability that our "metaphysical faculties" are reliable, given naturalism and evolution, is low. Therefore, the naturalist must provide reasons for confiding in the reliability of metaphysical faculties even if the popular common-sense objection to the EAAN succeeds.

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[272] Paul Griffiths and John Wilkins, *Darwin in the 21st Century: Nature, Humanity, and God* (ed. P.R Sloan; Notre Dame: Notre Dame University Press, 2015); Paul Griffiths and John Wilkins, *A New Science of Religion* (eds. James Maclaurin and Greg Dawes; New York: Routledge, 2013).

[273] Plantinga, *Where the Conflict*, 348-349.

In what follows, I respond to the weaker version of the EAAN by conjoining the theory of neural reuse with the common-sense objection to premise (1). Recall that neural reuse is the view that brain regions reuse their neural resources for multiple cognitive use. This theory of reuse undermines the weaker version of premise (1) in two related ways: (i) by challenging Plantinga's characterization of the functional architecture of the brain; and (ii), by undermining the distinction between faculties for common sense and faculties for metaphysics.

Consider the first implication of how reuse challenges the weaker version of premise (1). Plantinga describes the functional architecture of the brain by citing Thomas Reid.[274] Following Reid, says Plantinga, there exists cognitive faculties for sympathy, introspection, testimony, and so on. The difficulty with Plantinga's characterization of the brain is that this type of "Reidian faculty psychology" resembles modular theories about the functional architecture of the brain. Although not explicitly stated, Plantinga describes human cognition in a modular sense, such that humans exhibit distinct "faculties" (or modular structures) for different types of functions. It is this description of the functional architecture of the brain that insinuates the distinction between faculties for common sense and faculties for metaphysics. Neural reuse challenges this more traditional view of the modular brain in that the brain is not composed of these highly discrete, dissociable "faculties," (or modules) but rather the brain resembles a dynamic (changing) cognitive network, whereby common sense and metaphysics are the product of similar neural networks. This general view about the differences between a modular (faculty) brain and a brain exhibiting reuse introduces the second problem with the weaker version of premise (1).

According to the second problem with the weaker version of premise (1), Plantinga distinguishes between faculties for common sense and faculties for metaphysics. He accepts that, given N&E, while evolution may have produced reliable common-sense faculties for perception, navigation, and so on, evolution would likely not have produced reliable faculties for metaphysical beliefs. Plantinga's move at drawing a relevant distinction between faculties for common sense and faculties for metaphysics, however, assumes that there exists a relevant distinction between faculties for common sense and faculties for metaphysics. Following the

[274] Plantinga, *Where the Conflict*, 312.

theory of neural reuse and the first response to the weaker premise above, even if one could characterize the brain by using the term "faculties," higher faculties for metaphysics are really the product of lower common-sense faculties; common-sense faculties have been reused for higher cognitive use, including the production of metaphysical beliefs.

Therefore, the two problems outlined above challenge the weaker version of premise (1) because, first, the brain is likely not composed of highly discrete, dissociable and distinct faculties, but resembles a changing network; and secondly, even if the brain is characterized by these highly discrete faculties, brain regions for common sense have been reused for producing metaphysical beliefs.[275] If our common-sense faculties are reliable, given both naturalism and evolution, and those faculties have been reused for higher cognitive use, then the first premise of the weaker version of the EAAN appears false. If one can trust their faculties for common sense, and those faculties for common sense have been reused for higher cognitive use, then the probability that our faculties for metaphysics are reliable, given N&E, may not be as low as Plantinga suggests. Thus, if the common-sense strategy against the EAAN succeeds, and if the theory of neural reuse were true, then premise (1) of the weaker version of the EAAN would appear false and the weaker argument would fail.

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[275] A further implication of reuse for the first premise is that because human faculties were reused for higher cognitive use, the influence of evolution may not apply universally. There may exist reliable human belief-forming mechanisms functioning beyond the scope of evolutionary influence. Some of the functional operations of common-sense faculties have been reused to produce beliefs largely independent of evolved bias. Thus, even if the first premise of the EAAN were true, neural reuse is a theory that suggests humans can overcome their cognitive limitations inherited from evolution. Humans can, to some extent, overcome their evolved cognitive biases and produce beliefs distinct from those biases.

## Chapter Four

## Defense of Premise (4)

In the second chapter I introduced the theory of neural reuse and explained how that theory aligns with evolution. In chapter three, I stated additional evidence for neural reuse, showing the relationship between higher abilities and sensorimotor/perceptual systems, and how the functional operations of older brain structures were recruited for carrying out higher cognitive abilities (HCAs). These two chapters were an attempt to defend premise (2) of my argument for the evolution of HCAs: *brain regions xyz have been reused for carrying out HCAs*. In this fourth chapter, I defend premise (4) of my argument for the evolution of HCAs: *If brain regions xyz evolved and have been reused for HCAs, then HCAs are the product of evolution*. In the first section of this chapter, I examine the inferential processes utilized in science and show how these inferences support models of scientific confirmation and explanation. These inferences demonstrate how scientific hypotheses and testable observations support scientific conclusions. In sections two and three of this chapter, I focus on two models of confirmation and explanation and then apply these models to premise (4). I then conclude this chapter by noting some general objections and then providing responses.

### I. Scientific Confirmation and Explanation

There is a difference between scientific confirmation and scientific explanation. Providing a scientific confirmation for a hypothesis includes evidence for supporting the truth of the hypothesis. Suppose that one hypothesizes that during a lunar eclipse the color of the moon turns to copper. Confirmation of this hypothesis occurs by observing the eclipse or compiling the testimony of other people.[276] If it turns out that the observation or the testimony of the lunar eclipse affirms the truth of the copper-like color of the moon, then the hypothesis is confirmed. However, *confirmation* of the copper-like color of the moon does not *explain* the copper-like color of the moon. What is required for explanation of the color of the moon is some additional

[276] Wesley Salmon and John Earman's *Introduction to the Philosophy of Science* (Indianapolis, Cambridge: Hackett Publishing Company, 1992), 8.

information that provides understanding.[277] To appreciate this difference between confirmation and explanation for the argument for the evolution of HCAs, the current aim is to outline models of both confirmation and explanation. The goal is to show that the evolutionary view of higher abilities can be both confirmed and explained by the evidence presented in the previous two chapters. To understand these models of confirmation and explanation, a brief summary of the logic of inference must be made explicit.

There are three types of inference. The first type of inference is deductive. A deductive inference is such that if the premises of an argument were true, then the conclusion following those premises would have to be true. Deduction is an inference of certainty. It is impossible for the premises of a valid deductive argument to be true, but the conclusion false. A second type of inference is inductive. Inductive inferences can take a variety of forms, enumerative, analogical, and causal, but all share the same feature in that inductive inferences are not certain but probable. A third type of inference is abductive. There are two different (but related) types of abductive inference, the first developed by philosopher Charles Sanders Peirce, which focuses on the scientific practice of generating hypotheses, and the second associated with Inference to the Best Explanation (IBE), which aims to provide justification for a hypothesis by way of explanatory power.[278] These types of inferences are important for understanding the logical structure of the models of confirmation and explanation explored in this chapter and will be discussed throughout.

## II. Hypothetico-Deductive Model

The Hypothetico-Deductive model (H-D model) utilizes both deduction and induction to confirm hypotheses. There are two ways to use the H-D model, confirmation and disconfirmation. Confirmation using the H-D model includes two steps. The first step of using the H-D model for

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[277] Salmon and Earman, *Introduction to the Philosophy of Science*, 8-9.

[278] Ibid., 419-442; Igor Douven, “Abduction,” *The Stanford Encyclopedia of Philosophy*, accessed May 2017, https://plato.stanford.edu/archives/sum2017/entries/abduction/>. For a recent defense of inference to the best explanation, see Peter Lipton, *Inference to the Best Explanation*, second edition (Cambridge: Cambridge University Press, 2004).

confirmation is to identify an observation that derives from a hypothesis; that means locating an observation that is deductively implied by a hypothesis. The second step of using the H-D model for confirmation is to test the observation, and if the test is successful, the observation inductively supports the truth of the hypothesis. In other words, the first step of confirmation using the H-D model requires stating a premise whereby if such-and-such a hypothesis were true, then such-and-such an observation would follow. And then the second step of confirmation using the H-D model is to test the observation that followed from the hypothesis. This description of the H-D model can be confusing because the model utilizes both deductive and inductive methods for confirming and not only deductive inference, as the title H-D model suggests.

A classic example of how the H-D model applies to confirmation is Boyle's Law. Boyle's Law is that for any gas kept at a constant temperature, the pressure of the gas is inversely proportional to the volume of the gas. This means that doubling the pressure of the gas will reduce the volume of the gas by half and doubling the volume of the gas will reduce the pressure of the gas by half.[279] This law can be confirmed by the H-D model. In the example of the argument below, Boyle's Law is the hypothesis designated by premise (1), and then a set of auxiliary assumptions supporting Boyle's Law are designated by premises (2) – (5). Auxiliary assumptions are assumptions verified independently of the hypothesis.

1. At a constant temperature, the pressure of a gas is inversely proportional to its volume.
2. The initial volume of the gas is 1 cubic ft.
3. The initial atmospheric pressure of the gas is 1.
4. The atmospheric pressure of the gas is increased to 2.
5. The temperature remains constant.
6. Therefore, the volume of the gas decreases to ½ cubic ft.

In this example, the hypothesis and the auxiliary assumptions, premises (1) – (5), entail an observation, designated by the conclusion, (6). This is a deductively valid argument. If premises (1) – (5) were true, then the conclusion, (6), would have to be true. This argument describes the first step of scientific confirmation using the H-D model. It shows how an observation derives from a hypothesis and a set of auxiliary assumptions.

[279] Salmon and Earman, *Introduction to the Philosophy of Science*, 44-45.

The second step of confirmation using the H-D model is assessing whether the truth of the observation derived from the hypothesis confirms the hypothesis. As we shall see, this second step of using the H-D model for confirmation encounters some deductive problems. For instance:

7. If Boyle's Law were true, then, under such-and such initial conditions, the volume of the gas would decrease to ½ cubic ft.
8. Under such-and-such initial conditions, the volume of the gas decreased to ½ cubic ft.
9. So, Boyle's Law is true.

In this example, premise (7) describes statements (1) – (6) above in a conditional sentence. The first part of the conditional sentence beginning with "if" is the antecedent and this antecedent describes the hypothesis, Boyle's Law, along with the auxiliary assumptions, premises (1) – (5). The second part of the conditional sentence beginning with "then" is the consequent and this consequent describes the observation, premise (6). Premise (8) is a test that affirms the truth of the consequent, which is the observation about the volume of the gas.

The problem with the argument is that the conclusion, premise (9), does not follow deductively from premises (7) and (8). This argument commits the logical fallacy of affirming the consequent. Even if the premises are true, it does not follow that the conclusion is true. This argument proves that observations cannot deductively confirm a hypothesis. Observations can only strengthen the support of a hypothesis.

Consider a different example using Boyle's Law supporting the claim that observations cannot deductively confirm hypotheses.

10. The initial volume of the gas is 1 cubic ft.
11. The initial atmospheric pressure of the gas is 1.
12. The atmospheric pressure of the gas is increased to 2.
13. The temperature remains constant.
14. The volume of the gas decreases to ½ cubic ft.
15. Therefore, at constant temperature, the pressure of a gas is inversely proportional to its volume.

Premises (10) – (14) do not guarantee that the conclusion, premise (15), is true. What is required is an inductive maneuver estimating the probability that premise (15), which is Boyle's Law, is true. It could be that under different conditions the volume of the gas was decreased by ½ and the atmospheric pressure failed to double. Indeed, under initial conditions such that the temperature of the gas is closer to condensing into liquid, the law no longer applies.[280] That is to say, there exists an instance such that the premises (10) – (14) are true and the conclusion, (15), is false. Thus, one cannot derive a hypothesis from a set of observations but only provide probable support for the hypothesis from those observations.

The examples above show how to use the H-D model for confirmation, utilizing both deductive and inductive inferences. The second way to use the H-D model is disconfirmation. Disconfirmation also includes two steps, derive a hypothesis from an observation and then test the observation to see if a failed test disconfirms the hypothesis. Recall that in the method of confirmation above affirming the observation provided inductive support for the hypothesis, not deductive support, since the latter produced a logical fallacy. Using the H-D model for disconfirmation, however, does not commit the logical fallacy but would prove by deduction the falsity of the hypothesis. Still, as we shall see, this move of disconfirmation by deduction also introduces problems.

For example, consider the following deductively valid argument:

16. If Boyle's Law were true, then, under such-and-such initial conditions, the volume of the gas would decrease by ½ cubic ft.
17. Under such-and-such initial conditions, it is false that the volume of the gas decreased by ½ cubic ft.
18. So, Boyle's Law is false.

Resembling the conditional premise (7) above, premise (16) includes the hypothesis and the implied observation in one conditional premise. The hypothesis is the antecedent, the first part of the sentence, and the observation is the consequent, the second part of the sentence. Premise (17) denies the observation. Denying the observation logically entails the falsity of the hypothesis. Deduction in this case implies that a hypothesis is false by disconfirming the observation entailed by that hypothesis.

The problem with using the H-D model for disconfirmation is that a failed test of an observation may not always disconfirm the hypothesis, not because of deduction, which is

[280] Ibid., 45.

certain, but rather because of the auxiliary assumptions used within the deduction. Sometimes a failed observation disconfirms the auxiliary assumption used within the argument and does not disconfirm the hypothesis. For instance:

19. If Mercury has an irregular orbit and Newtonian mechanics were true, then another planet would exist nearby.

Premise (19) includes an observation about Mercury's orbit and the truth of an auxiliary assumption about Newtonian mechanics. The problem is that the observation about a nearby planet was disconfirmed. This failed observation does not undermine the truth of Mercury's irregular orbit, but rather the auxiliary assumption about Newtonian mechanics. It is Newtonian mechanics about planetary orbits that is false in this case, not the hypothesis about Mercury's orbit.[281] This analysis shows that one must consider auxiliary assumptions when disconfirming a hypothesis.

To summarize: there are two ways to utilize the H-D model, confirmation and disconfirmation. Using confirmation requires that one perform two steps. The first step is to derive an observation from a hypothesis and then secondly test the observation to inductively confirm the hypothesis. Disconfirmation also requires two steps. The first step for disconfirmation is to derive an observation from a hypothesis and then secondly test the observation to see if a failed observation undermines an auxiliary assumption used to support the hypothesis or undermine the hypothesis itself.

There is at least one relevant objection to the H-D model called the "tacking objection."[282] This objection is relevant for two reasons. First, it is a common objection against the H-D model and so requires attention.[283] Second, the tacking objection is one that Inference to

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[281] See Carl Hempel, "Studies in the Logic of Confirmation," *Aspects of Scientific Explanation* (The Free Press, New York: 1965), 346; Sprenger, "Hypothetico-Deductive Confirmation," 6-8; Earman and Salmon, *Introduction to Philosophy of Science,* 47- 49.

[282] Lipton, *Inference to the Best Explanation*, 91; Nelson Goodman, *Fact, Fiction, and Forecast*, 4th edition (Indianapolis: Bobbs-Merrill; 1983, 67-68.

[283] Luca Moretti, "The Tacking by Disjunction Paradox: Bayesianism Versus Hypothetico-Deductivism," *Erkenntnis* 64, no. 1 (2006): 115{138; Thomas R Grimes, "Truth, Content, and the Hypothetico-Deductive Method," *Philosophy of Science 57*, no. 3 (1990): 514-522.

the Best Explanation may address with greater success. Thus, even if the tacking objection succeeds and undermines utilizing the H-D model for supporting the argument for why HCAs are the product of evolution, the IBE model provides greater success against the tacking objection.

According to the tacking objection, irrelevant conjuncts can be conjoined with the original hypothesis, while preserving the confirmation relation between the hypothesis and the observation. Note the following example of using the H-D model for confirmation.

20. If Boyle's Law were true and the moon were made of green cheese, then, under such-and-such initial conditions, the volume of the gas would decrease by ½ cubic ft.
21. Under such-and-such initial conditions, the volume of the gas decreased by ½ cubic ft.
22. So, *probably*, Boyle's Law is true and the moon is made of green cheese.

Because the H-D model permits additional conjuncts to be conjoined to the original hypothesis, a successful test of the observation confirms both the original hypothesis and the secondary (nonsense) hypothesis. The proponent of the tacking objection therefore claims that this problem of irrelevant conjuncts leads to absurdity. The logic of the H-D model confirms any nonsense hypothesis whatever, in this case a hypothesis about the moon's green-cheese properties.

The same problem applies to the consequents, such that additional disjuncts can tack on irrelevant observations, thereby entailing both the observation and the added disjunct. This problem may also lead to absurdity. For example:

23. If Boyle's Law were true, then under such-and-such initial conditions, the volume of the gas would decrease by ½ cubic ft or the moon would be made of green cheese.
24. It is false that under such-and-such conditions the volume of the gas would decrease by ½ cubic ft or the moon would be made of green cheese.
25. So, Boyle's Law is false.

Comparable to the first problem of irrelevant conjuncts, the problem of irrelevant disjuncts equally applies. Deductive logic preserves the confirmation relation, thereby supporting irrelevant observations entailed by the hypothesis.[284]

[284] Gerhard Schurz, *Philosophy of Science: A Unified Approach* (New York: Routledge, 2014), 143-146; Irving Copi, *The Theory of Logical Types* (London: Routledge and Kagan Paul, 1971), 16-17.

One response to the tacking objection is called the replaceability salva validitate criterion (i.e. without harming validity criterion) [285] Here I outline a general view of the replaceability salva validitate criterion (RSV, for short) and do not consider additional subtleties, objections, and responses.[286] The RSV criterion identifies "nonessential" variables tacked on to hypotheses and observations. All nonessential variables can be replaced by any other variable whatever, salva validitate. More specifically, assume that $P \supset R$. R is a relevant conclusion of P if and only if R cannot be replaced by another variable, salva validitate of P. Otherwise, R is an irrelevant conclusion of P.[287] Consider the following example illustrating the RSV criterion below:

26. If Boyle's Law were true, then under such-and-such initial conditions, the volume of the gas would decrease by ½ cubic ft or the moon would be made of green cheese.

Premise (26) illustrates the RSV in that the added disjunct "the moon would be made of green cheese" is nonessential because that disjunct can be replaced with any variable, while preserving the confirmation relation. This is not the case with the original variable about the volume of the gas. One cannot replace the original variable about the volume of the gas and preserve the confirmation relation between hypothesis and observation. So, the variable about the volume of the gas remains essential for preserving the confirmation relation and the variable about the moon's green-cheese properties remains nonessential for preserving the confirmation relation.

While this analysis does not consider additional objections and further refinements, the H-D model describes the methods of contemporary science.[288] Indeed, as we shall see in section

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[285] Gerhard Schurz, "Relevant Deduction," *Erkenntnis* 35, no. 1-3 (1991): 391-437; Gerhard Schurz, "Relevant Deduction and Hypothetico-Deductivism: A Reply to Gemes" *Erkenntnis* 41, no. 2 (1994): 183-188.

[286] Sprenger, "Hypothetico-Deductive Confirmation," 500-507.

[287] Schurz, *Philosophy of Science*, 144.

[288] Ernst Mayr, *This is Biology: The Science of the Living World* (Cambridge, Massachusetts: Belknap Press, 1997), 54-56. See also William Whewell, *Philosophy of the Inductive Sciences, Founded Upon Their History*. Vol. II (London: Parker, 1847); Francisco J. Ayala, "Darwin and the Scientific Method," in *In the Light of Evolution, volume III: Two Centuries of Darwin* (eds. John C. Avise and Francisco Ayala; Washington: The National Academies Press, 2006), 274; For example, Albert Einstein's theory of relativity was confirmed by Arthur Eddington's observation of the bending light around the sun during an eclipse; see Lipton, *Inference to the Best*, 15; Regarding Darwin's method for discovering and developing

II with the IBE model, the fact that the H-D model has shown success in the past may contribute to the justification of utilizing the H-D model. This may be true even if the H-D model captures the truth of inductive practices only in part, and even if the H-D model cannot satisfy the demands required by the philosophy of science. In the next section I apply the H-D model to premise (4) of my argument.

**A. Defense of Premise (4): H-D Model**

Premise (4) of my argument states the following: *If brain regions xyz evolved and have been reused for HCAs, then HCAs are the product of evolution.* The claim is that the reuse of older evolved brain structures suggests the evolution of HCAs. More specifically, the fact that evolved structures contribute to both ancestral operations and higher operations suggests that HCAs are the product of evolution. This is the controversial move in the argument and requires additional discussion.

How does the H-D model support premise (4)? Note that at the end of chapter two I discussed reuse and evolution. Part of that discussion included a description of the three strategies for understanding how natural selection coincides with the evolution of HCAs. The first strategy was that natural selection was necessary but not sufficient for the evolution of HCAs. According to this first strategy, natural selection would have been required for constructing the cognitive infrastructure for reuse, but then other mechanisms of evolution and culture may have been required. The second strategy was that natural selection was both necessary and sufficient for constructing a brain for reuse. According to this second strategy, the fact that the brain exhibits neural search – i.e. the cognitive capacity for the brain to search for novel connections for performing successful action – suggests that evolution selected for a brain for reuse. The third strategy focused on evolutionary psychology. Evolutionary psychology describes HCAs as adaptations selected for by evolution. The point is to focus on the first two strategies. The claim is that the first two strategies for understanding reuse and natural selection

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evolution by natural selection, see Michael.T Ghiselin, *The Triumph of the Darwinian Method* (Univ California Press, Berkeley), 1969. For problems, see Elliott Sober, *Did Darwin Write the Origin Backwards* (Amherst, New York: Prometheus Books, 2011), 28.

assume a gradual process of change, from older evolved brain regions carrying out ancestral operations, to those same older evolved brain regions carrying out HCAs.

One way to support premise (4) of the argument for the evolution of HCAs is to make explicit the assumption that HCAs developed gradually. To say that HCAs are the product of evolution is just to say that HCAs were the result of an incremental biological process of change. The reason for thinking that the antecedent of (4) suggests that HCAs are the product of evolution is because the antecedent implies a gradual process of change and this process resembles evolution.

Recall that using the H-D model for confirmation included two steps: first, derive an observation from the hypothesis, and second, test the observation to show if the observation inductively confirms the hypothesis. Consider the following argument noting the first step:

27. If HCAs are the product of evolution, then HCAs developed gradually.[289]
28. HCAs developed gradually.
29. So, *probably*, HCAs are the product of evolution.

Premise (4) of my argument implicitly claims that the gradual process of evolution characterizes the way that HCAs developed by evolution. HCAs are the product of evolution because of the gradual process of the reuse of older brain regions. Premise (27) above details that hidden assumption about the gradual nature of evolution described in premise (4). That is, if HCAs are the product of evolution, which is the hypothesis, then one would expect to observe a gradual change from older brain operations to higher brain operations.

Step two of the H-D model for confirmation includes assessing the inductive maneuver for confirming the hypothesis. The observation is tested, and if successful, then the observation provides inductive support for the hypothesis. In support of premise (28), which is the observation to be tested, I argued that neural reuse provides an example of how an incremental process of evolution could lead to HCAs. HCAs are not instantiated by independent brain regions existing on their own, but rather instantiated by the same evolved brain regions that

[289] Richard Dawkins, *River Out of Eden: a Darwinian View of Life* (New York: Basic Books, 1995), 83; Ernst Mayr, *What Evolution Is* (New York: Basic Books, 2001), 80-87, 190; Jerry Coyne, *Why Evolution is True* (New York: Penguin, 2009), 3-4, 11; Kim Sterelny, “Philosophy of Evolutionary Thought,” in *The First Four Billion Years* (eds. Michael Ruse and Joseph Travis; Cambridge, Massachusetts: Belknap Press, 2009), 314.

contribute to more basic operations, such as perception and motor control. Therefore, observing older brain structures being reused for higher cognitive use implies a gradual process of change. There is change from older brain regions carrying out ancestral operations to those same brain regions carrying out HCAs. Thus, the antecedent of premise (4) assumes a gradual process of change. This gradual process of change resembles the processes of evolution, whether by natural selection or additional mechanisms, which is the consequent of (4). The reason for thinking that premise (4) is true is because the reuse of older brain regions for HCAs, which describes the antecedent, suggests a gradual process of evolution, which describes the consequent.

There is an objection, however. The second way of using the H-D model includes disconfirming a hypothesis (or an auxiliary assumption) by showing that the observation derived from the hypothesis fails to obtain. In this case, the critic of the evolutionary view of higher abilities may attempt disconfirmation. For instance:

30. If HCAs are the product of evolution, then HCAs evolved gradually.
31. It is false that HCAs evolved gradually.
32. So, it is false that HCAs are the product of evolution.

Provided that the critic affirms (30), such that the auxiliary assumption about gradualism is true, the critic may attempt to defend premise (31) and show that higher abilities are not the consequence of a gradual process.

According to this objection against a gradual process of HCAs, critics may argue that HCAs did not evolve gradually but evolved from a "punctuated" process.[290] The punctuated view is a model of evolution proposing that most species undergo few changes, and then exhibit

[290] For details regarding cognition as a result of a punctuated process, see G.P Rightmire, "Patterns in the evolution of Homo erectus," *Paleobiology* 7, no. 2 (1981): 241–246; J.E. Cronin, N.T Boaz, C.B Stringer, and Y. Rak, "Tempo and mode in hominid evolution," *Nature* 292 (1981): 113–122; see Susanne Shultz, Emma Nelson, and Robin I. M. Dunbar, "Hominin cognitive evolution: identifying patterns and processes in the fossil and archeological record," *Philosophical Transactions* 367, no. 1599 (2012): 2130–2140; C.B Ruff et. al., "Body mass and encephalization in Pleistocene Homo" *Nature* 387 (1997): 173-176; see also Merlin Donald, *Origins of the Modern Mind: Three Stages in the Evolution of Culture and Cognition* (Cambridge, Massachusetts, 1991).

interrupted (or punctuated) rapid change.[291] The implications of this objection for the evolutionary argument for HCAs is that the objection may include other causal mechanisms necessary for producing HCAs and undermine the current support for premise (4).[292]

One response to the punctuated objection is that it misunderstands the gradualist assumption. Accordingly, there is no conflict between the type of gradualism presumed by premise (28) and the punctuated model. The reason is because the punctuated model was traditionally understood as a critique of certain types of gradualism, not gradualism more generally. For instance, in a series of papers by Gould, he argued that there exist large changes that produce new types of species. These large gaps were thought to support a punctuated view of evolution that would diverge from the gradualist assumption.[293] But Gould corrects this misunderstanding by his critics, stating that while large changes may occur for ushering in new species, the "small genetic changes producing large effects by altering rates of development" remains. In other words, small gradual changes still exist that lead to larger effects.

Moreover, in a later piece, Gould argues that "Darwinians, with their traditional preferences for gradualism and continuity, might not shout hosannas for large phenotypic shifts induced rapidly by small genetic changes that affect early development; but nothing in Darwinian theory precludes such events, for the underlying continuity of small genetic changes

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[291] Carl Zimmer and Douglas J. Emlen, *Evolution: Making Sense of Life* (Colorado: Roberts and Company Publishers, 2013), 244-246; Niles Eldredge and Stephen J. Gould, "Punctuated Equilibria: An alternative to Phyletic Gradualism," in *Models in Paleobiology* (ed. T.J. M. Schopf; San Fransico: Freeman, Cooper and Company, 1985), 82-115; Stephen J. Gould and Niles Eldredge, "Punctuated Equilibria: the tempo and mode of evolution reconsidered," *Paleobiology* 3, no. 2 (1977): 115-151.

[292] Daniel Margoliash and Howard C. Nusbaum, "Language: The Perspective from Organismal Biology," *Trends Cogn Sci* 13, no. 12 (2009): 508.

[293] See Stephen Jay Gould, "Change in Development Timing as a Mechanism of Macroevolution," in *Evolution and Development* (ed. J.T Bonner; Berlin, Heidelberg, New York; Springer-Verlag), 338; Stephen Jay Gould, "The Uses of Heresy: An Introduction to Richard Goldschmidt's The Material Basis of Evolution," in *The Material Basis of Evolution* (ed. Richard Goldschmidt; reprinted New Haven: Yale University Press, 1982), xix; Daniel Dennett, *Darwin's Dangerous Idea: Evolution and the Meanings of Life* (New York: Simon and Schuster, 1995), 287-295; for how the punctuated view has incorrectly applied to other domains, especially language, see Stephen Jay Gould, "Life in a Punctuation," *Natural History* 101 (1992): 10-21.

remains."[294] Gould's notion of punctuated evolution did not undermine gradualism more generally since small incremental steps in genetic changes would have been required. This response undermines critics who attempt to challenge the gradualist assumption by incorrectly applying the punctuated model of evolution. The punctuated model of evolution does not undermine the fact that an incremental process of change must occur.

Applying the H-D model of confirmation provides support for premise (4) of the argument for the evolution of HCAs from neural reuse. The claim that evolution would have produced HCAs entails an observation about gradualism. This observation about gradualism can be tested. The evidence presented for neural reuse in the previous two chapters shows how an incremental process of change, from older evolved brain regions to HCAs, could have occurred. If those processes of reuse from older regions to HCAs occurred gradually, then that observation supports the conclusion that HCAs are the product of evolution. In the next section, I consider a different inferential move to support premise (4).

## III. Inference to the Best Explanation

In this section I explore the IBE model and how that model supports premise (4) of my fargument. Recall that according to the H-D model, the observation derived from the hypothesis confirms inductively the probable truth of the hypothesis. IBE confirms a hypothesis in a different way.

According to the IBE model, the hypothesis is confirmed when the hypothesis best explains the observation. One observes evidence and then postulates a hypothesis that, if the hypothesis were true, would best explain the observed evidence. The IBE model assumes that explanatory power provides an inferential link between observation and hypothesis, and thus explanatory considerations contribute to scientific confirmation.

Note the following example of IBE:

33. Moriarty's finger prints, gun, and cigar, were found at the crime scene.
34. The best explanation of (33) is that Moriarty committed the crime.
35. So, probably, Moriarty committed the crime.

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[294] Stephen Jay Gould, "The Uses of Heresy," xix.

A subtle difference between the H-D model and the IBE model is that the IBE reverses the order of when to apply the inference. The H-D model starts with a hypothesis and then one infers an observation derived from the hypothesis. The IBE model reverses this inferential process by first examining an observation and then seeking a hypothesis to explain the observation. The inference to the hypothesis occurs only after one decides on which hypothesis best explains the observation.[295]

One difficulty with the IBE model includes assessing under what conditions an explanation is considered the best. This question raises at least two problems. The first problem includes deciding on the criteria that determines the initial set of explanations from which one chooses the best explanation. What are the criteria for generating the initial list of explanations?[296] The second problem is deciding which explanation from the initial set is the best?

Both questions expressed above capture a general objection against the IBE model first raised by Bas van Fraassen.[297] This general objection is called the "best of a bad lot" objection. According to the best of a bad lot objection, the IBE model permits any explanation to enter the initial set of explanations. The consequence of including any explanation within the initial set suggests that the IBE permits the inclusion of bad explanations and bad explanations seem unrelated to explaining the phenomenon in question.

The strategy for responding to this objection includes two filters, the first for determining the initial set of explanations, and the second filter for choosing the best explanation from the initial set. As we shall see, the main criterion for the first filter is a causal criterion of explanation. The causal criterion can be well confirmed in evolutionary biology. The main criterion of the second filter is often a likelihood criterion. The likelihood criterion suggests that the best explanation chosen from the initial set is likely true. The likelihood criterion introduces

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[295] Peter Lipton, *Inference to the Best Explanation*, 2nd edition (New York: Routledge, 2004), 55-56.

[296] Ibid., 149-150.

[297] Bas van Fraassen, *Laws and Symmetry* (Oxford: Oxford University Press, 1989), 143.

problems associated with Bayesian confirmation theory. I will consider these objections and then introduce a more effective second criterion known as ampliative explanation afterwards.

Before exploring the causal criterion for the first filter, it is instructive to distinguish between potential explanations and actual explanations.[298] Potential explanations are possibilities that may be true; actual explanations are the ones that are true. The IBE model requires best *potential* explanations and avoids discussing best *actual* explanations. The reason is because the IBE model would lack any epistemic effectiveness if it was an inference to the best *actual* explanation, since this would already affirm the truth of the explanation prior to the inference, thereby begging the question in favor of the conclusion. For example:

36. Moriarty's fingers prints were found at the crime scene.
37. The best *actual* explanation of (36) is that Moriarty committed the crime.
38. So, probably, Moriarty committed the crime.

The first problem with this logical form is that the inference from (37) to (38) appears trivial. The reason for this is because the *truth* of the explanation in (37) provides trivial support for the *probability* of the hypothesis in (38). That is, one already affirms the truth of (37) by describing the best *actual* explanation and thus an inference from the truth of (37) to the probability of (38) becomes irrelevant. One need not affirm the probability of p after one affirms the truth of p.

The second problem with the form, and the source of the triviality just described, is that (37) begs the question. This means that (37) assumes the truth of the hypothesis it is meant to support because the proposition that Moriarty committed the crime is true (it is the *actual* state of affairs). But this confuses the nature of the inferential process of the IBE. According to the IBE model, it is the inference from observation to hypothesis that provides support for the best explanation and so affirming the actual explanation before the inference applies begs the question, creating the triviality.

One solution to the problems described above is to focus on best *potential* explanations and disregarding best *actual* explanations. For instance:

39. Moriarty's finger prints were found at the crime scene.
40. A best potential explanation of (39) is that Moriarty committed the crime.

[298] Ibid., 57-58.

41. So, probably, Moriarty committed the crime.

In this example, premise (40) does not beg the question. Rather the explanation is one of several explanations on offer and then the inferential process – choosing the best explanation – performs the epistemic work.[299] The distinction between potential explanations and actual explanations provides a context for analyzing the first filter of the IBE. One must first compile an initial set of potential explanations. From these potential explanations one then applies the second filter to affirm the best explanation from that initial set. As discussed above, compiling the initial set of potential explanations requires a first filter constrained by a casual criterion.

Describing the first filter for choosing a list of potential explanations traditionally includes two methods: the unification view and the causation view.[300] The unification view focuses on how explanation contributes to coherence. An explanation contributes to coherence when that explanation fits coherently within the broader web of scientific knowledge.[301] I do not explore the unification view here but focus only on the causal view of explanation.

One way to understand the causal view of explanation is describing an explanation that provides a historical account of the explanandum (the event to be explained).[302] One explains the mechanism linking cause and effect.[303] This causal view of explanation is attractive because

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[299] Ibid., 58.

[300] The causal view is found in Wesley Salmon, *Scientific Explanation and the Causal Structure of the World* (Princeton: Princeton University Press, 1984); the unification view is found in Phillip Kitcher “Explanatory Unification and the Causal Structure of the World,” in *Scientific Explanation* (eds. Phillip Kitcher and Wesley Salmon; Minneapolis: University of Minnesota Press, 1987), 410-505; see also Wesley Salmon and Phillip Kitcher, *Minnesota Studies in the Philosophy of Science, Vol 13: Scientific Explanation* (Minneapolis: University of Minnesota Press, 1989); for a discussion on how the unification view and the causal view apply to the IBE model, consider: Timothy Day and Harold Kincaid, “Putting Inference to the Best Explanation in its place,” *Synthese* 98, no. 2 (1994): 286-287.

[301] Carl Hempel, *Philosophy of Natural Science* (New Jersey: Prentice Hall, 1966); Lawrence BonJour, *The Structure of Empirical* Knowledge (Cambridge: Harvard University Press, 1985).

[302] David Lewis, “Causal Explanation,” in *Philosophical Papers, vol. II* (New York: Oxford University Press, 1986), 214-244.

[303] Lipton, *Inference to the Best Explanation*, 30.

explanation provides understanding and not only confirmation. At the beginning of this chapter I discussed the difference between a scientific confirmation and a scientific explanation. For S to know that p does not entail that S understand p. I know that the moon exhibits a copper-like color during an eclipse but fail to understand why this is the case. Causal explanations provide understanding in this way and it is this type of understanding that is meant to provide inferential power for drawing a conclusion.[304]

A second reason for preferring the causal view of explanation is how it addresses the tacking objection. One of the advantages of the IBE model over the H-D model is that by aligning IBE with a causal account of explanation, the tacking objection dissolves.[305] The tacking objection dissolves because a causal explanation constrains the irrelevant conjuncts and disjuncts, since the confirmation relation using IBE requires a causal relation and not a logical relation.[306] That is, the consequent of the antecedent in a causal conditional does not "logically" follow from the antecedent but rather follows "empirically." This causal constraint may suggest two things. First, irrelevant causes added to the best explanation may spoil the explanation and thus allow one to eliminate the irrelevant cause. Second, the scope of adding irrelevant explanations to the causal account remain limited. For example:

42. Moriarty's finger prints were found at the crime scene.
43. Some best potential explanations of (42) are that (i) Moriarty committed the crime and (ii) the moon is made of green cheese.
44. So, probably, Moriarty committed the crime and the moon is made of green cheese.

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[304] Ibid., 31. See also Nancy Cartwright, "When Explanation Leads to Inference," *Philosophical Topics* 13, no. 1 (1982): 111-121.

[305] There are additional subtleties here. When the H-D model conjoins with the deductive-nomological model of explanation, the tacking objection also applies. The deductive-nomological model aims to deduce observations from hypothesis by way of the laws of nature. The IBE model avoids the tacking objection because the best explanation does not allow for arbitrary nonsense explanations. If we say that A because of B, we cannot reasonably stipulate any nonsense cause as B. For details, see Lipton, *Inference to the Best Explanation,* 92.

[306] See Irvin Copi, *Symbolic Logic*, 5th edition (London: MacMillan Publishing, 1979), 16.

The irrelevant explanation described by (ii) does not align with the observation because of the causal constraint. The green-cheese explanation does not provide causal power for explaining the observation in (42). So not only does (ii) spoil the causal explanation but (ii) cannot be supported by the causal explanation.

A final reason for preferring the causal view of explanation is that the causal process of explanation aligns well with biological causes and biological causes describe the evolution of HCAs.[307] In what follows, I briefly introduce one description of causation and then introduce a classic summary of biological causation.

The causal view of explanation is a physical process characterized by two features.[308] The first feature is the transmission of a "mark." For example, imagine a car moving along the road with its shadow extending from its side. The moving car crashes into a fence and leaves a dent in the side of the car. This chain of events represents a causal process because the process contains the potential to transmit a mark that persists, such as the dent in the car.[309]

This causal process is different than a non-causal process because in a non-causal process there is no potential for a causal mark to persist. For instance, the shadow of the car "hitting" the fence is a non-causal (or pseudo-causal) process because the process does not contain the potential to transmit a mark that persists. There is no potential for physical evidence to instantiate the causal process. Even if the shadow were to exhibit a momentary deformity as a representation of the dented car, the shadow would resume its original state after one repaired the dent in the car. The shadow does not exhibit a mark of its own structure but is contingent on the physical and causal processes of the actual car. Therefore, one can in principle detect causal processes because of the potential evidence that such processes exhibit and this distinguishes between a causal and non-causal (or pseudo-causal) process.[310]

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[307] Ernst Mayr, "The autonomy of biology," in *Towards a New Philosophy of Biology* (Cambridge, Massachusetts: Harvard University Press, 1988), 8-21.

[308] Salmon, *Scientific Explanation*, 141.

[309] James, Woodward, "Scientific Explanation," *The Stanford Encyclopedia of Philosophy*, accessed January 2018, <https://plato.stanford.edu/archives/fall2017/entries/scientific-explanation/>.

[310] Salmon, *Scientific Explanation*, 142-144.

The second feature of a causal process is a causal interaction. A causal interaction involves two causal processes intersecting, such that before the intersection each process had certain features, and then after the intersection the processes exhibit new features, both of which display the potential to reveal physical marks.[311] For example, the moving car would not have exhibited the dent if the causal interaction with the fence failed to obtain. In a similar way, the fence would not have exhibited a dent if it had not intersected with the causal process of the moving car. It is only after these causal processes between the moving car and the stationary fence intersect that the features of each causal process change and exhibit physical marks that persist. It is this potential evidence exhibited physical marks and how those physical marks intersect that supports physical causation.

The view of causation above becomes relevant particularly for biological causation, since biological causation exhibits the potential for physical marks to intersect.[312] Physical marks produced by causal interactions instantiate biological causation. According to one view of biological causation, biological causation includes ultimate causes and proximate causes.[313] An ultimate cause is a historical cause; a proximate cause is an immediate cause. I do not address the many responses surrounding the distinction,[314] but focus on the details relevant to the IBE and the debate over the evolutionary view of HCAs.

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[311] Kenneth M. Sayre, “Statistical Models of Causal Relations,” *Philosophy of Science* 44, no. 2 (1977): 203-214.

[312] For a summary, see Wesley Salmon, *Four Decades of Scientific Explanation* (Pittsburg: Pittsburg University Press, 2006), 32.

[313] Ernst Mayr, “Cause and Effect in Biology,” in *Toward a New Philosophy of Biology: Observations of an Evolutionist* (Cambridge: Harvard University Press, 1988), 24-36; Niko Tinbergen and A.C Perdeck, “On the Stimulus Situation Releasing the Begging Response in the Newly Hatched Herring Gull Chick,” *Behavior* 3, no. 1 (1950): 3-29.

[314] Kevin N. Laland, Kim Sterelny, John Odling-Smee, William Hoppitt and Tobias Uller, “Cause and Effect in Biology Revisited: Is Mayr's Proximate-Ultimate Dichotomy Still Useful?” *Science* 334, no. 6062 (2011): 1512-1516; R. Lickliter and T.D Berry “The phylogeny fallacy: developmental psychology's misapplication of evolutionary theory,” *Devel Rev* 10, no. 4 (1990): 348–364; J. Beatty, “The proximate/ultimate distinction in the multiple careers of Ernst Mayr,” *Biol Philos* 9, no. 3 (1994):333–356.

Mayr illustrates the distinction between ultimate causes and proximate causes by describing the causes of bird migration.[315] Each of the examples below illustrate either ultimate or proximate causes and, for Mayr, jointly provide a complete causal picture:

A. An ecological cause: The warbler must migrate or it will starve to death.
B. A genetic cause: The warbler has acquired a genetic constitution during the evolutionary history of species which induces it to respond to the proper stimuli.
C. An intrinsic physiological cause: The warbler flew south because its migration is tied in with photoperiodicity. That means that the warbler responds to the decrease in day light and is ready to migrate when daylight sufficiently decreases.
D. An extrinsic physiological cause: Finally, the warbler migrated on a specific day because a cold air mass, with northerly winds, passed over our area on that day. The sudden drop in temperature and the associated weather conditions affected the bird, already in a general physiological readiness for migration, so that it took off.[316]

According to Mayr, examples (a) and (b) illustrate ultimate causes, since they delineate a history of the species. Examples (c) and (d) illustrate proximate causes, since they demonstrate the mechanisms that trigger the relevant behavior. The former causes are historical, while the latter causes are immediate, and both types of causes can be traced in a relevant way; both types of causes exhibit the potential to leave a physical mark instantiating their causal processes and interactions. While biologists disagree over the usefulness of the distinction,[317] the distinction remains helpful for clarifying how the term explanation applies to the evolutionary argument for HCAs from neural reuse.

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[315] Mayr, "Cause and Effect," 27.

[316] Ibid., 27-28.

[317] Mary-Jane West-Eberhard, *Developmental Plasticity and Evolution* (Oxford Univ. Press, Oxford, 2003), 11; R.C Francis, "Causes, proximate and ultimate," *Biol Philos* 5, no. 4 (1990):401–415; D.A Dewsbury, "The proximate and the ultimate: past, present, and future," *Behav Process* 46, no. 3 (1999):189–199; See Mayr, "Cause and Effect in Biology," 29-31; L.F. Koch, "Vitalistic-mechanistic controversy," *Sci. Monthly* 85, no. 5 (1957): 245-255; G.G Simpson, "Evolutionary determinism and the fossil record," *Sci. Monthly* 71, no. 4 (1950): 262-267; G.G Simpson, "The world into which Darwin led us," *Science* 131, no. 3405 (1960): 966-974.

Recall that the reason for examining the nature of causation as explanation was to resolve the problem of the "best of a bad lot objection," and specifically how to generate the initial set of explanations from which the best explanation is chosen. The first criterion for choosing the initial set of explanations is the causal criterion. This does not imply that the only constraint for utilizing IBE must be causal, but rather that in this case the constraint should be causal, [318] since the explanations which best explain HCAs include biological causation. Thus, contra van Fraassen, the initial set of potential explanations cannot include any explanation whatever – such as irrelevant explanations that could apply in the case of the H-D model – but only those explanations that provide a causal account, including biological proximate and ultimate causes.[319] So, the first group of chosen potential explanations is explanations that describe the ultimate and proximate physical causes of HCAs. I will apply these views of biological causation to neural reuse in a moment.

The second problem related with the best of a bad lot objection was how to determine the best explanation from the initial set. What is the second criterion – or second filter – for choosing the best explanation from the initial set of potential explanations? The provisional answer above included a likelihood explanation. Presumably the best potential (causal) explanation of the evidence would exhibit a likelihood of truth.[320] The problem with this move is that theorists already possess a method for determining the most likely explanation independent of IBE called Bayesian confirmation theory.

Bayesian confirmation utilizes conditional probability to show that a piece of evidence E confirms to some degree hypothesis H, if and only if the probability of H given E is greater than the probability of H.[321] In other words, E confirms H if and only if $P(H/E) > P(H)$. On this view,

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[318] Day and Kincaid, "Putting Inference to the Best Explanation," 288-290.

[319] Lipton outlines other features, including contrastive inference. See Lipton, *Inference to the Best*, 149.

[320] David H. Glass, "Inference to the best explanation: does it track truth?" *Synthese* 185, no. 3 (2012): 412.

[321] William, Talbott, "Bayesian Epistemology," *The Stanford Encyclopedia of Philosophy*, accessed April 2017, <https://plato.stanford.edu/archives/win2016/entries/epistemology-bayesian.

affirming the truth of a belief is matter of degrees. If one assigns a probability between 0 and 1 to a piece of evidence E, then E may raise the probability that a belief about a hypothesis is true.[322]

Critics of IBE raise two problems with how IBE relates to Bayesian confirmation theory. The first problem is that if IBE operates as an independent tool for inferring probable conclusions, then IBE is likely to fail in comparison to Bayesianism. The reason for the failure is that it remains unclear exactly how explanations provide inferential support from premise to conclusion. The second problem with IBE according to critics is that if IBE did not function independent of Bayesian confirmation theory and were to align with Bayesianism, then IBE would likely become trivial. IBE would require the basic apparatus of Bayes theorem to justify its inference and one only requires Bayes theorem to justify inferences.[323]

There are two strategies for overcoming these problems with IBE and how IBE aligns with Bayesian confirmation theory. The first strategy is to show how IBE and Bayesian confirmation work together in a non-trivial way. I briefly introduce this strategy below but do not consider it in detail. The second strategy includes utilizing IBE independent of Bayesianism as a form of ampliative reasoning. I note this second strategy in more detail and then apply the second strategy to my argument that HCAs are the product of evolution.

This first strategy aims to align IBE with Bayesianism and requires drawing a distinction between a likely explanation and a lovely explanation. The likeliest explanation of an observation is an explanation that is the most probable. The loveliest explanation of an observation is the explanation that provides the greatest understanding. Accordingly, explanations can be lovely and not likely, and vice versa. Conspiracy theories may be lovely explanations of a set of observations, in that they provide some understanding of the available evidence, but such explanations rarely exhibit likelihood.[324] Conspiracy theories are probably not true even though they offer a coherent understanding of the data.

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[322] Lipton, *Inference to the Best,* 103-104.

[323] Glass, "Inference to the best," 412-413; Nancy Cartwright, *How the Laws of Physics Lie* (Oxford: Oxford University Press, 1983), 6; Alexander Bird. "Inference to the Best Explanation, Bayesianism, and Knowledge," in *Best Explanations: New Essays on Inference to the Best Explanation* (eds., Kevin McCain and Ted Poston; Oxford: Oxford University Press, 2017), chapter 7.

[324] Lipton, *Inference to the Best,* 58-59.

Similarly, likely explanations may outline causal features of an observation, but may not provide understanding. For example, smoking opium causes sleepiness because of the dormitive powers of opium.[325] This explanation is likely but not lovely. The explanation about the effects of opium fails to provide understanding about the causal process. That is, what are the dormitive powers of opium and why do those powers cause sleepiness?

The distinction between likeliest and loveliness is meant to align IBE with Bayesianism. In particular, lovely explanations may contribute towards determining the prior probabilities required for Bayesian confirmation.[326] The prior probability of H is the degree of belief in hypothesis H before one adds the additional evidence E, and the degree of belief in E before the relevant observation for E is included. According to Peter Lipton, IBE operates as a heuristic for establishing these prior probabilities. This is important because, according to Lipton, we naturally do not reason well regarding probabilities. Thus, explanatory considerations utilized by the IBE and the loveliness condition may enhance the ability to perform Bayesian confirmation by improving the heuristics when applying prior probabilities.[327] I do not explore this strategy here but consider the second strategy.

The second strategy aims to utilize IBE independent of Bayesian confirmation. This strategy requires two moves. First, proponents of IBE must show how IBE operates as a tool of inference independent of Bayesian confirmation. Below I will briefly outline one strategy by Richard Boyd. The second move includes describing IBE as ampliative inference. An ampliative

[325] Lipton, *Inference to the Best,* 59-60.

[326] Igor Douven, "Inference to the Best Explanation Made Coherent," *Philosophy of Science* 66, (1998): 424-435; Valeriano Iranzo, "Bayesianism and Inference to the Best Explanation," *Segunda Epoca* 23, no. 61 (2008): 89-106; For a recent debate, see Wesley C. Salmon, "Explanation and Confirmation: a Bayesian critique of Inference to the best explanation," in *Explanations: Theoretical Approaches and Applications* (Netherlands: Kluwer Academic Publishers, 2001), 61-91; responses by Peter Lipton, "Is Explanation a guide to inference: a reply to Wesley C. Salmon," in *Explanations: Theoretical Approaches and Applications* (Netherlands: Kluwer Academic Publishers, 2001), 93-120; for a recent treatment, see Kevin McCain and Ted Poston, *Best Explanations: New Essays on Inference to the Best Explanation* (Oxford: Oxford University Press, 2017).

[327] Ibid., 108-109; For discussion, see Stathis Psillos, "Inference to the Best Explanation and Bayesianism: comments on Ilkka Niiniluoto's 'truth-seeking by abduction," in *Induction and Deduction in Sciences* (ed. E. Stadler; Netherlands: Kluwer Academic Publishers, 2004), 81-93.

inference extends knowledge beyond the content of the established premises. That means that IBE as ampliative inference infers to a conclusion with content beyond the initial set of observations, data, and evidence found in the premises.[328] Ampliative inference is important because it is the reasoning of discovery and a relevant method within science.[329] And unlike deduction and Bayesian confirmation, neither of which provide ampliative benefits, IBE may establish a form of scientific inference when assessing the evolution of HCAs.[330] Below I discuss both moves, the first is an attempt to defend IBE as a justified form of non-deductive inference independent of Bayesianism; and the second move is a more complete description of how that inferential tool provides ampliative benefits for science and the evolution of HCAs.

One way to argue that IBE is a justification-conferring process independent of Bayesian confirmation includes subsuming IBE within a version of reliabilism. Reliabilism is an epistemological thesis about epistemic justification. According to one version of the reliabilist thesis of epistemic justification, S is justified in believing that p if and only if p is produced by a reliable cognitive process.[331] A reliable cognitive process is a process that produces mostly true beliefs. For example, some belief-forming processes, such as wishful thinking and confused reasoning, exhibit a similar defect: they produce mostly false beliefs. Other belief-forming processes, such as perception, exhibit the opposite feature: these processes produce mostly true beliefs. The idea is to align IBE with reliabilism. The claim is that IBE is a reliable justification-conferring inference for supporting the truth of scientific hypotheses.

Richard Boyd defends a reliability theory of IBE. According to Boyd, scientific theories rely on methods of experimentation, such as data collection and contrastive analysis. These methods of experimentation further rely on principles that Boyd claims were developed by abductive reasoning – reasoning that includes both hypothesis generation and IBE. Boyd then

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[328] Stathis Psillos, "The Fine Structure of Inference to the Best Explanation," *Philosophy and Phenomenological Research* 74, no. 2 (2007): 446.

[329] Especially Hans Reichenbach, *Experience and Prediction* (Chicago: University of Chicago Press, 1938), section I.

[330] Stathis Psillos, "Inference to the Best Explanation and Bayesianism," 83.

[331] Alvin Goldman, "What is Justified Belief?" in *Justification and Knowledge* (ed. George Pappas; Netherlands: D. Reidel, 1979), 9, 20.

asks why the methods of experimentation are so successful in producing scientific theories. His answer is that the *best explanation* for why the methods of experimentation are successful is because the deeper principles grounding those methods are approximately true.

So, Boyd defends the reliability of IBE in two ways. First, he argues that the deeper principles grounding the methods of experimentation were developed by IBE and these principles are approximately true. Second, he utilizes IBE to establish that first claim about the reliability of IBE.[332]

Boyd's description may appear confusing and so note the following attempt to reconstruct his argument:

45. The deeper principles grounding science are approximately true.
46. The best explanation for why the deeper principles grounding science are approximately true is the application of IBE.
47. So, probably, the best explanation for why the deeper principles grounding science are approximately true is the application of IBE.

Boyd uses IBE to establish the reliability of IBE. One objection against Boyd's formulation is circularity.[333] Roughly, the justification of IBE obtains because the reliability of IBE is the best explanation of past scientific success. [334] Critics may argue that this is circular because the conclusion about the reliability of IBE already employs IBE as the tool of inference. One affirms the reliability of IBE by utilizing IBE as the inferential process to support the conclusion.

In response to the circularity objection, some circular arguments are vicious in that one of the premises of the argument assumes the truth of the conclusion; other circular arguments

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[332] Boyd, "The Current Status," 41.

[333] Laudan, L., 1981. "A Confutation of Convergent Realism," *Philosophy of Science* 48, no. 1 (1981): 19–49; for more general objections about the circularity of reliabilism, see Richard Fumerton, *Epistemology* (Oxford: Oxford University Press, 2006). In fact, circularity is a more general objection to reliability accounts of justification. For this view and a relevant response, see Michael Bergmann, "Malignant and Benign," *Philosophy and Phenomenological Research* 69 (3) (2004): 709-727; and Michael Bergmann, *Justification without Awareness: A defense of epistemic externalism* (Oxford: Oxford University Press, 2006).

[334] Boyd, "Current Status," 74. See also Douven, "Testing Inference to the Best Explanation," 362-363.

appear innocent, in that the rule of inference being defended is the rule of inference within the argument. The argument above is "rule circular" but not "premise circular."[335] Rule-circular arguments do not include a question-begging premise, but rather utilize the inference rule for supporting (but not guaranteeing the truth of) the inference rule under analysis. The conclusion states that IBE is a reliable inference strategy and this conclusion utilizes IBE to establish that point. Note that the IBE inference in this case does not guarantee the truth of the conclusion. Any other potential model of science may compete with IBE as a best potential explanation of the success of science. If this response is correct, then the track record of IBE favors the justification of utilizing IBE for scientific inquiry.

Boyd's approach to defending the reliability of IBE remains puzzling. There is a simpler way to defend the reliability of IBE without employing the rule-circular argument. One applies enumerative induction and includes within a sample the scientific theories that have been established by IBE. For instance, Darwin's theory of evolution by natural selection, Mendel's discovery of genes, and the discovery of Neptune, were all inferred by IBE.[336] As IBE supports additional scientific theories, the greater the strength that the IBE is a reliable method of inference. These two ways of defending the justification of utilizing IBE may support non-deductive inferences independent of Bayesianism.

The second question is how does this model of IBE apply to the strategy of adopting ampliative reasoning? IBE is a unique type of inference because it purports to extend knowledge beyond the scope of the established premises. Here it worth quoting Stathis Psillos at length, who recently articulated several criteria of a successful ampliative inference, including IBE:

> One, [ampliative inference] is psychologically real and compelling. Two, it is reasonable, that is it can offer at least prima facie entitlement to form new beliefs and justification for having them. Three, it is sensitive to the context, background information, cognitive aims and values etc. Four, it works, (it produces truths or likely truths), only if the external circumstances are right (if the world co-operates). Five, it offers warrant that can be revoked in the presence of new information and hence requires taking into account

[335] Stathis Psillos, *Scientific Realism: How Science Tracks Truth* (London: Routledge, 1999), chapter four.

[336] Phillip Kitcher, "Real Realism: The Galilean Strategy," *Philosophical Review* 110, no. 2 (2001): 151–197.

> considerations external to the inference itself, e.g., whether the evidence is total, whether there are defeaters etc. The key point is that this type of inference does not admit of a simple abstract-logical form. Nor does it admit of an analysis suitable for deductive logic. Its details are too messy to admit of a neat formal characterization, but its strength is precisely in those details. Unlike deductive reasoning and Bayesian updating (which are both non-ampliative), defeasible inference has the prima facie advantage that it takes us to beliefs with new content. It does not start with the assumption that reasoning (and inference) is about updating an already existing (learned at our mother's knee?) belief corpus in light of new information. It plays an active role in creating and maintaining this belief-corpus.[337]

Psillos' description of ampliative inference is instructive for applying IBE to the defense of premise (4) of my argument, particularly criteria two, three, and four. I apply these criteria to IBE and my defense of (4) below.

**A. Defense of Premise (4): IBE Model**

Premise (4) of my argument for the evolution of HCAs is that: *if brain regions xyz evolved and have been reused for carrying out HCAs, then HCAs are the product of evolution.* IBE supports this premise in a different way than the H-D model. According to IBE, one first states the observation, in this case the observation that brain regions xyz evolved and have been reused for carrying out HCAs. Second, one then postulates various potential explanations that, if true, would best explain that observation. For example, what explanation, if true, would best explain why brain regions for perception have been reused for carrying out HCAs? What explanation, if true, would best explain why brain regions for motor control have been reused for higher cognitive use in higher domains such as logic and math? The central claim is that evolutionary processes – both natural selection, as well as other mechanisms of change – best explain those observations of reuse. Consider this central claim in greater detail.

Recall that choosing the best explanation requires identifying a set of potential explanations and these potential explanations must address the two problems associated with the best of a bad lot objection. Specifically, the potential explanations must (i) satisfy the causal

[337] Psillos, "The Fine Structure of Inference to the Best Explanation," 442.

criterion; and (ii) causal processes that are both physical and biological must adopt a justification-conferring inference. Note the following:

48. Brain regions xyz evolved and have been reused for carrying out HCAs.
49. The best potential explanation of (48) is evolution.
50. So, the best explanation of (48) is evolution.

Does premise (49) satisfy the first problem with the best of a bad lot objection by providing a causal explanation? And does the inference from (49) to (50) satisfy the second problem with a best of a bad lot objection by providing a justified inference?

Regarding the first problem, premise (49) generates an explanation within the initial first-filter constrained by biological causes.[338] The causal account I described includes physical marks left by physical interactions by both proximate and ultimate causes. The proximate causes of higher abilities include a variety of neural mechanisms that cause reuse. As alluded to in chapters two and three, experimenters can identify physical marks associated with the functional architecture of the brain, such that when HCAs leave their mark, evidence for neural reuse becomes apparent. Thus, the proximate causes which best explain premise (48) include the neural mechanisms causing reuse.

The ultimate cause explaining premise (48) is evolution more generally. As discussed in the second chapter, the proximate causes of neural reuse, and how ancestral brain regions were coopted for higher cognitive use, align within a broader ultimate evolutionary account of change. There I focused on the two strategies. The first was that evolution by natural selection would have been necessary but not sufficient for the development of HCAs. This was the main strategy. It could be that natural selection forged a brain with the capacity for reuse and then other cultural artifacts and experiences caused reuse for HCAs to occur. This is one ultimate cause using the first strategy of aligning natural selection with neural reuse.

The second strategy was that evolution by natural selection was both necessary and sufficient for the development of HCAs. This second strategy would require explicating the

[338] According to Elliott Sober, this is the "Achilles heel" of various critics because they do not offer alternative causal explanations. For this response to critics, see Elliott Sober, "The Design Argument," in *The Blackwell Companion to Philosophy of Religion* (ed. William E. Mann; Oxford: Blackwell Publishing, 2005), 127.

evolutionary story of why a brain for reuse was an adaptation by virtue of the function of neural search. If this second account were true, then the account would provide a second ultimate cause for explaining the observation described by premise (48).

In either case described above, the first strategy or the second, whether the brain exhibits the capacity for reuse, or the brain was selected by evolution for reuse, there exists a potential biological explanation with a causal account for why one observes brain regions xyz being reused for higher cognitive use.[339] In other words, if the proximate causes of reuse were true (i.e. the neural mechanisms causing reuse), and if those proximate causes aligned with a broader ultimate explanation involving natural selection and other processes of biological change, then those two causal processes would best explain premise (48).

The inference from (49) to (50) also satisfies the second problem associated with the best of a bad lot objection, in that the inference is not reduced to likelihoods but offers ampliative justification for the conclusion. Premise (49) offers new information about the world beyond the observations found in (48) and this method of offering new information has been successful in the past. To apply Psillos's second and third criteria for ampliative reasoning: evolution, if true, exhibits prima facie support, especially because of the background context about the evolution of species on this planet and human evolution specifically. Given our knowledge of human evolution, there exists initial support for supposing that HCAs evolved comparable to other human features. Following Psillos's fourth criterion that ampliative reasoning "works" only if the world cooperates, such a criterion may not capture the precision demanded by the philosophy of science, but nevertheless constrains and tests various scientific hypotheses.

Applying the IBE model of confirmation provides support for premise (4) of the argument for the evolution of HCAs from neural reuse. The claim that HCAs are the product of evolution is the best explanation of the observation of neural reuse. The evidence presented for neural reuse in the previous two chapters shows how older evolved brain regions were redeployed for carrying out higher cognitive use. Recall premise (4): *if brain regions xyz evolved and have been reused for carrying out HCAs, then HCAs are the product of evolution*. Utilizing

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[339] For discussion, see Anderson, *After Phrenology*, 36-42; 74. For an alternative view, see H.C Barrett and R. Kurzban, "Modularity in Cognition: Framing the debate," *Psychological Review* 113, no. 3 (2006): 630.

the IBE model, the reason for thinking that the antecedent supports the consequent is that the consequent best explains the antecedent.

The critic will offer objections at this point. I consider objections by Wallace and Nagel in the final chapter. Before considering those specific objections from Wallace and Nagel, some broader issues with the foregoing discussion must be analyzed first.

## IV. General Objections and Responses

A general objection reconsiders Bayesian confirmation. The Bayesian confirmation objection is this: why explore the H-D model and IBE when philosophers of science claim that the Bayesian model of confirmation is preferred?[340]

One response to the Bayesian objection is that Bayesian confirmation seems equally controversial to the other models considered thus far, the H-D model and IBE. It is not obvious that Bayesian confirmation is the more accurate model of scientific confirmation.[341] Psillos raises several concerns about Bayesian confirmation for scientific belief and then notes how IBE is superior to Bayesianism.

A relevant concern described by Psillos is that Bayesianism does not permit accepting the truth of a hypothesis, but only raises or reduces the probability of the truth of that hypothesis.

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[340] For a helpful introduction, see Lipton, *Inference to the Best*, 103; See also John Earman, *Bayes or Bust? A Critical Examination of Baysian Confirmation Theory* (Massachusetts: MIT Press, 1996); See Jan Sprenger, "Hypothetico-Deductive Confirmation," *Philosophy Compass* 6, no. 7 (2011):497-508; For a brief analysis of the Law of Likelihood and how it applies to Darwin's views, see Elliott Sober, *Evidence and Evolution: The Logic Behind the Science* (Cambridge: Cambridge University Press, 2008); John D. Norton, "Challenges to Bayesian Confirmation Theory," in *Handbook of the Philosophy of Science, volume 7*: *Philosophy of Statistics* (eds. Prasanta S. Bandyopadhyay Malcolm R. Forster; Oxford: Elsevier, 2011).

[341] Kevin Kelly and Clark Glymour, "Why Bayesian Confirmation Does Not Capture the Logic of Scientific Justification," accessed February 13, 2018, https://www.cmu.edu/dietrich/philosophy/docs/tech-reports/138_Kelly.pdf; Kevin Kelly and O. Shulte, "The Computable Testability of Theories with Uncomputable Predictions," *Erkenntnis* 42, no. 1 (1995): 29-66; P. Lee, *Bayesian Statistics: An Introduction* (London: Edward Arnold), 236-237; Henry Kyburg, "Subjective Probability: Criticisms, Reflections, and Problems," *Journal of Philosophical Logic* 7, no. 1 (1978): 157-180.

According to Psillos, this type of Bayesian confirmation is neither necessary nor sufficient for affirming the truth of the hypothesis. It is not necessary because a hypothesis may be disconfirmed and yet reasonable to support if there are no alternatives to that hypothesis.[342] Indeed, one could argue that accepting the hypothesis that HCAs are the product of evolution appears reasonable because there is no other current hypothesis. Moreover, according to Psillos, Bayesian confirmation is not sufficient for affirming a hypothesis, because a piece of evidence that raises the probability of a hypothesis does not, on its own, make the hypothesis reasonable to accept. By contrast, according to Psillos, IBE is a theory of acceptance. It allows one to accept the truth of a hypothesis because that hypothesis is the best explanation of the available evidence.

A second response to the Bayesian question has been considered already, in that previous scientific success follows both the H-D model and the IBE. Both models have contributed to scientific confirmation and explanation in the past and both the H-D model of confirmation and IBE have been defined by some as the "scientific method."[343] Even if these models of scientific theorizing capture only portions of our inductive practices of confirmation and explanation, they nevertheless contribute to those inductive practices. This response is telling, since it reflects the justification processes used to defend the reliability of IBE as ampliative inference. That is, the H-D model and IBE appear justified because of their past success in producing successful scientific theories.

## V. Conclusions

In this chapter I explored two models of scientific confirmation and explanation to support premise (4) of my argument for the evolution of HCAs, the H-D model and the IBE model. The H-D model attempts to derive an observation from a hypothesis and then show that the truth of the observation inductively confirms the truth of the hypothesis. If HCAs are the product of evolution, then one would expect to observe a gradual process of the development of higher

[342] Stathis Psillos, "The Fine Structure of Inference to the Best Explanation," *Philosophy and Phenomenological Research* 74, no. 2 (2007): 446.

[343] See footnote 288. Ernan McMullin, *The Inference that Makes Science* (Milwaukee WI: Marquette University Press, 1992).

abilities. This gradual development of HCAs is exactly what neural reuse predicts and what the evidence establishes. The IBE model purports to offer an explanation that would best explain the observation of the reuse of older brain regions for higher cognitive use. This move requires a defense of the term explanation, which in this case is a causal defense. The causal account includes proximate causes and ultimate causes, both of which exhibit physical features with the potential to exhibit physical marks. The proximate cause of higher abilities includes the mechanisms causing neural reuse. The ultimate cause of higher abilities is the evolution of the human brain, either by way of natural selection, or natural selection plus other descriptive processes. By using these two classic methods of scientific confirmation and explanation, one can support the truth of premise (4) of the argument.

## Chapter 5
## Objections, Responses, and Conclusions

In chapters two and three, I both introduced the theory of neural reuse and then summarized recent evidence demonstrating how ancestral brain regions were redeployed for carrying out HCAs. The evidence in those two chapters support premise (2) of the argument. In chapter four, I applied two models of scientific confirmation and explanation to show how the inference from the observation of reuse to the conclusion that HCAs are the product of evolution is established. I argued that the evolutionary view of HCAs can be confirmed by a gradual process of neural reuse and that neural reuse is best explained by evolution. In this final chapter, I briefly revisit the relevant premises of the argument for the evolution of HCAs and then consider and respond to objections by Wallace and Nagel.

### I. Brigham's Argument: Assessing Objections

To recap briefly: I have argued that HCAs are the product of evolution, both by natural selection and other mechanisms of change. The reason for thinking that conclusion is true is by considering neural reuse. Note again the argument:

1. Brain regions xyz evolved.
2. Brain regions xyz have been reused for carrying out HCAs.
3. So, brain regions xyz evolved and have been reused for carrying out HCAs.
4. If brain regions xyz evolved and have been reused for carrying out HCAs, then HCAs are the product of evolution.
5. So, HCAs are the product of evolution.

The critic who rejects this argument can take aim at premises (1), (2), and (4). I did not explore premise (1) besides identifying brain regions xyz as ancestral brain regions for carrying out primitive operations, such as perception and motor control. I defended the second premise in chapters two and three. In chapter two, I described neural reuse and one version of reuse called neural recycling. According to neural recycling, higher operations encroach on already existing brain structures. For example, the ability to read encroached on the occipito-temporal cortex, a primitive region which carries out perceptual operations for object and scene recognition.

In chapter three, I expanded on this evidence for neural reuse with three pieces of evidence. The first piece of evidence described the functional relations between ancestral operations and higher operations. Recall the implicit assumption in that section was that ancestral operations are instantiated by ancestral brain regions. The second and third pieces of evidence included the reuse of sub-cortical structures. Cases of sub-cortical functions included contributions to both human culture and language. For example, the cerebellum plays an important role in working memory and specifically as a predictive mechanism. A predictive mechanism enables creatures to learn new types of skills by streamlining the process of that skill for future use. According to some theorists, the advance of human culture, including shared knowledge, skills, and language, would have benefited by how the cerebellum operated as a predictive mechanism.

The central point is that humans (and other primates) possess a cognitive infrastructure with the potential for that infrastructure to develop higher abilities. The common distinction drawn between ancestral brain regions and higher brain regions appears confused; the operations of the former contribute to the operations of the latter. The prior events that caused this ancestral infrastructure to carry out HCAs may be unknown. As discussed in the introduction, this causal just-so-story is irrelevant for defending the argument for the evolution of HCAs. What is relevant is that the human brain can in principle accommodate HCAs by using the cognitive material already available, in that HCAs do not require distinct neural regions for their operation.

In chapter four, I inferred from this observation of neural reuse to the conclusion that HCAs are the product of evolution. I supported this inference in two ways. The first way utilized the hypothetico-deductive model of confirmation (H-D model) and the second type utilized the inference to the best explanation (IBE). Consider each sub-argument from chapter four briefly:

6. If HCAs are the product of evolution, then HCAs developed gradually.
7. HCAs developed gradually.
8. So, *probably*, HCAs are the product of evolution.

This argument makes explicit the assumption about gradualism within premise (4) of my argument. The reason the argument above supports premise (4) is because one would expect the evolution of higher abilities to occur gradually and that gradual process can be observed with neural reuse.

The second type of support for premise (4) was inference to the best explanation:

9. Brain regions xyz evolved and have been reused for carrying out HCAs.
10. The best potential explanation of (9) is evolution.
11. So, the best explanation of (9) is evolution.

Recall that the term "explanation" means causal explanation. This causal explanation includes three features: a persistent physical mark that intersects with other persistent physical marks, a proximate mechanism, and an ultimate mechanism. According to the argument from IBE, one starts with the observation of neural reuse, premise (9), and then determines which causes, if true, would best explain premise (9). I argued that evolutionary processes, including natural selection and other mechanisms of change, provide a best potential explanation because of the causal features present. Specifically, the reuse of older brain regions for higher cognitive use exhibit physical marks that persist, and these physical marks exhibit both proximate and ultimate causes.

In what follows, I examine in greater detail the objections against the evolution of HCAs from Wallace and Nagel. Wallace departed from Darwin's view about natural selection in that he thought natural selection could not explain the production of HCAs. The second objection is from Nagel, who argues that while more primitive operations, such as perception and motor control, may have been the product of natural selection, HCAs are likely not the product of natural selection. Beginning with Wallace, I will first examine some broader objections against the evolution of HCAs, which often include teleological claims and solutions, and then focus in on his descriptive objections against the evolution of HCAs. The reason is because while both Wallace and Nagel offer concise descriptive objections against the evolution of HCAs, those objections are often couched within their broader philosophical concerns. Recall from the introduction that both Wallace and Nagel conflate the teleological and descriptive objections to HCAs and for that reason I discuss each type of objection separately.

## A. Wallace's General Objections

Wallace initially supported Darwin's view that natural selection was the only mechanism which caused the evolution of the human brain,[344] and eventually the brain would become the primary target of selection.[345] However, Wallace later rejected his claim.[346] In his book *Darwinism*, Wallace denies that natural selection produced human "special faculties,"[347] and challenges Darwin's application of natural selection for explaining these faculties.[348] By "special faculties" Wallace means higher abilities, such as spiritual, moral, and intellectual beliefs:

> …the existence in man of…his most characteristic and noblest faculties, those which raise him furthest above the brutes and open up possibilities of almost indefinite advancement. These faculties could not possibly have been developed by means of the same laws which have determined the progressive development of the organic world in general, and also of man's physical organism.[349]

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[344] A.R Wallace, "The Origin of Human Races and the Antiquity of Man Deduced from the Theory of Natural Selection," *Anthropological Review 2*, 1864: clviii–clxx, accessed July 28, 2016, http://people.wku.edu/charles.smith/wallace/S093.htm.

[345] Charles Darwin, "Letter to J. Hooker, May 22," *Darwin Correspondence Project Database*, accessed July 28, 2016, http://www.darwinproject.ac.uk/entry-4506. For an in-depth look, see Gross, "Alfred Russell," 499.

[346] Gross, "Alfred Russell," 499. There are subtleties here. Some historians have argued that Wallace's views are more continuous and that there isn't a radical shift in opinion. See Martin Fichman, "Science in Theistic Contexts: A Case Study of Alfred Russell Wallace on Human Evolution," in *Science in Theistic Contexts: Cognitive Dimensions, Osiris, 2nd Series* 16 (2001): 227-250.

[347] A.R. Wallace, *Studies scientific & social*. *Vol. 2* (New York: Macmillan, 1900). Cited from Gross, "Alfred Russell," 502.

[348] A.R. Wallace, "Darwinism Applied to Man," in *Darwinism* (London: Macmillan, 1889), accessed September 2016, http://people.wku.edu/charles.smith/wallace/S724CH15.htm. See also Michael Shermer, *In Darwin's Shadow: The Life and Science of Alfred Russell Wallace* (Oxford: Oxford University Press, 2002).

[349] A.R. Wallace, "Darwinism," accessed July 26, 2016, http://people.wku.edu/charles.smith/wallace/S724CH15.htm. Also see Shermer, *In Darwin's*, 174-5.

One reason Wallace doubts the efficacy and scope of natural selection for explaining HCAs is his view of humanity:

> …as far as we yet know, of the pre-historic races, we have an organ so little inferior in size and complexity to that of the highest types (such as the average European), that we must believe it capable, under a similar process of gradual development during the space of two or three thousand years, of producing equal average results. But the mental requirements of the lowest savages…are very little above those of many animals. The higher moral faculties and those of pure intellect and refined emotion are useless to them, are rarely if ever manifested, and have no relation to their wants, desires, or well-being. How, then, was an organ developed so far beyond the needs of its possessor? Natural selection could only have endowed the savage with a brain of little superiority to that of an ape, whereas he possesses one but very little inferior to that of the average members of our learned society.[350]

Wallace's claim is that since tribal groups – that is, non-Europeans – did not require "special faculties" for their evolutionary development, but only ancestral faculties for survival, the fact that these tribal groups possess special faculties is evidence that natural selection is not the cause of those special faculties.

A brief parenthetical note is that a contemporary view would obviously reject Wallace's view of humanity. Still, Gould notes that Wallace's view of humanity was morally superior for his time, since, unlike his contemporaries, Wallace believed that all humans shared equal intellectual capacities. According to Gould:

> Wallace advanced several arguments for the uniqueness of human intellect, but his central claim begins with an extremely uncommon position for his time, one that commands our highest praise in retrospect. Wallace was one of the few non-racists of the nineteenth century. He really believed that all human groups had innately equal capacities of intellect.[351]

[350] This quotation was cited from Charles Gross, "Alfred Russell Wallace and the evolution of the human mind," *Neuroscientist* 16 (2010): 500; see also Stephen Jay Gould, "Wallace's fatal flaw," *Natural History* 89, no. 1 (1980): 26–40.

[351] Gould, *"Wallace's Fatal Flaw*," 28-35.

Wallace argued that every human possessed HCAs. But unlike Darwin, to Wallace this observation that everyone possessed HCAs conflicted with the scope of natural selection.

Darwin rejected Wallace's conclusion about HCAs and the scope of natural selection, contending that while direct evidence for the development of HCAs seemed untenable, HCAs likely resulted from the incremental change by natural selection. Darwin argues:

> We have seen in the first chapter that the homological structure of man, his embryological development and the rudiments which he still retains, all declare in the plainest manner that he is descended from some lower form. The possession of *exalted mental powers* is no insuperable objection to this conclusion. In order that an ape-like creature should have been transformed into man, it is necessary that this early form, as well as many successive links, should all have varied in mind and body. It is impossible to obtain direct evidence on this head; but if it can be [shown] that man now varies – that his variations are induced by the same general causes, and obey the same general laws, as in the case of the lower animals – there can be little doubt that the preceding intermediate links varied in like manner.[352]

Wallace responded to Darwin, arguing that even if the incremental development of HCAs were correct, it did not follow that HCAs were the product of evolution, notably the human intellect. In a later piece in response to Darwin, Wallace states the following:

> The point…[to which]…I wish…to call attention is…that to prove continuity and progressive development of the moral and intellectual faculties from animal to man is not the same as proving that these faculties have been developed by natural selection…Because a man's physical structure has been developed from an animal form by natural selection, it does not necessarily follow that his mental nature, even though developed *pari passu* with it, has been developed by the same causes only.[353]

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[352] Charles Darwin, *The Descent of Man, and Selection in Relation to Sex* (New York: Dover, 2010), 64. (emphasis mine).

[353] Alfred Russell Wallace, *Darwinism: An Exposition of the Theory of Natural Selection With some of its Applications* (London: MacMillan, 1889), 462-463, accessed November 2016, https://archive.org/details/darwinism00unkngoog.

So far, the passages above depict Darwin and Wallace disagreeing about the evolution of HCAs.[354] Before commenting on Wallace's teleological solution to his version of the descriptive problem of HCAs, first notice a different issue with the last passage above.

In the passage above, Wallace claims that even if natural selection produced the physical structure of humans, it would not "necessarily follow" that human mental nature developed by natural selection. Without digressing into the concept of necessity, if by "necessarily follows" Wallace means a logical entailment, then of course the production of the physical structure of humans does not logically entail the production of mental faculties by natural selection. Indeed, if one were to replay the history of evolution, one would likely observe different creatures living on earth. Here Gould notes:

> I call this experiment 'replaying life's tape.' You press the rewind button and, making sure you thoroughly erase everything that actually happened, go back to any time and place in the past – say, to the seas of the Burgess Shale. Then let the tape run again and see if the repetition looks at all like the original. If each replay strongly resembles life's actual pathway, then we must conclude that what happened pretty must had to happen. But suppose the experimental versions all yield sensible results strikingly different from the actual history of life? What could we then say about the predictability of self-conscious intelligence? Or of mammals? Or of life on land? Or simply the persistence of multicellular life for 600 million years? [355]

Predictions in evolutionary biology do not apply with strict necessity.[356] Therefore, few would defend the view that since natural selection produced a physical human body, that this production would entail that human mental faculties are the product of natural selection. Rather the claim is that since natural selection produced a physical human body and brain, it remains possible (indeed, likely and as a best explanation) that natural selection contributed to the production of human mental faculties and HCAs. This likelihood claim does not describe a premise with a logical relation of entailment but rather a causal relation. The point is that

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[354] Recall the distinction between the scientific problem and the philosophical problem of HCAs from the introduction. See pages 3-5 above.

[355] Stephen Jay Gould, *Wonderful Life* (London: Penguin, 1991), 48-50.

[356] See especially Mayr, *This is* Biology, 54-5; See also Elliott Sober, *Did Darwin Write the Origin Backwards* (New York: Prometheus Books, 2011), 28.

Wallace may be incorrectly characterizing the nature of evolutionary processes when constructing his objection.

Still, a more charitable reading of Wallace may suggest a likelihood claim, such that natural selection is the type of process that can accommodate HCAs. It is at this point that we can return to Wallace's teleological solution to this descriptive problem of the evolution of HCAs:

> "while admitting to the full extent the agency of the same great laws of organic development in the origin of the human race as in the origin of all organized beings, yet there seems to be a Power which has guided the action of those laws (of organic development) in definite directions and for special ends."[357]

According to Wallace, since HCAs are likely not the product of evolution by natural selection, another teleological explanation is required. Therefore, in addition to the philosophical claim above, we find Wallace asserting that "beyond all the phenomena of nature and their immediate causes and laws there is Mind and Purpose; and that the ultimate purpose is the development of mankind for an enduring spiritual existence." And that "it is not blind laws and forces, but…immanent directive and organizing MIND, acting on and in every living cell of every living organism, during every moment of its existence."[358] And finally:

> Let us fearlessly admit that the mind of man (itself living proof of a supreme mind) is able to trace, and to a considerable amount has traced, the laws by means of which the organic no less the inorganic world has been developed. But let us not shut our eyes to the evidence that an Overruling Intelligence has watched over the action of those laws, so directing variations and determining their accumulation, as finally to produce an organization sufficiently perfect to admit of, and even to aid in, the indefinite advancement of our mental and moral nature."[359]

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[357] Cited from Stephen E. Glickman, "Charles Darwin, Alfred Russell Wallace and the Evolution/Creation of the Human Brain and Mind," *Gayana* 73 (2009): 36.

[358] Alfred Russell Wallace, *The World of Life: A Manifestation of Creative Power, Directive Mind and Ultimate Purpose* (London: Chapman and Hall, 1914), 353. But neither was Wallace a theist. He did not envision the "mind" as a god of either traditional theism or deism; see Wallace, *The World of Life*, 392.

[359] Wallace, "Sir Charles Lyell," 394.

As stated above, one difficulty with navigating Wallace's claims is that those claims conflate descriptive and teleological views. Recall the descriptive problem of the evolution of HCAs resembles the evolution of the vertebrate eye and whether the natural processes of evolution could have contributed to the development of HCAs. The teleological problem with HCAs includes additional metaphysical concepts about the nature of the mind and whether those concepts of the mind require teleological explanations.[360]

Note again the sand-castle analogy in the introduction. Both sand castles exhibit physical causes that can be examined in descriptive terms. When comparing sand castles to HCAs, there exists a descriptive account about the causal processes that gave rise to HCAs just as there exists a descriptive account about the causal processes that gave rise to both sand castles. And just as there exists a teleological question about the causes of the first type of sand castle – which included agent causation – so there may exist a teleological question about whether HCAs require agent causation. But the focus here is on the descriptive claim about whether HCAs are the product of evolution. That question is analogous to exploring the descriptive causes of each sand castle. The question of whether or not HCAs resemble the first sand castle or the second castle-like structure, and thus whether HCAs require additional teleological causes, is another question beyond the scope of this project. Clearly, if Wallace were correct that HCAs resemble

[360] A concluding remark about Wallace's broader philosophical views is that even if Wallace were correct about his philosophical claims, such that humans exhibit mental features that require other types of philosophical explanation, that philosophical claim does not proceed from his descriptive problem of cognitive evolution. That is, his reasons for doubting the descriptive view of human cognitive evolution and how HCAs were produced, does not on its own justify his philosophical claims about teleology. What is required to defend the philosophical claim about teleology is another philosophical argument. But this additional philosophical argument is lacking. This is important because some critics of the evolutionary view of HCAs (or other types of physical features) assert their doubts about the descriptive process, and then suggest that such doubt supports a philosophical solution, at times at odds with evolutionary theory. The problem with this strategy is that fails to appreciate the advancements of scientific progress. The move from descriptive doubt to philosophical solution is too quick. While there may exist principled arguments to suggest that evolution cannot explain everything about human HCAs, these types of arguments must be made explicit. Notwithstanding these principled philosophical arguments, one should not suppose that because a current scientific theory fails to explain a phenomenon at one point, that science will never explain that phenomenon in the future. Perhaps one day in the future a scientific explanation will become more evidentially supported and undermine whatever philosophical solution was earlier suggested.

the first type of sand castle, then his philosophical solution about a designer would become relevant. But that philosophical question remains distinct from the descriptive claim about whether or not HCAs are the product of evolution. Thus, my aim is to assess Wallace's descriptive objection against the evolution of HCAs and not his teleological objections and solutions to the problem of HCAs. Why does Wallace think that HCAs cannot be the product of evolution, regardless of his view about human nature and a designer?

### B. Wallace's Descriptive Objections

While Wallace's prior views of phrenology, strong adaptationism, sexual selection, spiritualism, and his experience living with non-Europeans in the tropics may have contributed to his doubts about the scope of natural selection,[361] his main scientific argument for rejecting the evolution of HCAs seems to be the following:

12. If any human characteristic was either maladaptive at its first appearance or its uselessness was not proportionate to its development, then that characteristic could not have been the product of natural selection.[362]
13. Human higher abilities were either maladaptive at their first appearance or their uselessness was not proportionate to their development.
14. So, human higher abilities could not have been the product of natural selection.

The first premise suggests that traits caused by natural selection must either not initially undermine fitness (i.e. be maladaptive), or, even if the trait did initially undermine fitness and was selected by evolution regardless, its maladaptiveness would not be greater than its contributions to reproductive success.[363] A maladaptive trait may undermine fitness but could be

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[361] F.M Turner, *Between science and religion: the reaction to scientific naturalism in late Victorian England* (New Haven: Yale University Press, 1974); S.E Glickman, "Charles Darwin, Alfred Russel Wallace and the creation/evolution of the human brain and mind," *Gayana* 73 (2009):32–41; Stephen Jay Gould, "Wallace's fatal flaw," 26–40.

[362] For a longer summary of Wallace's position, see Alfred Wallace, *Contributions to the theory of natural selection* (London: Macmillan, 1870), 334.

[363] For a discussion on the nature of fitness, see Sean B. Carroll, *The making of the fittest: DNA and the ultimate forensic record of evolution* (New York: Norton, 2006).

"carried along for the ride" provided that the maladaptive trait did not undermine the net fitness of the organism. The second premise, (13), affirms that HCAs may satisfy either of the antecedent conditions outlined in premise (12). The phrase "at first appearance" seems to indicate the initial states of primate brain evolution. Wallace thinks that HCAs developing by natural selection would have required that HCAs as adaptations exhibit sufficient fitness early in primate brain development. So, then the conclusion follows.

While the structure of the argument above is valid, the truth of the premises remains controversial. Consider premise (12). As discussed in the introduction, if exaptation situates within the concept of natural selection, then exaptation undermines (12). Characteristics exhibiting maladaptiveness may be exapted and become adaptations in the future by way of natural selection. This response to premise (12) represents a common rebuttal to Wallace's "hyper-selectionist" views of evolution.[364] There exist other mechanisms of evolution that may have contributed to the development of HCAs, including sexual selection, exaptation, and genetic drift, and in some cases these developments may align within the notion of natural selection. Thus, the truth of premise (12) does not include a more robust view of evolutionary mechanisms and explanations.

Moreover, even if (12) were true and could undermine the other mechanisms of evolution discussed above, or one appealed to Wallace's ignorance about evolutionary processes, premise (13) is the main problem. This premise assumes that higher abilities existed "at first appearance." If I am correct that this phrase refers to early primate brain development, then that assumption is false. HCAs developed later after ancestral brain regions were reused for carrying out HCAs.

A final objection is that even if the argument above were sound, the conclusion could be misleading. As discussed, if one adopts the first strategy, then natural selection plays a more basic role in the formation of HCAs. This first strategy does not fall under Wallace's objection, since natural selection is not sufficient for explaining the development of HCAs. It is only if one adopts the third strategy – evolutionary psychology – that one must account for HCAs as adaptations and perhaps here Wallace's argument becomes more relevant. As we shall see, this

[364] Gross, "Alfred Russell Wallace," 500. Michael Shermer, "The Natural and the Supernatural: Alfred Russell Wallace and the Nature of Science," accessed April 1, 2018, https://evolutionnews.org/2012/01/the_natural_and/.

response to Wallace by distinguishing between the first strategy of cognitive evolution and the third strategy applies to Nagel's objections as well.

### C. Nagel's General Objections

Nagel doubts the evolutionary view of HCAs and situates his doubt within broader philosophical objections against the Neo-Darwinian and reductionist research program in science and philosophy.[365] The term "Neo-Darwinian" appears ambiguous,[366] but Nagel uses this phrase in conjunction with the term "reductionism" to describe an explanation about the "origin and evolution of life."[367] He raises two problems here. First, does there exist an account about the origin of life that can be explained in reductionist terms, the chemical and genetic basis of life? The second problem is whether the Darwinian mechanism of natural selection explains the changes from the primordial constituents of life to the wide range of species that exist, particularly humans and their higher types of cognitive abilities?[368]

Nagel doubts that either question can be sufficiently answered by using current scientific assumptions about reductionism and Darwinian mechanisms. Here it is worth quoting Nagel at length:

> We and other creatures with mental lives are organisms, and our mental capacities apparently depend on our physical constitution. So what explains the existence of organisms like us must also explain the existence of mind. But if the mental is not itself

[365] Thomas Nagel, "What is it like to be a bat?" *The Philosophical Review*, vol. 83, No. 4. (1974). See the following sources for definitions, respectively: Stephen Jay Gould, *The Structure of Evolutionary Theory* (Cambridge, MA: Belknap Press, 2002; Alan Lacey, "Materialism," in *The Oxford Companion to Philosophy, New Edition* (Oxford: Oxford University Press, 2003), 566; Michael Ruse, "Reductionism," in *The Oxford Companion to Philosophy, New Edition* (Oxford: Oxford University Press, 2003), 793.

[366] Ernst Mayr, "What is Darwinism Today?" *Proceedings of the Biennial Meeting of the Philosophy of Science Association* 2 (1984): 145–156.

[367] Thomas Nagel, *Mind and Cosmos: Why the Materialist Neo-Darwinian Conception of Nature is Almost Certainly False* (Oxford: Oxford University Press, 2012), 6.

[368] Ibid., 6-7.

> merely physical, it cannot be fully explained by physical science. And then, as I shall argue, it is difficult to avoid the conclusion that those aspects of our physical constitution that bring with them the mental cannot be fully explained by physical science either. If evolutionary biology is a physical theory—as it is generally taken to be— then it cannot account for the appearance of consciousness and of other phenomena that are not physically reducible. So if mind is a product of biological evolution—if organisms with mental life are not miraculous anomalies but an integral part of nature—then biology cannot be a purely physical science. The possibility opens up of a pervasive conception of the natural order very different from materialism—one that makes mind central, rather than a side effect of physical law.[369]

The issue for Nagel is that evolutionary biology must be not just a physical theory but also a mental theory, and therefore Darwinian evolutionary biology cannot fully explain the development of human mental capacities. According to Nagel, a physical theory is insufficient for explaining mental phenomena. While Nagel does not provide an alternative solution to the problem of the evolution of consciousness and mental content, Nagel argues that a naturalistic form of teleology (an idea that he concedes remains entirely vague) is more likely the best explanation for such non-physical phenomenon, such as consciousness, qualia, and so on.[370] Thus, so far the problem for Nagel is that there exist mental phenomena that cannot be fully explained in traditional reductive and physicalist terms. One of these phenomena is consciousness. For Nagel, cognition in general and HCAs in particular rely on consciousness. Therefore, since traditional science cannot explain consciousness, it follows a fortiori that traditional science cannot explain cognition and HCAs.

However, in his recent book, *Mind and Cosmos*, Nagel ignores for the sake of argument the foregoing philosophical problem in the philosophy of mind and aims to tackle the evolutionary view of HCAs on its own descriptive grounds. He argues that HCAs are likely not the product of evolution by natural selection. This descriptive objection is worth considering.

[369] Ibid., 19.

[370] Ibid., 67.

## D. Nagel's Descriptive Objections

In *Mind and Cosmos*, Nagel attempts to answer the question whether "our cognitive capacities can be placed in the framework of an evolutionary theory that is in this way no longer exclusively materialist but retains the Darwinian structure."[371] Nagel imagines that the problems associated with consciousness above no longer apply. Even then, says Nagel, a Darwinian view of HCAs cannot succeed.

The phrase "Darwinian structure" remains unclear, but one guess is that Nagel refers to the mechanism of natural selection. This guess is confirmed in the paragraph that immediately follows his question:

> The problem has two aspects. The first concerns the likelihood that the process of natural selection should have generated creatures with the capacity to discover by reason the truth about a reality that extends vastly beyond the initial appearances – as we take ourselves to have done and to continue to do collectively in science, logic, and ethics. Is it credible that selection for fitness in the prehistoric past should have fixed capacities that are effective in theoretical pursuits that were unimaginable at the time?[372]

If by "Darwinian structure" Nagel means natural selection, then his formulation of the problem resembles Wallace's view (although for different reasons) and could therefore exhibit a similar defect. More specifically, Nagel's questioning in the passage above captures the spirit of Wallace's doubt in that the primitive natural capacities for promoting fitness would not have been conducive to producing "theoretical" beliefs "unimaginable at the time," and thus the neural hardware necessary for producing theoretical beliefs would not have been selected for. This formulation of the problem relies heavily on natural selection. I return to this in a moment.

Nagel defended a similar objection to the evolution of HCAs with a focus on natural selection in a previous work, *The View From Nowhere*, where he writes the following:

> The question is whether not only the physical but the mental capacity needed to make a stone axe automatically bring with it the capacity to take each of the steps that have led from there to the construction of the hydrogen bomb, or whether an enormous excess

[371] Ibid., 74

[372] Thomas Nagel, *Mind and Cosmos*, 74

mental capacity, not explainable by natural selection, was responsible for the generation and spread of the sequence of intellectual instruments that has emerged over the last thirty-thousand years. This question is unforgettably posed by the stunning transformation of bone into spaceship in Stanley Kubrick's *2001*. I see absolutely no reason to believe that the truth lies in the first alternative. The only reason so many people do believe it is that advanced intellectual capacities clearly exist and this [natural selection] is the only available candidate for a Darwinian explanation of their existence. So it all rests on the assumption that a noteworthy characteristic of humans beings, or any other organism, must have a Darwinian explanation. But what is the reason to believe that? Even if natural selection explains all adaptive evolution, there may be developments in the history of species that are not specifically adaptive and can't be explained in terms of natural selection. Why not take the development of the human intellect as a probable counter-example to the law that natural selection explains everything, instead of forcing it under the law with improbable speculations unsupported by evidence? We have here one of those powerful reductionist dogmas which seem to be part of the intellectual atmosphere we breathe.[373]

This passage creates some confusion about natural selection and the development of HCAs. Natural selection is the central target for Nagel, particularly the view that "there may be developments in the history of species that are not specifically adaptive and can't be explained in terms of natural selection." What is confusing about this statement is that Nagel cites Gould at this point and the mechanism of exaptation as an alternative to natural selection. But as discussed, exaptation is either just a variable of natural selection, or, even if exaptation remains distinct from natural selection, exaptation does not undermine the "Darwinian structure." Even on Nagel's own terms, he has not shown how the Neo-Darwinian account of the development of HCAs no longer applies.

Returning to his more recent work, the centrality of natural selection is supported again in *Mind and Cosmos,* where we find the central scientific objection to the evolution of HCAs:

…the best hope for a naturalistic response to the first problem would be that evolutionary theory, and in particular evolutionary psychology, is in fact capable of giving a credible account of the success of our cognitive capacities. For factual knowledge, this is the aim of naturalized epistemology. The goal would be to explain how innate mental capacities that were selected for their immediate adaptive value are also capable of generating, through extended cultural evolutionary history, true theories about a law-governed natural order that there was no adaptive need to understand earlier. The evolutionary explanation would have to be indirect, since scientific knowledge had no role in the selection of the

[373] Thomas Nagel, *The View From Nowhere* (Oxford: Oxford University Press, 1986), 80.

capacities that generated it. The just-so story would go roughly like this. Even in the wild, it isn't just perception and operant conditioning that have survival value. The capacity to generalize from experience and to allow those generalizations, or general expectations, to be confirmed or disconfirmed by subsequent experience is also adaptive. So is a basic disposition to maintain logical consistency in belief, by modifying beliefs when inconsistencies arise. A further, very important step would be the capacity to correct individual appearances not only by reference to other conflicting appearances of one's own but also by reference to how things appear to other perceivers. That requires recognition of other minds, an ability with obvious adaptive potential. The reach of these capacities can be greatly extended and deliberately exercised with the help of language, which also permits knowledge to be collectively created, accumulated, and transmitted. With language we can hold in our minds and share with others alternative possibilities, and decide among them on the basis of their consistency or inconsistency with further observations. Complex scientific theories that entail empirical predictions are therefore extensions of the highly adaptive capacity to learn from experience—our own and that of others.[374]

In this passage, the problem with the evolution of HCAs are best described by evolutionary psychology and natural selection. This assumption resembles the problem with Wallace's objection. Nagel assumes that the most effective method for understanding human cognition generally and HCAs specifically is the third strategy, evolutionary psychology. Recall from the introduction that evolutionary psychology assumes that human cognition and its higher cognitive abilities are the product of adaptations developed by natural selection.[375] Therefore, according to Nagel, to support an evolutionary view of HCAs that retains the "Darwinian structure" requires natural selection as the sufficient mechanism responsible for those higher abilities. So, even if Nagel is correct about natural selection, the problem with his view is the assumption affirming the third strategy. However, one need not affirm the third strategy and thus Nagel's objections would fail to address neural reuse and other possible solutions to how HCAs are the product of evolutionary processes.

Moreover, to briefly return to Nagel's philosophical solution to this evolutionary problem, nothing here suggests a need to replace natural selection (or other mechanisms of evolution) with a distinct explanation – teleological, immaterial, or otherwise. The descriptive

[374] Nagel, *Mind and Cosmos*, 76-77.

[375] For an introduction, see also Stephen M. Downes, "Evolutionary Psychology," *The Stanford Encyclopedia of Philosophy*, accessed March 2017, <https://plato.stanford.edu/archives/sum2014/entries/evolutionary-psychology/>.

problem of HCAs – resembling the descriptive problem of the evolution of the vertebrate eye – does not require a teleological solution at this point, even if other metaphysical considerations require attention. As already discussed, other mechanisms may have been responsible for the development of HCAs that align with a Darwinian view and this is the more accurate way to formulate the descriptive view of the evolutionary view of HCAs.[376] Now, one could inquire

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[376] A second issue is Nagel's claim that assessing human cognitive evolution operates within the aims of "naturalized epistemology." He suggests that the goal of naturalized epistemology is "to explain how innate mental capacities that were selected for their immediate adaptive value are also capable of generating, through extended cultural evolutionary history, true theories about a law-governed natural order that there was no adaptive need to understand earlier." This is an incomplete description of the goal of naturalized epistemology. In particular, some of the "Darwinian arguments" defending naturalized epistemology cohere with Nagel's objections. For example, some versions of evolutionary epistemology, a branch of naturalized epistemology, reject the view that natural selection explains human "innate capacities," and then affirms that these capacities require non-adaptationist views of evolution. Non-adaptationist views do not require natural selection as the mechanism of change but suggest other mechanisms for cognitive evolution. Clearly, then, some epistemologists developing a naturalized epistemology recognize the limitations of natural selection, and this recognition does not compromise a naturalized epistemology upholding a Darwinian view. Therefore, even if Nagel is correct about the limitations of natural selection on human higher cognition, that limitation does not require alternative mechanisms conflicting with a Darwinian view. One could reject natural selection entirely or in part as the appropriate mechanism for producing higher cognition and still retain a Darwinian view. In fact, there exist more pertinent challenges to natural selection, and these challenges do not undermine the Darwinian view, but clarify various hypotheses within the Darwinian view. For positions that follow Nagel's portrayal, see Konrad Lorenz, "Kant's Doctrine of the *A Priori* in the Light of Contemporary Biology" in *Philosophy After Darwin: Classic and Contemporary Readings* (ed. Michael Ruse; New Jersey: Princeton, 2009), 231; Robert Richards, "Darwin's Metaphysics of Mind," in *Darwin and Philosophy* (eds. V. Hoesle and C. Illies; Notre Dame University Press, 2005); Donald Campbell, "Evolutionary Epistemology," in *The Philosophy of Karl Popper Vol. I* (ed. Paul A. Schlipp; Illinois: La Salle, 1974), 413-459; W.V.O Quine, *Ontological Relativity and Other Essays* (New York: Columbia University Press, 1969), 126-7; W.V.O. Quine, "The nature of natural knowledge," in *Mind and Language: Wolfson College Lectures* (Clarendon Press: Oxford, 1975),70; for positions that diverge from Nagel's portrayal, see Franz Wuketits, *Concepts and Approaches in Evolutionary Epistemology* (Dordrecht: D. Reidel Publishing Company, 1984); Franz Wuketits, *Evolutionary Epistemology and its Implications for Humankind* (New York: State University of New York Press, 1990); See also Hilary Kornblith, *Inductive Inference and Its Natural Ground: An Essay in Naturalistic Epistemology* (Cambridge, MA: MIT Press, 1993); Hilary Kornblith, *Naturalizing Epistemology* (Cambridge, MA: MIT Press, 1987); For similar criticisms to evolutionary epistemology that do not undermine a Darwinian position, see David Sloan Wilson, "Species of Thought: A Comment on Evolutionary Epistemology," *Biology and Philosophy* 5, no. 1 (1990): 37-62; Franz Wuketits, "Evolutionary Epistemology: A Non-Adaptationist Approach," in

whether Nagel provides principled philosophical arguments favoring his doubts. But these arguments would remain distinct from the descriptive problems. So even if Nagel successfully defends some broader philosophical problems related to the philosophy of mind, consciousness, and so on, at this point those philosophical problems do not explicitly relate to the descriptive problem of whether or not HCAs are the product of evolution.

**II. General Responses and Conclusions**

The main criticism of Wallace and Nagel includes rejecting their assumption that the third strategy of understanding the evolution of HCAs – that is, evolutionary psychology and that HCAs must be adaptations – is the best way to characterize the evolution of HCAs. I argued that the response from neural reuse is an effective strategy of assessing the evolution of HCAs and this strategy undermines the force of their objections.

Still, suppose for the sake of argument that a complete explanation for the evolution of HCAs did require natural selection as a sufficient cause, which is often assumed by the third strategy, evolutionary psychology. Following the second strategy discussed throughout, even here reuse provides traction for a response to critics. Recall that at the end of chapter two I discussed the second strategy and the function of neural search. The adaptation that evolution selected for was a brain with neural search; the brain continuously builds cognitive networks for accomplishing different tasks. This second strategy remains hypothetical, to be sure, and at this point would likely amount to a just-so-story. The point, however, is that as new evidence becomes available about the brain and its cognitive potential, it could be that most of our cognitive capacities align with an evolutionary story of natural selection as a sufficient cause for selecting a brain for reuse.

Regardless, the focus on natural selection is irrelevant insofar as critics undermine arguments that HCAs are the product of evolution. If these arguments require natural selection, then those arguments are more difficult to defend and often fuel objections which lead to controversial philosophical solutions, as described by Wallace and Nagel. What I have proposed by utilizing neural reuse and the first strategy is a type of argument that does not depend on the

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*Evolutionary Epistemology, Language, and Culture* (eds. N. Gontier, Jean Paul Van Bendegem, Diederek Aerts; Netherlands: Springer, 2006).

sufficiency of natural selection or the causal story. Perhaps the causal story of how selection produced HCAs will be discovered in the future. But even if this causal story of the selection of HCAs were not discovered, the argument for the evolution of HCAs from neural reuse and the first strategy would provide a defense for affirming the position that HCAs are the product of evolution.

Throughout this project I explored the question whether or not HCAs are the project of evolution. My project focused on the descriptive view of this question and not the teleological view. According to the descriptive view, evolution by natural selection produced a brain with the capacity for reuse. This is the first strategy of how to understand the evolution of HCAs and that strategy appears easier to defend than the second or third strategies discussed in the introduction. If evolution produced a brain with the capacity for reuse, then the human brain can in principle carry out HCAs by recruiting the operations of ancestral brain regions. Not only does there exist evidence for neural reuse, but there is evidence that the reusable brain recruits the operations of older brain regions for higher cognitive use. Thus, even if broader philosophical issues about the human mind remain, including non-physical causes, teleology, or whatever, there exists a descriptive account of why HCAs are the product of evolution. In other words, it remains an open question whether or not HCAs are analogous to the first sand castle or the second castle-like structure. What is apparent is that regardless of that teleological question about sand castles and HCAs, the descriptive question about whether or not HCAs are the product of evolution can be answered by including the processes of neural reuse.

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