Two conceptions of the mind

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Two Conceptions of the Mind

By

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Abstract

Since the cognitive revolution during the last century the mind has been conceived of as being computer-like. Like a computer, the brain was assumed to be a physical structure (hardware) upon which a computational mind (software) was built. The mind was seen as a collection of independent programs which each have their own specific tasks, or modules. These modules took sensory input "data" and transduced it into language-like representations which were used in mental computations. Recently, a new conception of the mind has developed, grounded cognition. According to this model, sensory stimulus is saved in the original format in which it was received and recalled using association mechanisms. Rather than representations being language-like they are instead multimodal. The manipulation of these multimodal representations requires processing distributed throughout the brain. A new holistic model for mental architecture has developed in which the concerted activity of the brain's modal systems produces functional systems which are intimately codependent with one another. The purpose of this thesis is to explore both the modular and multimodal theories of mental architecture. Each will be described in detail along with their supporting paradigms, cognitivism and grounded cognition. After my expositions I will offer support for my own position regarding these two theories before suggesting avenues for future research.

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1.0 Introduction

One of the great mysteries that philosophy and science have always dealt with but have made seemingly little progress toward answering is the mind. Although (arguably) we all have phenomenal experiences, the nature of phenomenal experience is apparently an intractable problem. During the 20^{th} century it became common knowledge that the brain is the seat of the mind, but with the technology available at the time, studies of the brain itself yielded little practical information that would address the problem. Instead philosophers and scientists of the mind decided to set the question of phenomenal experience aside and to take a metaphorical approach to understanding the mind by viewing it in computational terms. This *modular view* dominated cognitive science for the past five decades. It features a number of functionally distinct mechanisms within the brain operating in a step-wise or serial fashion. Recently, neuroscientists have been able to analyze the actual workings of the brain in finer detail than ever before. The results have been astonishing and confusing as it is clear that the activity of the brain is more distributed and complex than we had imagined. These observations have led to the *multimodal view*, which, although having a long history, is a relative newcomer to the cognitive science context. This interpretation features a holistic interpretation of the brain where several fundamental systems work in unison to create the mind.

Proponents on either side – modular or multimodal – often view scientists with the opposite view as intellectual opponents. This adversarial approach to academic debates is often advantageous because it assures that the scholarship is rigorous on both sides. My intent in this thesis is not to advance one of the theories at the expense of the other. Rather I shall take a hermeneutical approach where both sides are presented as strongly as possible and the furthering of our understanding of the mind is prioritized over deciding the 'winner' in a debate. In order to do this I will begin by finding a common ground between these two hypotheses.

1.1 Common Ground

Both the multimodal and modular sides agree that the mind is a natural part of a natural universe. Neither of these explanations advocates a supernatural cause for the mind that is beyond the reach of science. Additionally, both sides agree fully that understanding the mind in a natural context is an important goal, for both practical (e.g. medicine or technology) and theoretical (e.g. philosophical) reasons. Advocates for both sides agree on both the theoretical and practical importance of the issues, which means that in a real sense they have a mutual goal. Both profit from the other's successes and failures because they are part of the same explanatory endeavor.

Both sides seek a 'mechanistic' explanation for the mind. Mechanistic in this sense is a functional term for an important piece of a larger system that is causally and organizationally related to the working of the system as a whole (Craver & Bechtel, 2006). In other words, theorists from both camps are looking for the smallest functional pieces that can then be organized into larger functional pieces. The modular view is an explicit formulation of this concept in which there are specialized compartments of the mind for different tasks, but it should be noted that even the multimodal view requires subdivisions for its systems; at the very least this provide a useful heuristic. These mechanisms allow for a more precise, fine-grained understanding of the inner workings of the mind required for further advancement in the mind and brain sciences.

Finally, scientific advancements from both sides have been hard-won through theorizing and experimentation. As we shall see, both have roots in philosophical traditions that stretch back hundreds of years to the debates between supporters of Hume and Descartes. Despite any reservations one might have about the validity of either side of this old dialogue, the brilliance of the participants cannot be overstated as the issues contested play a part in most if not all contemporary debates. Both sides have brought important insights to epistemology and metaphysics, and therefore neither side can be summarily dismissed.

Unavoidably, I do have a preference in this debate, namely, the multimodal view. We are all affected by our "historicity" as it is simply impossible to not form an opinion (Gadamer, 1975). In this thesis, however, when describing the tenets of either side I will provide their most powerful arguments in the most convincing fashion I can muster. Toward the end I will defend my own views, but until then I am resolved to make both sides as tenable as possible because I understand that, as mentioned above, the purpose of this conflict is ultimately to advance our understanding. In the interest of an eventual synthesis I will advocate for explanatory pluralism or at the very least intellectual tolerance. Currently both sides have much to contribute through either suggestions for future empirical research or descriptions of the relationship between the mind and the world as a whole (Dale, Dietrich, & Chemero, 2009). It is my opinion that the multimodal view will eventually replace the modular view, but, because of the ideological positions of the participants, this will take an academic "changing of the guard" as a new generation of cognitive scientists and philosophers with their own influences will usher in the new paradigm. These newcomers (myself included) are the intended targets of comparative expositions like this one as, with both sides presented fairly and in parallel, they can decide for themselves which description is superior.

1.2 The Gameplan

In order to achieve these goals, I will present the modular theory of neural architecture in Chapter 2, and its supporting paradigm, cognitivism. I shall describe the assumptions that are related to this the modular theory: computationalism and adaptationism. These tenets are codependent on each other, and, collectively, they constitute the cognitivist research program. I will then describe the different variations of the modular theory of mind which have developed since its inception. Like all mature paradigms, modularity has been appropriated by various camps and variations have arisen over time.

I will focus on the three primary versions of a modular mind by featuring a single paradigmatic supporter as a representative for their specific view. I will start with the traditional version originally postulated by Fodor (1983), the peripheral-systems modularity thesis which features the non-modular general-learning or central system. Then I will present the massively modular theory supported by Pinker (1997) which instead advocates for modularity in all aspects of cognition. Afterwards I will describe the moderately massive modularity hypothesis offered by Carruthers (2003a) which, on the face of it, is very similar to Pinker's architecture; however, Carruthers proposes that the linguistic module serves the function of the general-learning system that Fodor endorses. Finally I will describe the problems with the modularity theory proposed by Fodor (1983) – under the headings of flexibility of content, creativity of content, and abducted inference – and the answers to them offered by Carruthers (2003b).

In chapter 3 I will turn my attention to the multimodal theory and the grounded cognition paradigm that supports it. Because the multimodal theories are new in comparison to the modular theories, I will begin by describing what exactly it means to call the mind multimodal. The study of the brain through neuroscience is one of the cornerstones of grounded cognition, and, in order to explain the multimodal theory, I will need to explain the hypothesized neural architectures that make it possible: association, neural control structures, and simulation. These neural mechanisms provide headway into discovering the neural correlates of cognition.

I will then explore the assumptions supporting the grounded cognition research program: embodiment and dynamic systems. The body and brain play a central role in grounded cognition, and most grounded theories are heavily influenced by the dynamic systems description. Finally I will describe grounded theories that explain some of our cognitive abilities using the multimodal architecture of the brain.

Multimodal theories can explain the constitution of concepts, both abstract and concrete, without reference to amodal representations through cognitive linguistic theories (Aziz-Zadeh & Damasio; Lakoff & Johnson, 1999). Cognitive simulation theories provide multimodal explanations for both representations (Barsalou, 1999) and memory (Conway, 2009). Simulation can also explain social cognition in social simulation theories (Goldman, 2006; Gallese & Lakoff, 2005). Each of these theories makes use of the neural architectures mentioned above to produce a picture of cognition that is grounded in neuroscience.

Chapter 4 will consist of a direct comparison/contrast between the two architectures. I will provide the advantages and disadvantages of both theories. I will then defend my own argument for why the multimodal view is superior, and provide suggestions to improve the theory. I will show in the end that the two positions are not completely exclusive to one another; rather they represent progress toward a better, more fecund, description of the mind as they are two parts of one partially-synthetic theory in which the mind is a natural phenomenon in the universe that can be explained scientifically. First, however, it is appropriate to begin with a brief historical review of the origins of both sides.

1.3 History

It will be useful to rehearse some of the historical precedents of these theories, and especially the debate between rationalism and empiricism, which is normally considered to have its beginnings in the writings of Descartes, on the rationalist side, and Locke and Hume, on the empiricist side. Following Locke, Hume suggests that there is nothing in the mind that did not originate in the senses. In other words, all of knowledge is experiential, and cognition is the processing of information that is perceptual in nature. Descartes, on the other hand, took the opposite stance and claimed that at least some knowledge comes from innate faculties for reasoning and that there are innate ideas. The only way to attain truth is through reflection which is a native ability. These opposing views dominated the philosophical psychology, which existed for hundreds of years prior to James and the first psychologists, and the formulation of psychology as its own distinct discipline.

With the advent of psychology as a scientific discipline came reformulations of the classical empiricism and rationalism. Both sides have controversial histories which are often ignored. Psychological nativism and the modular conception of the mind can trace its history to the pseudo-science of phrenology originally proposed by Gall (Fodor, 1983; Mundale, 2002). In phrenology the brain is proposed to be subdivided into spatially localized and innate mental faculties whose shapes reflect an individual's natural talents. Gall hypothesized faculties for everything, including musical talent, general intelligence, and perceptual acuity. The fixed nature of one's talents and the blatant eliminativism of this theory made it unpopular, and when it was quickly discovered that the shape of the brain did not have such predictive powers the theory attained its present opprobrium. Regardless of the distaste this discipline inspired, it could be credited with the beginnings of neuroscience and modularity.

Empiricism also has historical baggage in the often reviled behaviorism that dominated psychology for a time in the early 20th century. According to behaviorists, the mind is a blank slate and we are born with only a natural capacity for intelligence. Different stimuli form associations with responses and these associations govern our behavior and preferences subconsciously. The catch with behaviorism was the explicit rejection of unscientific references to mental states. Stimulus and response are the only things worth talking about in behaviorism because they are the only things that are verifiable. All references to internal experience such as intention, emotion, and cognition were to be avoided at all costs in order to make a truly rigorous science. This demand for purity, although admirable, severely limited advances in the philosophy of mind, and when the Turing machine model provided an alternative it was seized upon to begin the cognitive revolution.

The current formulations for empiricism and rationalism have been modified to accommodate the growing field of the cognitive sciences. Rationalism leans towards nativism and draws its support from a variety of disciplines. In linguistics Chomsky (1980) developed the “poverty of the stimulus argument,” which states that language cannot simply be learned because children do not experience enough language to generate their extensive knowledge of grammar. In clinical psychology localized areas of the brain have been identified that, when impaired, cause very specific effects on cognition. And in developmental psychology it has been shown that children achieve specific proficiencies according to a fixed schedule as their brains develop. In order to explain these observations under the cognitivist paradigm, a modular conception of the mind was assumed with each specialized area working together to produce cognition.

Empiricism has been recently revived as “neo-empiricism”, and it shares many of the features of its ancestry. Two “dogmas of neo-empiricism” have been identified and described by Machery.

1. The knowledge that is stored in a concept is encoded in several perceptual representational systems.
2. Conceptual processing involves reenacting some perceptual states and manipulating these perceptual states. (2006, pp. 398-399)

In other words, knowledge, or the basis of knowledge is fundamentally experiential. This tenet is significant for our current purposes because the view that concepts are created and stored as bundles of properties, a position known as concept empiricism, is a central tenet for the neo-empiricist “lower-order” or “minimal” simulation architecture that is strongly associated with grounded cognition (Michael, In Press). This echoes Hume’s argument about the source of knowledge and how it is stored in the brain. Furthermore, our minds use this experiential knowledge as the “currency of cognition”. The manipulation of these stored percepts is how we achieve the various forms of thinking. These principles suggest that the perceptual systems are multimodal and that they operate in a concerted manner.

I will show, however, that these two perspectives are not necessarily exclusive to one another. Each side incorporates explanatory tenets from the other approach, and they therefore work together to create an explanation of the mind. We have native mental faculties, but they are actually tendencies to react to experiences. The best description of the relationship between learning and innateness can be appropriated from Pinker when he describes with his usual clarity the opposition to his stance regarding the innateness versus learning debate.

> All behavior is the product of an inextricable interaction between heredity and environment during development, so the answer to the nature-nurture question is "some of each."… biology has made the very distinction [obsolete because] a given set of genes can have different effects in different environments, there may always be an environment in which a supposed effect of the genes can be reversed or cancelled; therefore the genes impose no significant constraints on behavior. Indeed, genes are expressed in response to environmental signals, so it is meaningless to try to distinguish genes and environments. (2004, p. 3)

2.0 The Modular Mind

During the last century the budding science of psychology experienced what has aptly been called "the cognitive revolution" as a reaction towards the verificationist behaviorism which dominated beforehand. The goal was to bring internal experience and cognition back to the center of our studies of the mind. In order to do this, a new metaphor for the mind was seized upon. Rather than the mind being a blank slate that became conditioned to respond to stimuli, the mind became a type of computer or information processor that performs computations on non-isomorphic representations to create cognition. This interpretation ran into empirical problems because it quickly became apparent that even the mind of a child is capable of feats that even the most advanced computers cannot hope to match. It seemed that the computation being performed in the mind is an incredibly complex process, and, in order to explain it, a modular interpretation of the mind was adopted.

In this chapter I will describe the modular theory of mind. In order to fully explain this proposed architecture I will need to describe the paradigm that originally proposed it and supports it: cognitivism. I will also discuss the other theories about the mind that are tied to modularity in cognitivism: computationalism and adaptationalism. Afterwards I will describe three different versions of the modularity thesis: Fodor's (1983; 2000) peripheral systems modularity, Pinker's (1997) massive modularity, and Carruthers (2003a) moderately massive modularity. Finally I will discuss the problems with modularity which were originally forwarded by Fodor (1983) and the answers given by Carruthers (2003b).

But what is a module? In the broadest sense "a module is a system whose internal processes are mostly inaccessible to other systems and that, at any time, uses only a subset of the information that is present in other systems" (Machery, 2008, p. 264). Modules are categorized by some of the following characteristics (Prinz, 2006):

1. *Mandatory*: The activity of the modules happens automatically without volition. For example, in vision we cannot help but see distinct objects rather than a blur of colors and lines because the vision module acts automatically.
2. *Fast*: Processing in each module happens very quickly. Once again, the processing of sight happens so fast that we cannot interfere even if we try.
3. *Shallow*: Outputs from the modules are simple and do not require much processing upon reaching the cognitive level. For example, visual experiences are processed quickly into basic representations which are then assessed cognitively.
4. *Localized*: Each module has a dedicated neural structure in the brain, whether it is spatially localized or distributed across various areas. For example, language is a system of modules that could be considered one larger functional module which is localized in Broca's and Wernicke's areas.
5. *Subject to characteristic breakdowns*: Individual modules can be selectively impaired while leaving other modules intact which produces very specific results. For example, in autism the theory of mind module is presumed to be impaired which affects social interactions.
6. *Follow distinctive patterns during development*: During development different modules develop at different predetermined paces which can be observed in experiments in

developmental psychology. For example, a child's language module is presumed to develop adequately enough to learn words at eight months and to combine words at eighteen months due to an innately specified schedule of neural development.

7. *Domain specific*: Each module has its own subject matter which it is dedicated to exclusively. Obvious examples are the senses which are each in charge of their own responsibilities and have their own proprietary inputs (i.e. taste, sight, etc.).
8. *Cognitively impenetrable*: The activity of modules cannot be accessed or interfered with by higher-level cognitive processes. In addition to being mandatory in operation, modules cannot be accessed by first-person introspection while performing their duties.
9. *Informationally encapsulated*: Modules are unable to draw on any of the agent's beliefs during computation. For example, during a visual illusion one may know that they are experiencing an illusion but cannot help but see otherwise.

Of these properties, 1-3 are focused on the speed and efficiency of the processing. This is very important for the modular view because, as I shall explain, a computational theory of mind requires such processing. Properties 4-6 deal with the relationship between mental modules and the physical brain. Some of the most significant evidence for modularity comes from clinical psychology which is full of examples of subjects with brain damage exhibiting very selective impairment. Properties 7-9 deal with the relationship between the individual modules during computation. These are normally considered to be the core requirements for what constitutes a mental module.

It is important to note that there are different variations of modularity which support different combinations of the nine principles described by Fodor. Often these differences are overlooked by detractors, but it could almost be claimed that no one (not even Fodor) is committed to all nine properties. The differences between these theories will be discussed in greater details soon, but first we should examine the assumptions underlying modular theories of the mind.

2.1 Cognitivism

As mentioned previously, the cognitive revolution was the direct forerunner for the modular theory of mind. During the last century, the scientific paradigm shifted from a state of specifically avoiding talking about internal states to a state where mental cognition is the explanandum or target of the explanations. This new paradigm I will henceforth refer to as "cognitivism". According to cognitivism the mind is a naturally occurring phenomenon in the physical world. Like behaviorists, cognitivists reject occult explanations, but unlike behaviorists, cognitivists are (generally) optimistic about science's ability to explain mental phenomena in a rigorous manner. The motivation behind this shift in priorities was the invention of the Turing machine which provided a model for how a mind could work without reference to supernaturalism: computationalism.

2.1.1 Computationalism

Computationalism is the cornerstone of cognitivism as in it there is an answer to how a physical lump of flesh can create cognition through logical operations. "The notion of computation is intrinsically connected to such semantical concepts as implication, confirmation, and logical consequence. Specifically, a computation is a transformation of representations which respects these sorts of semantic relationships” (Fodor, 1983, p. 5). A thoroughly detailed description of computationalism is beyond the scope of this paper, but at least a cursory understanding is necessary due to its relationship with modularity. In the computational model information is processed in the mind by transducing sensory information into representations and manipulating these representations algorithmically (Fodor, 1983; Pinker, 1997; Carruthers, 2004). This model is based on a Turing machine-like architecture for mental operations.

“Information is a correlation between two things that is produced by lawful processes” (Pinker, 1997, p. 65). Whenever a physical object is statistically correlated with an event or situation it is said to be carrying information. This information-carrying object is called a symbol. Whenever these isomorphic symbols are further interpreted by specialized modules into abstract versions specifically tailored to carry the information that can then be manipulated, it is called information processing. As an example, imagine a simple counting machine that places a mark at every integer of ten that it counts. After performing its duties we could go behind it and count the marks to deduce the total number counted by the machine. Each number is a basic isomorphic symbol, but the marks produced by the machine represent sets of ten numbers which are processed by an interpreter.

Information is created from sensory experience through a process called transduction. Whenever photons cause our optic nerves to fire the activity is then transduced into the symbols necessary for information processing. Transduction happens first, before any processing occurs. Sensory information entering the senses is immediately transduced and that information is then fed into the sensory modalities which then process it to be presented to cognition (Pinker, 2005).

A representation is the product of transduction and information processing that occurs in the mind. “Something is a representation if it denotes, designates, stands for, refers to, or is about something else” (Barsalou & Prinz, 2000, p. 54). These representations are the symbols that are manipulated in cognition and ordinarily are sentence-like structures (Fodor, 2000). There is a representation for every piece of information that is processed by the modules, and groups of representations combine to form larger representations or concepts, and they are hierarchically organized by complexity and the highest levels are concepts used in mental feats such as abstraction and generalization. Most representations are subpersonal and remain “behind the scenes” in cognition.

The metaphor evoked for computationalism is the computer or, more specifically, the Turing machine. The invention of the Turing machine was the impetus that kicked off the cognitive revolution.

> [A] hypothetical machine whose input symbols and output symbols could correspond, depending on the details of the machine, to any one of a vast number of sensible interpretations. The machine consists of a tape divided into squares, a read-write head that can print or read a symbol on a square and move the tape in either direction, a pointer that can point to a fixed number of tickmarks on the machine, and a set of mechanical reflexes. Each reflex is triggered by the symbol being read and the current position of the pointer, and it prints a symbol on the tape, moves the tape, and/or shifts the pointer. The machine is allowed as much tape as it needs. This design is called a Turing machine. (Pinker, 1997, p. 67)

In other words, the machine is designed to apply algorithmic processes to information that is presented to it. All it needs is a set of logical rules and some information in order to guarantee a solution to some problem in a finite amount of time. This design is so interesting because it is an example of a “stupid” machine performing mind-like activities. It was heralded as a model for the mind as a set of rules or “software” running on the “hardware” that is the brain. Like the

Turing machine, the mind is programmed to react algorithmically to stimuli in order to process information and produce cognition.

> Symbolic operations provide an intelligent system with considerable power for interpreting its experience. Using type-token binding, an intelligent system can place individual components of an image in familiar categories. [This supports] high-level cognitive operations, such as decision making, planning, and problem solving, [and also] includes a variety of operations for combining symbols, such that an intelligent system can construct complex symbolic expressions. Finally, by establishing abstract concepts about mental states and mental operations, an intelligent system can categorize its mental life in a metacognitive manner and reason about it. (Barsalou, 2008b, pp. 9-10)

This theory dominated cognitive science since its inception. However, this view cannot stand on its own because it fails to answer how this system evolved, how it can run in a brain with limited capacity, and how it is related to the brain. Computationalism is dependent on certain other theoretical assumptions: adaptationism and modularity.

2.1.2 Adaptationism

Evolutionary psychology is one of most important disciplines that underlie computationalism. According to evolutionary psychologists, the mind is a system of modules shaped by natural selection (Pinker, 1997; Tooby & Cosmides, 1992). “Biological systems ‘bolt on’ specialized components to already-existing systems in response to specific evolutionary pressures” (Carruthers, 2003a, p. 71). As humans evolved we were faced with very specific pressures, and our brains adapted to deal with these problems by creating specialized sub-systems. For example, social pressures have presumably always been present in the lives of hominids. Because of this pressure a capacity to “mind-read” others in order to predict their intentions was adaptive which eventually led to a mind-reading module. Similarly, during our time in the trees we developed a folk physics module which we share with the other great apes, and during our time as foragers we developed a folk biology module which eventually culminated in our ability to farm (Carruthers, 2005).

The metaphor commonly evoked is that the mind is like a "Swiss army knife" or "tool kit" which has different components dedicated to different tasks. Similar to how a tool kit has a hammer to deal with nails, our minds have a geometry module to deal with objects. This makes sense because evolution works by augmenting existing structures rather than creating new or all-purpose ones.[1]

2.1.3 Modularity

Modularity is essential to computationalism because of the nature of the computational processes.

> If a processing system can look at any arbitrary item of information in the course of its processing, then the algorithms on which that system runs will have to be arbitrarily complex also. For those algorithms will have to specify, in respect of each item of information that it could access, what step should be taken next – presumably different for each such item of information, if the system is to be a context-sensitive one. So the more items of information a program can look at while processing, the more complex its algorithms will need to be. So conversely, if a system's algorithms are to be computationally tractable, limits will need to be placed on the set of items of information that it can look at. (Carruthers, 2006, p. 184)

In other words, if every piece of information was available to every mental mechanism then processing would require a review of all this information which would, at the very least, take longer than would be reasonable for primitive man living under the time pressures of life.

[1] This description of adaptationism should suffice for my purposes (see Pinker 1997).

This is the primary impetus for properties 1, 2, 3, 7, and 9 listed above. Modules must be fast and mandatory in their operations, they must produce outputs that are simple, they must each have their own domain, and, most importantly, they cannot be allowed to interact with one another during processing. Essentially, perceptual information is transduced into symbols which are very rapidly processed by designated modules into simple representations available for cognitive processing. A computational explosion is avoided because information is divided and processed independently. However, as mentioned above, not all modular theories subscribe to the nine properties originally proposed by Fodor.

2.2 Themes and Variations

Throughout the years, different versions of the modularity thesis have been advanced by different theorists. Often the differences deal with what combination of properties compose the theoretical modules. However, these basic differences are over exaggerated in my opinion as most theorists (Pinker, 1997; Carruthers, 2003a; Fodor, 1983) actually believe that a mental module is a functionally defined entity rather than necessarily a physical thing. The true difference between the versions is the nature of the analog reasoning faculty that performs the executive function.

2.2.1 Peripheral Systems Modularity

In addition to providing the canonical definition of a mental module, Fodor (1983) proposed the original version of modularity, peripheral systems modularity. According to this hypothesis, the mind is composed of modules for input and output (perception and action) which transduce sensory information or carry out motor commands. These modules possess all of the properties listed above in that they respond automatically and quickly to stimuli to produce simple results. While performing these operations the thinking agent has no access to the processes. Additionally, other processes occurring simultaneously have little or no effect on one another.

The actual cognition occurs in a non-modular central system. This system performs the function of the executive controller by having access to the outputs from all the modules. After assessing the information presented to it, the central system generates a response which it signals to the motor system. This system involves our experience as an active agent in the world taking in data and deciding responses to it.

Fodor (1983) insists that a central system is necessary because full modularity cannot explain a variety of operations that we perform with ease. Specifically three features of cognitive processes are seemingly impossible to explain in purely modular terms: flexibility of content, creativity of content and abductive inferences performed upon such content (Carruthers, 2003b). How could a modular system, operating on designated algorithms, possibly create something new from preexisting information? A computer, for example, can process information that it knows, but it cannot then use that information to infer a solution to another similar problem. It cannot create something new and sensible from the information, and it cannot use that information for other orthogonal purposes.

Instead Fodor (1983) proposes that peripheral systems are composed of *vertical* faculties. By this he means that they are domain specific and informationally encapsulated. One might use a city block as an example of vertical faculties: the buildings that rise from the ground are each separate and distinct and never (hopefully) touch one another. Conversely, the central system is a *horizontal* faculty. Returning to the city block example, the infrastructure that the buildings are built upon is a horizontal faculty because it crosses domains and unites them. This system, due to its distributed nature, is unspecialized and therefore general purpose.

The conclusion Fodor (1983) draws from his observation is decidedly pessimistic. He asserts that "if central processes have the sorts of principles I have ascribed to them, then they are bad candidates for scientific study" (p. 127). He then goes on to explain his assertion, "The fact is that… global systems are per se bad domains for computational models… The condition of a successful science is that nature should have joints to carve it at… Modules satisfy this condition; [general-purpose] systems do not. If the central cognitive processes are nonmodular, [then this] is very bad news for cognitive science" (p. 128).

2.2.2 Massive Modularity

Not all theorists are convinced by Fodor's (1983) conclusions about the nature of the central system or the possibility of understanding the mind. Evolutionary psychologists especially have taken offense to Fodor's (2000) dismissal of their research program as unimportant for understanding the mind. Pinker (1997), for example, has taken on the challenge of explaining the mind with a strictly computational and modular interpretation.

According to Pinker (1997), the mind is massively modular. There are many modules whose operations can be combined to create all of human cognition. "[The] mind consists *almost entirely* of modular systems. There probably is no such thing as 'general-learning' at all, and all of the processes which generate beliefs, desires, and decisions are modular in nature" (Carruthers, 2003a, p. 67). This stands in stark contrast to Fodor's theory in the claim that there are only modules inside of modules rather than a central non-modular system.

Like peripheral systems modularity theories, perceptual information is transduced and processed by input modules. However, this processed information is immediately moved to other modules that perform various functions of cognition. For example, when looking at a family member the information is processed as normal, but the information, rather than going to a central system, is then processed by a "facial recognition module" and a "kinship recognition module" and a "cheater-detection module" which collectively form a shallow result: phenomenal experience (Pinker, 1997).

One problem with this version is that, although it was obviously formulated as an ahomuncular alternative to peripheral systems modularity, it has simply moved the homunculus back a step. In Fodor's formulation the peripheral system is an obvious homunculus because it has a detached and causal role in cognition. Massive modularity seeks to provide an alternative but still hits a roadblock when determining what information is important because it seems that at some point a central executive will be necessary. Pinker (1997) answers this problem by adopting a connectionist-like position regarding the bottom layers of cognition.

> In [connectionism], the computational system is construed as a network of very simple units partially analogous to neurons. Whereas neurons discharge or spike, these units become activated or deactivated and, depending on their activation, excite and inhibit other units to which they are connected. To model cognitive processing, some of these units are designated as inputs and others as outputs; cognitive tasks are supplied to a network activating some of its input units and allowing activation to spread through the network until the network stabilizes or a pattern is produced on the output units. (Bechtel, Mandik, & Mundale, 2001, p. 20)

Originally this theory was touted as a replacement for computationalism and representationalism, but it has been unsuccessful thus far. Pinker (1997) appropriates the idea to provide a different level of explanation that underlies his massively modular theory.

The bottom-up architecture for the mind as described by Pinker consists of neural networks at the lowest levels which “respond to familiar patterns and associate them with other patterns” (p. 112). The activity of these networks form the basis upon which the rest of computation relies. According to Pinker, “Neural networks alone cannot do the job. It is the *structuring* of networks into programs for manipulating symbols that explains much of human intelligence (p. 112). In other words, connectionist networks do not represent information directly, but rather they form the systems that handle the computations on that representation. At higher levels these systems are organized in a modular fashion and function as a production system.

2.2.3 Moderately Massive Modularity

The massive modularity thesis does not enjoy overwhelming popularity despite how well-known its chief proponent is in the public sphere. The issue is the nativism that is explicit in this theory and the determinism that is implicit. The mental modules proposed are innately specified, meaning they develop regardless of any learning that takes place. Their operations are algorithmic and mandatory so there is little room for free will. Indeed, this fixed view of human nature is one of Pinker’s most radical claims (2002; 2004). However, there are variations of it that allow for learning and explain the unavoidable horizontal faculty that seems to be necessary for abduction and global processing.

Carruthers (2003a; 2003b), for example, proposes that a central processor with global access to information is unnecessary. Instead, he asserts that the language module can perform both input (comprehension) and output (speech) functions so can allow for global access of information across modules. “[This] natural-language module which serves to integrate the outputs of the various central-conceptual modules, and which subserves conscious belief-formation and decision-making" (Carruthers, 2003a, p. 67).

2.3 Fodor's Problems

The massive or moderately massive modularity proposals address several of the problems that Fodor had identified as requiring a non-modular central processor: flexibility of content, creativity of content, and abductive inference (Fodor, 1983).

2.3.1 Flexibility of Content

The first problem deals with our cognitive ability to freely combine concepts and propositions across modular boundaries. For example, I can think about the mental experience of others, I can think about animals, and I can think about gravity. These are the domains of different mental modules (i.e. folk-psychology, folk-biology, folk-physics). I can then wonder if my dog is afraid of falling off of my furniture which is a combination of all three. The ability to access all three modules simultaneously and in combination would seem to require a central non-modular system because, by most definitions, a module is domain-specific and informationally encapsulated.

In order to deal with this problem, Carruthers (2003b) asserts that the language module can perform the integrative functions.

> Thoughts created by central modules are used to generate domain-specific natural language sentences, which are then combined to frame a content-integrating natural language representation; the latter is then used to generate a sentence in auditory imagination, which is then taken as input by the central modules. One can suppose that cycles of processing of this sort might sometimes issue in usefully-novel information. (p. 509)

This cycle begins when input is transduced by sensory modules and processed into representations before arriving at the central modules. These modules then generate natural language sentences which are processed into auditory imagination. We essentially "hear" our thoughts in our heads as if they were spoken aloud. These imagined thoughts are then fed back into the input system to be reprocessed in the same manner the original information was processed. These cycles of processing allow for new combinations of thoughts.

2.3.2 Creativity of Content

Another problem is our ability to generate wholly new ideas that are not tied directly to the perceived environment. "[These ideas] cannot be the outputs of particular modules, if the latter are designed to process information and issue in new domain-specific beliefs and desires. And they cannot result directly from the combinatorial powers of language, if all that language does is combine together and integrate the outputs of the various modular systems" (Carruthers, 2003b, p. 511). This is an ability we use constantly and a hallmark of our mental life; how is it possible?

Carruthers response to this challenge is to postulate the existence of a "supposition-generator" which is part of the language module. "This supposer would exploit the combinatorial powers of the language faculty to generate novel sentences… cued by similarities, analogies, and past associations" (2003b, pp. 509-510). In other words, there must be a species-specific capacity to generate whole new ideas out of existing ones either randomly or by association. Pretend play is an example of this kind of supposition generation.

2.3.3 Abductive Inference of New Content

Fodor (1983; 2000) asserts that abduction, or the ability to choose the best choice from a number of options, is the most difficult capacity humans have which cannot be explained without a non-modular central system. As described above, for an agent to check a new belief against all of its other beliefs is computationally intractable, which is one of the primary reasons for postulating mental modules in the first place. Abduction requires either this impossible review of beliefs or some kind of unencapsulated seemingly top-down central processor.

However, evolutionary psychology may provide an answer for this issue. According to many theorists, human beings evolved in a social context so we have always had an adaptive pressure to be able to detect cheaters (Carruthers, 2005; Pinker, 2005; Tooby & Cosmides, 1992). Therefore we evolved a "cheat detection module" which would necessitate the ability to evaluate testimonies. This module would make use of the supposition generator to suspect deception, and the internal language loop to ponder the motives of the liar and actual truth behind the statement. The way to check a statement for honesty is to consider the consistency of the speaker and the coherence of the statement in regards to other beliefs the evaluator may have.

Abductive inference makes use of this same process. We suppose new ideas, ponder their details using the supposition generator and language-loop, and then choose whether to incorporate them into our belief structure based upon the same heuristics used in testimony discrimination: consistency, coherence, and simplicity (Carruthers, 2003b). For example, when early man found animal tracks he was forced to use abduction to infer the type of animal that created the marks. Immediately his supposition generator generated the possibilities: zebra, deer, or bison. The language loop would then go to work and, by counting the toes and comparing that information to preexisting knowledge, eliminate the possibility that it is a zebra. Despite the fact that deer and bison have similarly shaped hooves, the ecological niches of the two animals are different; so if our early man was on the plains then he would infer that the animal that made the tracks is a bison rather than a deer. While it would be possible that the tracks were made by a deer that got lost and wandered into the plains, such a possibility is not parsimonious and therefore much less likely.

2.4 Summary

According to the modularity model, the mind is composed of a system of distinct modules which are similar to dissociable components. Each module has its own task, its own method of performing the task, and its own store of knowledge in order to do the task. These modules do their jobs automatically without conscious control, and, indeed, many of them are impervious to cognitive meddling. The modules are unintelligent as individuals, but when output from one is manipulated to become input for another the collective system is capable of intelligent activity.

Evidence for modularity is found in evolutionary biology, clinical neuroscience, and developmental psychology. However, modularity is further implicated by its consilience with other research programs dealing with the mind such as computer science, computationalism, and evolutionary theories of adaptationism. Modularity has been a staple for cognitive science since its inception during the last century.

There are different versions of the modular thesis. Some variations propose that the mind is fully modular and that all cognition is information processing performed upon symbols in an algorithmic fashion (Pinker, 1997). Other versions assert that the mind cannot be fully modular because such a system would not be able to account for various abilities that humans possess which could not be explained by algorithmic information processing between modules (Fodor, 2000; Fodor, 1983). This problem is the impetus for other versions which postulate additional mechanisms and roles for modules that make distinctly human thinking possible in a fully modular mind.

3.0 Multimodal Cognition

In the past couple of decades there has been a shift in the field of cognitive science away from the cognitivist paradigm which conceptualizes the mind as a complex computer running computational algorithms on internal representations. According to the new view, the interplay between the brain, the body, and the environment plays a crucial role in cognition. We are essentially embodied agents navigating the world around us in pursuit of our goals rather than detached entities reacting to stimuli. While this description sounds more natural than the computer metaphor, the real standard for its usefulness is the amount of explanatory power it provides us. If cognition is not being performed through computation, then how can we explain the incredibly complex psychological capacities we all share? Amodal symbols seem necessary to explain our ability to imagine, plan, and understand (Fodor, 1983; Fodor, 2000; Carruthers, 2003a).

The solution has been to revive the school of empiricism which had been discarded with the fall of behaviorism, appropriately called "neo-empiricism". Internal knowledge, if there is such a thing, retains the format in which it was originally acquired. Rather than being transduced into amodal symbols, information is stored in the perceptual modalities. All knowledge must first pass through the senses, and when retrieved it is in the form of the original sensory impressions. When understanding a concept we are actually referring to a collection of impressions from the different modalities which collectively constitute the concept (Barsalou, 2008b; Barsalou, 2009; Machery, 2006). "Perceptual mechanisms provide unexpectedly rich and useful resources for implementing a conceptual system" (Goldstone & Barsalou, 1998, p. 254).

In this chapter I will describe the multimodal theory of neural architecture. This model is essential for the grounded cognition research program which includes embodied theories of mind, simulation architectures, and neo-empiricist models of concepts and knowledge. In order to explain the grounded cognition paradigm I must first describe the hypothesized neural mechanisms and structures that coordinate the different modalities; association, neural control hypotheses, and simulation. I will then provide a description of the theoretical assumptions made in grounded cognition (embodied cognition and dynamic systems theory). Finally I will explain some of the current grounded theories that use multimodal architectures to answer questions about abstraction, representations, memory, and social cognition. However, first it is important to define and describe the different modalities proposed by Barsalou (2008a):

The perceptual modalities include the five senses normally recognized (sight, hearing, touch, taste, and smell) along with the sense of kinesthesia which informs us of our movement and stability in reference to the ground (which way is up or down). Another sensory modality which is not often recognized as such is proprioception, which is the pre-reflective knowledge of the positions of our bodies (Gallagher, 2005). In addition to sensory information, the perceptual modalities play a large role in both the motor and introspective modalities.

The motor modalities are the possibilities for action and the actions themselves that are motor systems are capable of performing. For example, complex innate motor actions such as walking, reaching, grasping, etc. which we are always capable of but must be learned through experience are motor modalities. In addition to set motor patterns, the motor system frames perceptual experience by providing spatial dimensions like distance, height, and location.

Conversely, the perceptual modalities frame motor experience in modalities such as our body schema which is a subconscious knowledge of our body's position and shape (Gallagher, 2005), and peripersonal space (Rizzolatti, Fadiga, Fogassi, & Gallese, 1997), which is the knowledge of the environment within arm's reach.

The introspective modalities can be described as internally generated processes such as cognition, affect, and motivation. These are the raw phenomenological experiences that compose our mental life such as inner speech, natural kind emotions, and the basic urges necessary for life (Barsalou, 2008a). The introspective modality also frames and is framed by the motor and perceptual systems. Salience and attention are examples of introspective and perceptual multimodal experiences; similarly, intention and agency might be examples of introspective and motor system interactions

"Circuitry across brain regions links modalities, infusing each with properties of the others. The sensory-motor system of the brain is thus 'multimodal' rather than modular" (Gallese & Lakoff, 2005, p. 2). This highlights an important feature of the multimodal system: no modalities ever act in isolation. In contrast to the idea that sensory modules each act in separate domains and send transduced information to a higher module, each modality is constrained and shaped by the other modalities (Garbarini & Adenzato, 2004). Moreover, the three systems are acting in a concerted manner and are so closely related that any distinction made between them is only for functional purposes. In order to see how the modalities are integrated it is necessary to understand this circuitry by examining the brain itself.

3.1 Neural Architectures

3.1.1 Associationist

The underlying mechanism for neo-empiricism is association. Association is whenever two separate stimuli are presented together and are therefore grouped together. Whenever one stimulus is presented, the associated stimulus is also recalled or reactivated or whatever the case may be. The behaviorists called associative learning "conditioning" and performed a number of experiments that verified this phenomenon. In 1901 Pavlov performed the most famous of association experiments with his dogs. These dogs were conditioned by always being fed in coordination with a bell. After experiencing these simultaneous occurrences a few times the dog would come to expect the food upon hearing the bell. In order to show his results, Pavlov recorded the salivation rate of the dogs before and upon hearing the bell. He found that when the dog heard the bell it began salivating in anticipation without the actual food yet present.

Important for our purposes is the fact that these associations are based on statistical correlations. The likelihood of two stimuli being associated is based primarily upon the consistency of their correlation in past experiences. Statistical correlation plays a crucial role in the neural control hypotheses which will be discussed below. Each of these hypothesized architectures is based upon pattern-completion mechanisms, and a pattern-completion mechanism is determined by the statistical likelihood of one aspect of the pattern triggering the completed pattern.

3.1.2 Simulation

An important aspect of the multimodal theory is neural simulation (Barsalou, 2008a; Barsalou, 2009; Gallese & Lakoff, 2005). This is a process whereby the brain acts *as-if* it is experiencing a stimulus in the absence of said stimulus. These simulations are pervasive in cognition; they can be implicit such as for understanding a concept or predicting movement or explicit such as the use of imagination (Barsalou, 2009).

> Simulation is the reenactment of perceptual, motor, and introspective states acquired during experience with the world, body, and mind. As an experience occurs (e.g., easing into a chair), the brain captures states across the modalities and integrates them with a multimodal representations stored in memory (e.g. how a chair looks and feels, the action of sitting, introspections of comfort and relaxation). Later when knowledge is needed to represent a category (e.g. chair) multimodal representations captured during experience with its instances are reactivated to simulate how the brain represented the perception, action, and introspection associated with it. (Barsalou, 2008a, pp. 618-619)

Simulations are triggered by simulators. A simulator "functions as a concept or type in more traditional theories by integrating the multi-modal content of a category across instances, and by providing the ability to interpret individuals as tokens of the type" (Barsalou, 2009, p. 1282). They are the stored representations which constitute a whole category based upon previous experiences over time that have become associated by conjunctive neurons. A simulator is a complete representation, but the simulation that it produces is highly situated according to the context.

Presently we distinguish two different kinds of simulation. The traditional definition of simulation is that simulations play an instrumental role in knowledge (Michael, In Press). In other words, whenever you imagine something your brain engages in a simulation which aids in conceptualizing the imagined object. Likewise, when you interact with another person your brain implicitly or explicitly simulates the mental state of the other in order to draw inferences about their reasons and predict their behavior. This definition has a distinctly cognitivist flavor because it includes an internal agent which initiates these simulation and draws inferences from them (Gallagher, 2007).

On the other hand, neo-empiricists advocate a minimal form of simulation in which simulation plays a constitutive role in knowledge. In other words, whenever you imagine something your brain enters a very similar state to if you were actually experiencing the object. There is no internal agent or initiator because your conceptualization of the object *itself* is composed of these multimodal simulations. Whenever your environment evokes a concept, the modal properties are not combined with a mental representation, but rather the totality of modal properties *is* the mental representation (Michael, In Press). In intersubjective situations simulation is not initiated in order to help understand the other person's internal state. Instead, the knowledge *itself* of their internal state is a simulation.

3.1.3 Neural Control Hypotheses

A neural control hypothesis is any theory involving neurons that function as directors of other neural activities, or conjunctive neurons. The primary mechanisms of the neural control hypothesis are called neural control structures. These populations of neurons "are any neural circuits, structures, or processes whose primary role is to modulate the activity of other neural circuits, structures or processes – that is to say, any items or processes whose role is to control the inner economy rather than to track external states of affairs or to directly control bodily activity" (Clark, 1997, p. 136). Clark uses the example of a factory which, in addition to workers dealing with input and output, has specialized workers that are in charge of trafficking materials internally.

3.1.3.1 Convergence/Divergence Zones

One neural control hypothesis is the architecture proposed by Damasio and Damasio (1994) called the convergence/divergence zone (CDZ) framework. According to this hypothesis, these zones are distributed yet functionally localized populations of neurons that capture pieces of incoming perceptual information and associate them with information from other modalities that converge on the same conjunctive neurons within a certain temporal window. Later when a similar stimulus occurs in one of the modalities it activates relevant parts through pattern completion causing a divergence and partial re-experiencing of the other modalities (Damasio & Meyer, 2009). These proposed zones provide an extremely powerful explanation for all forms of association.

A technical definition of these neural control structures is this:

> The architecture is constituted by two crucial elements: (i) neuron ensembles in early sensory and motor cortices, which represent separate knowledge fragments about a given object; and (ii) neuron ensembles located downstream from the former in association cortices, which operate as convergence-divergence zones (CDZs). CDZs receive convergent projections from the early sensorimotor sites and send back divergent projections to the same sites. CDZs contain records of the combinatorial arrangement of the knowledge fragments coded in the early cortices, that is, they hold information about how those fragments must be combined to represent an object comprehensively. CDZ records are shaped by experience. When the organism interacts with an object t, several aspects of the interaction are mapped simultaneously at separate sites in early sensorimotor cortices. The temporally coincident activity at the separate sites modifies the connectivity patterns to, from and within a shared CDZ downstream, with the result that various fragments of information about the object become associated. (Damasio & Meyer, 2009, pp. 376-377)

For example, upon seeing a dog certain perceptual features are retained by conjunctive neurons. Upon hearing the word “dog” the perceptual features that have been retained by the conjunctive neurons will activate within the CDZ’s which will stimulate the associated modalities to fire. The firing of these modalities allows us to mentally recollect the dog and even to understand the concept of a dog.

3.1.3.2 Somatic Markers

Another similar theory also proposed by Damasio (1994) deals instead with the relationship between affect and perception, the somatic marker hypothesis. According to this idea the systems for both memory and decision-making are very closely related through multimodal interactions of perceptual and affective experience. “It is proposed that the ventromedial prefrontal cortex establishes a linkage between the disposition for a certain aspect of a situation and the disposition for the type of emotion that in past experience has been associated with the situation” (Bechara, Damasio, & Damasio, 2000, pp. 295-296). In other words, when confronted with a situation that calls for a decision we are guided by instantly experienced ‘gut-feelings’ rather than a cost/benefit analysis. The ‘gut-feeling’ is the activation of somatic markers which are linked to the affective experience as a result of previous instances when similar decisions were confronted. “The somatic marker hypothesis proposes that individuals make judgments not only by assessing the severity of the outcomes and their probability of occurrence, but also and primary in terms of their emotional quality” (Bechara, Damasio, & Damasio, 2000, p. 305).

> [Somatic markers] force attention on the negative outcome to which a given action may lead, and functions as an automated alarm signal... The signal may lead you to reject *immediately*, the negative course of action and thus make you choose among other alternatives… There is still room for using a cost/benefit analysis and proper deductive competence, but only after the automated step drastically reduces the number of options… Somatic markers probably increase the accuracy and efficiency of the decision process. (Damasio, 1994, p. 173)

For example, if one touches a hot stove he experiences intense pain and displeasure which creates a somatic marker; the next time a hot stove is approached any thoughts of touching it trigger the marker which produces the same feelings of displeasure previously experienced and therefore acts as discouragement. This applies to all instances of decision-making, and it highlights the crucial role affect plays in cognition. Indeed, some affective scientists go so far as to claim that affect is cognition (Duncan & Barrett, 2007).

3.1.3.3 Cogs

"Cogs [are] structuring circuits in the sensorimotor system, which normally functions as part of the sensorimotor operations, but whose neural connections to specific details can be inhibited, allowing them to provide inferential structure to "abstract" concepts. If all of this is correct then abstract reasoning in general *exploits* the sensorimotor system" (Gallese & Lakoff, 2005, p. 19). In other words, these cogs specify the simulations discussed in the previous section into specific relevant modalities for understanding concepts. These simulations use only the sensorimotor areas that are relevant to them even in instances where the relevance is purely conceptual. Similarly, these sensorimotor neurons inhibit activation patterns for certain details during simulation which causes a simulator to produce a generalized simulation that allows for the blurring and filtering described below.

"A reenactment never constitutes a complete reinstatement of an original modal state, and various sources of bias may often distort it" (Barsalou, 2009, p. 1282). So when a modal representation is activated cogs restrict firing to only the relevant modalities rather than all of them. "If the brain attempts to simulate a perceptual experience when representing a concept, it should typically simulate a situation, because situations are intrinsic to perception" (Barsalou, 2009, p. 1283). For example, when a chair is imagined it is recreated in whatever context is relevant to the current situation; if you are in an airport then the imagined chair is one of the seats on a plane and when you are at a bar the imagined chair is a barstool. A multimodal representation has "no existence separate from the process, but is instead embedded in, distributed across, and is thus inseparable from real time processes. From this perspective, there is not a fixed and separate representation of anything" (Barsalou, Breazeal, & Smith, 2007, p. 80). Simply put, information is not preserved in whole like a bitmapped picture, but rather it is always ready to be partially reenacted. Partial reenactments are much more economical and efficient than full reenactments which would be advantageous to the organism utilizing the representations (Yeh & Barsalou, 2006).

What all of these architectures have in common is the multimodal nature of cognition. In neural control hypotheses the perceptual, motor, and introspective modalities are linked together through neural control structures so that activity in one can affect activity in the others. The advantage to this interaction is that it eliminates the need for a central executive to direct information because the interplay between the modalities is a fundamental aspect of the actual makeup of the brain. Likewise, in simulation theories the mind is using the modalities to represent information in their original format. This removes a need for amodal representations that do not have any kind of neural correlate. Collectively, these architectures allow for the newer, grounded view of the mind featured in the next section.

3.2 Grounded Cognition

To ground cognition is to remove the unassailable mystery that surrounds it. In order to understand the concept of grounded cognition an analysis of the metaphor that is its namesake is appropriate. Grounding is a term familiar to electricians that deals with the equalization of electrons between two separate objects. Every atom by nature wants to be "full" of electrons, so much so that an atom that is missing electrons creates suction on other atoms in order to steal their loose electrons. In a thunderstorm clouds are rubbing together incessantly which results in certain clouds that have a great need for electrons. The earth has an inexhaustible supply of electrons which can easily be shared. At times the need for electrons becomes so intense in a storm cloud that the suction it produces literally rips a stream of electrons from the ground to the impoverished cloud. This is the phenomenon we call “lightning”.

In cognition the earth can be seen as biology, and the clouds can be seen as the cognitive sciences. The cognitive sciences have a great need for explanations, and biology provides a plethora of possible answers. They are separated by a seemingly unbridgeable gap in terminology and assumptions. If only the cognitive sciences could somehow reach biology then we would have a larger picture of the natural mind and, possibly, consilience of the sciences. This project, to connect the cognitive sciences to biology through sciences like neuroscience and philosophies like embodied cognition, is called “grounded cognition” (Barsalou, 2008a).

3.2.1 Embodied Cognition

“[Embodiment means] that cognition depends upon the kinds of experience that comes from having a body with various sensorimotor capacities, and these individual sensorimotor capacities are themselves embedded in a more encompassing biological, psychological, and cultural context” (Varela, Thompson, & Rosch, 1991, pp. 172-173). What this means is that the mind is a tool that certain organisms have evolved in order to negotiate their environments in goal-directed activity. It is specifically an interaction between the organism and its world, and all of its capacities are oriented as such. In other words, the mind is the way that the body engages with the environment.

This view is a hallmark for all grounded theories because of the implicit naturalism involved in placing the body in the center of our understanding cognition. We are, after all, animals and as such it would seem unnatural for our kind of mind to be altogether different than other animals. There are many different embodied theories, but for our purposes I will focus on two closely related versions: ecological and enactive cognition.

3.2.1.1 Ecological Cognition

It could be argued that embodied cognition is descended primarily from ecological psychology and Gibson's theories of direct perception (Chemero, 2009). Drawing on Dewey, Gibson (1979) asserted that there is no extra representational level between perception and action; rather perception is a form of action and action is instrumental for perception. "So we must perceive in order to move, but we must also move in order to perceive" (p. 223). When perceiving the world around us we are confronted with boundaries that constrain our actions and objects that afford different motor possibilities.

An affordance is "a specific combination of the properties of its substance and its surfaces taken with reference to an animal" (Gibson, 1977, p. 67). In other words, an affordance is the opportunity for action an object presents to a perceiving animal. According to Gibson affordances are located within the objects themselves rather than in the mind of the perceiver (Garbarini & Adenzato, 2004). "The affordance of something does not change as the need of the observer changes. An affordance is not bestowed upon an object by a need of an observer and his act of perceiving it. The object offers what it does because it is what it is" (Gibson, 1979, pp. 138-139). Perceived objects stand out precisely because they have some kind of motor possibility for goal oriented use which is instantly apparent when they are perceived.

3.2.1.2 Enactive Cognition

Enactive cognition takes ecological psychology a step further by giving perception a constitutive role in action rather than just an instrumental role. "The enactive approach consists of two points: perception consists in perceptually guided action and cognitive structures emerge from recurrent sensorimotor patterns that enable actions to be perceptually guided" (Varela, Thompson, & Rosch, 1991, p. 173). Rather than using movement in order to help perception, the very act of perceiving is constructed from action. Together action and perception are utilized in order to enact an experience and generate meaning from the world around us. As Torrance (2006) describes it,

> Minds are the possessions of embodied biological organisms viewed as autonomous – self-generating and self-maintaining – agents. In sufficiently complex organisms, these agents possess nervous systems working as organizationally closed networks, generating meaning… Cognition, conceived fundamentally as meaning-generation, arises from the sensorimotor coupling between organism and environment. The organism's world is 'enacted' or 'brought forth' by that organism's sensorimotor activity; with world and organism mutually co-determining one another… The organism's experiential awareness of its self and its world is a central feature of its lived embodiment in the world, and therefore of any science of the mind. (p. 358)

In other words, we are not passive receptacles of sensory information, but rather we are actively constructing vision (for example) using our motor and introspective systems to inform our possibilities for action and to add relevance to particular environmental features. "Sensory modalities like vision, touch, hearing, and so on are actually integrated with each other *and* with motor control and planning" (Gallese & Lakoff, 2005, p. 5). This is what it means to "generate meaning", we use our motor possibilities for action to inform our perception which are impoverished otherwise. Pure visual perception is simply a 2-dimensional blur of colors and shapes; our motor system provides the depth and contours by establishing the boundaries of our movements and the possibilities of our actions toward what the environment affords us. We 'see' with our motor systems and 'move' with our perceptual systems (Gibson, 1979; Garbarini & Adenzato, 2004). "Enaction thus characterized… states that our capacity to perceive presupposes the ability to orient in the environment… Sensorimotor activity is the capacity to master the way in which perception varies as a function of action; it is thus a skill of the whole organism, for a disembodied brain would not be able to acquire any such skill" (Columbetti, 2007, p. 530). Visually scanning a room might be likened to touching every wall and corner or leaping to touch the ceiling.

As mentioned above, there are other embodied theories that are also mostly grounded which I shall refrain from describing in detail here. Each has a number of things in common, the significance of the body being the most obvious, but differ in the details such as how embodied the mind is, what terminology to use or discard from cognitivism, and even what counts as cognition. One unifying principle is that almost all embodied theories support the dynamical systems model of cognition.

3.2.2 Dynamic Systems

Dynamic systems is a new field derived from mathematics which draws upon mathematical modeling in order to explain a variety of cognitive related phenomenon, e.g. cognitive development in infants, the movement of an organism through its environment toward its goals, as well as the complex neuronal processes in the brain (Hotton & Yoshimi, 2010). "Advocates of dynamic systems theory emphasize the interdependent relationship of elements in the brain and the interactive relations of these parts of the body and features of the world" (Bechtel, Mandik, & Mundale, 2001, p. 21). I will endeavor to explain my understanding of dynamic systems with no reference to mathematical equations or obscure terminology. Hopefully, my description will provide some philosophical insight regarding why dynamic systems theory is an important element to grounded theories of the mind. To begin I will identify three characteristics of a dynamic system:

Dynamic systems change over time (van Gelder, 1997). There it is not a static system that can be analyzed properly at any one specific time. Rather we must conceive of the system as moving and changing while negotiating its environment. The changing nature of a dynamic system is important because we as organisms are always in a state of flux and interaction with our worlds so trying to understand our minds without considering the way the environment changes them is futile.

Dynamic systems are self-organizing and self-sustaining. Essentially a dynamic system's behavior emerges from its constant need to keep itself upright and forward moving towards its goals. The classic example used for dynamic systems is the Watt's governor which has been described and discussed in great detail by Clark (1997), van Gelder (1997), Chemero (2009), and Barsalou and Prinz (2000) as well as many other supporters of grounded theories. Essentially a Watt's governor is a simple device designed to maintain a steady rate of motion using only the energy that moves it and its physical instantiation. As the energy applied increases the device itself suppresses its activity using a mechanism that exploits the devices own weight and simple physics. This process creates its behavior as an emergent property of a number of simple mechanisms acting in coordination. Similarly, the mind is composed of a number of simpler mechanisms which utilize environmental features in order to regulate itself in its environment.

Dynamic systems are embedded within other dynamic systems. Dynamic systems are engaged with other dynamic systems in its local environment. These two systems are directly coupled so that the activity of one system affects the activity in the other. This coupling produces one larger system in which both of the subordinate systems are embedded (Hotton & Yoshimi, 2010).

Collectively these three features summarize a more philosophical perspective on dynamic systems theory. To say that a system is dynamic is to say that it operates within a larger system composed of other systems. These other systems interact with the system in such a way that each system is mutually affected or perturbed (Fong, Nourbakhsh, & Dautenhahn, 2003). The dynamic system is in a constant state of reacting to this perturbing force in order to maintain itself while exerting its own perturbations on the other systems as well. For example, as organisms we are engaged in a constant struggle against our environments in order to maintain our lives. In order to survive the perturbations of hunger or danger we must strive after goals such as food or domination which requires our own perturbations toward the other organisms and toward the larger system, the environment, in which we are all embedded. There is no need for an internal executive as the behavior of each system is entrained by the behavior of the smaller systems within it and by interactions with the environment; the executive, or better, the organization or order is an emergent feature. The attractiveness of dynamic systems is that it is philosophically naturalistic, scientifically explanatory, and undeniably embodied. Because of this the basic concept of dynamic systems can be found in almost all of the grounded theories which will be discussed in the following section.

3.3 Multimodal Theories

One of the major criticisms directed at multimodal theories, embodied cognition, and dynamic systems theory is that they are primarily descriptive rather than explanatory (Chemero, 2009). In other words, these theories cannot be used to formulate experiments or predict results. It is one thing to say that the mind is like a dynamic system, but it is another thing entirely to use that description to explain how it is that we mentally re-experience past events or formulate thoughts about imaginary situations. However, a number of grounded theories have been proposed which do offer predictions and explanations for mental phenomenon.

3.3.1 Cognitive Linguistics Theories

One of the areas where grounded theories are implemented is in linguistics. Building upon the multimodal connection between action and perception, Gallese and Lakoff and asserted that "language makes direct use of the same brain structures used in perception and action" (2005, p. 19). For example, the word "grasping" is represented by a simulation in the sensorimotor areas responsible for physically grasping an object. In these theories every aspect of the mind is embodied because concepts are grounded in metaphors which are represented in the body's motor modalities. Even the tendency to categorize is an aspect of the fact that our vision recognizes distinct and separate objects (Lakoff & Johnson, 1999).

These theories offer a solution to the problem of grounding abstract concepts in the modal systems. After all, how could concepts that cannot be physically experienced, such as time or beauty for example, possibly be represented in the brain if nothing is represented in the mind that is not first represented in the senses? Abstraction is "often considered the epitome of cognition that has transcended perception" (Goldstone & Barsalou, 1998, p. 249) so it seems impossible to ground in perceptions. “The theory of embodied semantics states that concepts are represented in the brain within the same sensory-motor circuitry in which the enactment of that concept relies” (Aziz-Zadeh & Damasio, 2008, p. 35). This also applies to abstract concepts like time which is represented in the brain by the firing of the spatial motor modalities for motion and could even be generalized to concepts like beauty because, “conceptual content can come from internal states as well” (Barsalou, 2008a, p. 634).

Similarly, multimodal representations can be generalized into abstract concepts through “the “lowly process” of blurring and filtering. By blurring, [Barsalou is] referring to any process that removes detailed information from further processing. To abstract is to distill the essence from its superficial trappings. The conventional way to do this is by developing a ‘schema’ that is tuned to the essence” (Goldstone & Barsalou, 1998, p. 249). In other words we have the capacity to generalize or specify a concept into its subordinate and/or superordinate categories which, as mentioned above, are a default feature of our embodied minds. A dog, for example, can easily be generalized to an animal or specified to a poodle using processes that remove or add the particulars of a concept.

3.3.2 Cognitive Simulation Theories

3.3.2.1 Perceptual Symbol Systems

Representations have been mentioned intermittently throughout this chapter and the previous one. These are typically conceived of as sentence-like piece of information that stands in for a proposition or belief in its absence (Carruthers, 2004). They are such a powerful notion because we can phenomenologically conceptualize objects and ideas without those things being physically present. This is a challenge to grounded theories because representations are conceived by many cognitivists as amodal functional symbols used in computational processing (Machery, 2007). They are the units being manipulated in order to produce thoughts. Amodal representations are incompatible with grounded theories because one of the most important tenets of grounded cognition is that all of knowledge is ultimately experiential and therefore modal. Therefore, some grounded theories have endeavored to do away with representations altogether in order to replace them with dynamic systems explanations (van Gelder, 1997).

Other theorists would preserve the concept of representations by changing the details of their constitution. Barsalou and Prinz (2000), for example, assert that representations can be preserved if they are instead conceived of as multimodal and simultaneous. Following Bechtel (1996), they argue that classic anti-representational example of the Watt's governor could be conceived as representational because each mechanism that collectively constitutes the device could be seen as a single modality. Each modality's operation could be considered a form of minimal representation (Michael, In Press) which together create a larger multimodal representation when activated simultaneously with other minimal representations. They then generalize this representational system to the mind using simulation theory. This theory of multimodal representations is called perceptual symbol systems (PSS).

A multimodal representation is the simultaneous activation of a number of relevant sensory, motor, and introspective modalities which collectively constitute the piece of information. For example, when you imagine a dog what you are consciously experiencing are the previous sensory inputs (brown, soft, stinky, etc.), motor possibilities (petting, kicking, etc.), and introspective states (fondness, fear, etc.) that you have experienced when interacting with dogs in real time. The simultaneous firing of all these relevant modalities collectively constitutes the mental representation of the dog. In other words, knowledge of what a dog looks like, what dogs do, and what you think about a dog is literally constituted by the simulation. This simulation is incorporated into a larger simulator or concept that represents knowledge in the brain. These multimodal symbols are then manipulated in mental computations which make this theory friendly to both traditional and grounded theories of cognition (Barsalou, 1999).

3.3.2.2 Memory Theories

Another important area where simulation architecture can be consulted to explain mental phenomena is in theories regarding memories. Traditional theories of memory posit three separate memory systems which are controlled by different neural structures. The procedural memory system is unconscious and deals with performance of activities such as driving a standard where one must practice in order to learn the procedure, but once learned the performance is automatic and requires little to no attention. The semantic memory system deals with conscious knowledge of general facts about the world such as knowing that the tallest mountain in the world is Mt. Everest and where you parked your car this morning. The episodic memory system is the most explicit, and it deals with memories of past events where you actually mentally re-experience the event phenomenally (Tulving, 2002).

“Episodic memory is a recently evolved, late-developing, and early-deteriorating past-oriented memory system, more vulnerable than other memory systems to neuronal dysfunction, and probably unique to humans” (Tulving, 2002, p. 5). An episodic memory might be the specific recollection of a conversation you had with your boss yesterday or any other incident that stands out in memory. On the traditional account, these different systems are related, but they are distinct and independent from other systems within the brain. Using these memory systems we can recall past events and use those memories to predict future situations that may be similar. Then we can perform a cost-benefit analysis to guide our decisions away from possibly negative outcomes.

Alternatively, the somatic marker hypothesis mentioned above can explain memory as multimodal activations between the different systems. According to the somatic marker hypothesis, when prior affective experiences are activated by somatic markers they also trigger the perceptual experience that initially triggered them (Damasio, 1994). The more affectively infused a percept is the more salient it is in memory. For example, I associate my grandmother's apple pie with feelings of pleasure and comfort; upon smelling apple pie I might feel a sense of pleasure and comfort (Goleman, 1995). Likewise when I feel pleasure and comfort the perceptual representations for my grandmother will be primed and I am able to call her to mind with greater speed. When these simulations occur without conscious awareness and are organized sub-personally they create semantic and procedural memory. On the other hand, episodic memory is explicit in that it uses conscious mental imagery which makes it the most obviously multimodal of the three systems.

Another way to conceive of memory in a multimodal way is to think of memory as composed of episodic elements organized in conceptual frames (Conway, 2009). An episodic element is a perceptual scene that has been captured by the mind and can be remembered explicitly. It is a time-slice of visual experience stored in perceptual modalities and associated with other episodic elements temporally. A conceptual frame is "conceived of as a conceptual contextualizing knowledge that organizes either a single [episodic element] or more usually a set of [episodic elements]" (Conway, 2009, p. 2308). These are introspective modal states that activate the multimodal episodic elements that were associated with them.

3.3.3 Social Simulation Theories

A multimodal architecture can also explain social interactions between primates. Recently mirror neurons were discovered in the brains of primates; these are "individual neurons that are activated both during the execution of purposeful, goal-related actions, …and during the observation of similar actions performed by another individual" (Gallese & Lakoff, 2005, p. 8). They are conjunctive neurons that not only provide a direct link between perception and action, but they also provide a direct link between different agents which may form the basis for all of social cognition. For example, when I observe another person reaching for an object the same motor activity for reaching is simulated in my own brain. Interestingly, this activation only occurs when the observed is performing an action with a goal. In the above example, if I simply observed another person extending his arm incomprehensibly it would not activate my mirror neurons. What this indicates is that mirror neurons are specifically tailored for social cognition. Their job is to inform me of the other person's intention through associations that have been made within my own experiences.

Obviously, mirror neurons cannot act completely on their own, but the CDZ architecture proposed previously provides details of this process. Mirror neurons are a type of CDZ. "Their connections to other CDZ's and their ability to collect and distribute signals based upon learned experience allow the brain to reconstruct an action from only part of the story" (Damasio & Meyer, 2009, p. 168). In other words, when I reach for an object there are traces of the various modalities that fire during this activity which are stored in CDZ's, including the introspective aspect that deals with goal-directedness. Upon seeing another person reaching for an object the visual stimulus triggers the other conjoined modalities including the introspective aspect previously mentioned. On this view, with this simulation I can infer the others intention and understand his action in relation to it (Gallese & Lakoff, 2005).

This activity forms the basis for simulation-based theories of our theory of mind ability. When I witness another person's activity and emotional state my brain experiences a simulation similar to the activity of the observed person's actions. This informs me of their internal state which aids in my anticipation of their actions. In some versions of this theory the simulation is performed explicitly in a manner that might resemble watching a preparatory exercise. All of the activity is performed *as-if* the actual event was occurring, but instead it is a dry run in order to provide insight on the possible nuances involved. This is sometimes referred to as "higher-level" simulation (Goldman, 2006).[2] In other versions the simulation is implicit and subpersonal ("low level"). When I observe another person's actions or emotional states my brain simulates what I observe in such a way that it does not appear explicitly in phenomenal consciousness. Instead the information subtly affects me and makes the observed persons intentions immediately apparent pre-reflectively.

3.4 Summary

On the multimodal view, the mind is constituted by the interactions between a few fundamental systems. These systems are the motor, the perceptual, and the introspective modalities which collectively create all of experience. Neural control structures such as

[2] See Gallagher 2007 for critical comments

convergence/divergence zones, somatic markers, and cogs enable the coordination of the basic modalities through statistically correlated association (Damasio & Meyer, 2009; Gallese & Lakoff, 2005). The brain simulates activity in these modalities in order to create mental imagery, concepts, and memory. A simulation is a partial reenactment of a previous experience which can be drawn upon for future processing (Barsalou, 2008a).

A multimodal mind forms the basis for the new wave of cognitive science collectively called "grounded cognition". Grounded cognition draws upon neo-empiricism, embodied cognition, and dynamic systems theories to create a new description of the mind that is intimately connected to the body and world (Barsalou, 2008a). Simulation allows for an alternative explanation to how knowledge is stored in the brain. Rather than amodal representations and information being the currency of the mind, modal experiences are stored in their original format and then reactivated through statistical association. Embodied cognition provides a naturalistic description of the mind as a part of the body which is actively engaged in the world. Dynamic systems provides a model for how intelligent activity can emerge from the coordination of a number of other abilities which are designed to navigate the environment in goal-directed activity without the need for a disembodied agent outside of the system.

A variety of grounded theories already exist which provide research opportunities. Metaphors and linguistic conventions have been shown to be embodied in the brains modal systems. In this way our conceptual capacities are directly dependent upon the sensorimotor modalities that provide us with conscious experience. Representations can be explained using simulation architectures. A representation is composed of multimodal activations that have been associated and which, when reactivated, can serve as symbols in cognitive operations. Likewise, memory is created through multimodal simulation and associations. Somatic markers and introspective states provide the modal clues needed to access memories and make decisions. Finally, multimodal simulation can explain social cognition. Mirror neurons are a direct link between perception and action which aid in the identification of the intentions of others that we observe.

4.0 Competing Paradigms

The debate between modular and multimodal architectures of the mind parallels many other current topics in the cognitive sciences. Other debates such as localization versus holism, computationalism versus embodiment, rationalism versus empiricism, consilience versus disunity, and even science versus mysterianism have parallels to the conflict between modularity and multimodality in the brain. Obviously full treatments of these debates are beyond the scope of this thesis, but some aspects of these issues are implicit or in the background of our descriptions of the two sides and in any attempt to adjudicate between them. The question is whether or not one side can decidedly win the debate, and, if not, then how can reconciliation be made.

Now that both the modular and the multimodal views have been described in relative isolation to one another, we are in a position to actually compare the two side-by-side. In order to do this I will first discuss the advantages each paradigm has over the other before describing the weaknesses that have emerged as particularly salient. Then I will set out my own argument regarding which side is superior. Finally I will discuss the future relationship of these theories along with my own recommendations for improvements.

4.1 The Case for Modularity

4.1.1 Modular Advantages

4.1.1.1 Explanatory Power

The best feature of a modular theory of the brain is its explanatory power. Any difficult problem can be explained by postulating another module or functional mechanism that makes a specific kind of computation possible. For example, the supposition-generator advocated by Carruthers (2003b) is a functional mechanism that automatically creates new ideas from existing knowledge through "similarities, analogies, and past associations" (p. 510). This module is an intuitive exaptation from the language module which already uses sentence-like representations to control inner speech and cognition in general.

These modules and mechanisms can then be confirmed using evidence from clinical neuroscience, evolutionary theory, developmental psychology, and computer science. Evolutionary theory supports modularity because it is well-known that evolution works through a process of building new structures upon older existing structures. New structures have been selected for as a reaction to very specific pressures in the environments of our ancestors. The mind, in a common metaphor, is like a swiss-army knife of different tools for different tasks such as mind-reading, language, folk-biology, and sensory systems (Pinker, 1997; Tooby & Cosmides, 1992; Carruthers, 2005). In developmental psychology some evidence indicates that the brain develops in a predictable pattern based on our genetic endowment. This is taken as evidence that the various modules are forming within the brain on different schedules. In clinical neuroscience it has been observed that damage to specific parts of the brain produces selective impairments of different faculties. The standard interpretation is that specific modules have been damaged and the impairments observed are the result of malfunctioning of the modules. Finally, in computer science we have been able to reproduce computational machines that can imitate some parts of human cognition (Fong, Nourbakhsh, & Dautenhahn, 2003).

4.1.1.2 Theoretical Position

Another advantage that is often overlooked is the fact that modularity is part of the incumbent paradigm that dominates cognitive science. Whenever newcomers to the field are first introduced they are taught about cognitivism and its close relations: representationalism, computationalism, adaptationism, and modularity. Workers in the field are thus provided with the ontological framework in which all new information is interpreted. This is especially relevant in the other fields of cognitive science besides philosophy. Scientists in these fields often do not question their ontological assumptions and simply operate within the framework provided to them. On one interpretation, it is the philosopher's job to question these assumptions in an attempt to build a better description with which to interpret experimental results.

This is not a bad thing in itself as ultimately ontological commitments are necessary in order to build an epistemology, and any new paradigm seeks to replace the old ontology with its own. Due to the dominant position of the modular paradigm, the burden of proof falls upon the contender theories. Cognitivism is the current null hypothesis that any new paradigm will need to defeat. The interpretation of the brain as computer-like is even pervasive in areas outside of cognitive science such as popular culture, economics, and politics which envision the mind as seated within the body and as a detached rational decision-maker.

4.1.2 Multimodal Weaknesses

4.1.2.1 Theoretical Position

In contrast to the strengths of the modular theories, the multimodal theories have a number of weaknesses. The first and most obvious weakness was just discussed in the previous section. Multimodal theories are part of the newer paradigm of grounded cognition that seeks to usurp the well-entrenched cognitivist paradigm, and, as such, the onus is upon the contender to offer proof. One difficulty in this regard is that the language of current cognitive science does not support the emerging paradigm. In order to make sense, grounded theories need to use metaphors, appropriate what, on their view, is misleading terminology (representation and simulation for example), and struggle with what some consider to be vague phenomenological descriptions that the less philosophically inclined scientists are willing to try to understand.

4.1.2.2 Descriptive Limitations

The fact that multimodal theories are so new means that they are primarily descriptive rather than explanatory. Dynamic systems, for example, is a great description of a system in its environment, but the math is entirely too complex to actually predict the behavior of a particular system in a particular circumstance "[Dynamic systems] theories are simply too complex to be *computationally* tractable… Furthermore, the differential equations are *analytically* intractable; there is simply no way to solve them" (Chemero, 2009, p. 100). Many new theories utilizing multimodal models have been offered, but most of these theories require entirely new forms of experimentation in neuroscience that have not yet been conceived or cannot yet be performed due to technological limitations. Alas, despite all of our advancements in recording brain activity we still do not know the neural correlates of consciousness.

So far experiments are demonstrative in that they are geared toward simply showing that multimodal processing occurs. For example, canonical neurons are motor neurons which, similar to mirror neurons, activate both when an action is performed upon an object, such as a tool, and when the object is simply perceived. This is taken as evidence for simulation. These neurons, like mirror neurons, are examples of a direct link between perception and action. However, in order for these theories to be significant to the cognitive sciences, they also require experiments that are analytic. Analytic experiments use the proposed architectures to explain functions such as memory, imagery, and knowledge better than the older paradigm (Barsalou, 2008a). Unfortunately, such experiments would rely upon evidence from neuroscience, and neuroscientific evidence can be surprisingly ambiguous which qualifies their use in cognitive science. Therefore, “we must be willing to work at a theoretical level where arguments are adjudicated by the weight of evidence rather than definitive proof” (Panksepp, 2005, p. 31). In other words, until we improve our technology, or change the way we think about what counts as proof we will not be able to move past this stalemate. After all, we do observe multimodal neurons, motor command emulations, and cognitive impairments during modality switching which, if we were able to move past the old paradigm, should count as evidence of a multimodal mind.

4.1.2.3 Incomplete

Another problem facing multimodal theories of grounded cognition is that they are not yet complete. Because these theories are so recent in cognitive science, the details have not been worked out to the same degree they have been in modular theories. There are a variety of very different theories that are lumped under the name “grounded cognition” despite the fact they may disagree completely on very fundamental issues. For example, enactive cognition is typically anti-representational and anti-simulation because these processes are conceived of as extra steps that prevent direct perception (Gallese & Lakoff, 2005). Conversely, many simulation theorists insist that cognition is only partially embodied and perception has little direct role in action (Prinz, 2009; Goldman & de Vignemont, 2009).

I also have my own criticisms regarding the inconsistency of certain tenets and details of grounded theories. The introspective system, for example, has not been fleshed out sufficiently. According to Barsalou (2008a), introspections are internal states and the modalities include affect, motivation, and cognition. This is a strange description because cognition is obviously not a basic modality, but rather it is an emergent process from the activity of the basic modalities. "Cognition emerges from dependencies between all of the basic systems in the brain, including goal management, perception, action, memory, reward, affect, and learning" (Barsalou, Breazeal, & Smith, 2007, p. 79). This definition of cognition is rife with ambiguity considering Barsalou et. al.'s claim that "to understand cognition, it is essential to understand fundamental contributions from what have traditionally been viewed as non-cognitive systems" (pp. 80-81). I take this to mean that we must focus our investigation on the fundamental systems which Barsalou (2008a) insists are the motor, perceptual, and introspective modalities. Additionally, the distinction between certain "basic systems" is unclear since reward may involve affect, just as learning necessarily involves memory and even perception and action involve each other.

Also, consider the fact that Barsalou included a goal management system. This highlights my biggest problem with grounded cognition. Part of the attractiveness of the dynamic systems description is that there is no necessary executive controller. The system emerges from interactions between fundamental processes in such a way that there is no room for a meddlesome internal executive (Clark, 1997). The goal management system is one example of the subtle ontological commitments many of these theorists have that affect their theories. It is a naturally intuitive assumption that there is something like a Cartesian *res cogito* that dispassionately serves as an appraiser and decider which, ostensibly, would be the role of a goal management system. Indeed, Barsalou confirms these suspicions when he states that "executive systems are also necessary for maintaining goals in working memory, and for deciding when to pursue or drop goals" (Barsalou, Breazeal, & Smith, 2007, p. 82). Unfortunately, this executive system would be an exception to the fully integrated interaction between the organism and its environment. Such a homunculus is not subject to scientific explanation and an unnecessary addition to our ontology. In other words, in order for the mind to be truly grounded there cannot be an internal agent that is not composed of the other more basic processes.

4.2 The Multimodal Case

4.2.1 Multimodal Advantages

4.2.1.1 Ontological Commitments

The most powerful attraction of multimodal theories is the ontological assumption that underlies them. Rather than a dispassionate and detached agent taking in sensory information, processing it in hypothesized modules, and sending out motor responses, the mind and the body are conjoined so that all three of these processes are codependent for their very functioning. This has the advantage of grounding the mind in the brain which places it within a larger scientific framework. A grounded mind helps complete an elegant and parsimonious interpretation of the universe as an orderly and somewhat knowable system. The benefit of such an interpretation is that it might enable a consilience of the sciences where all of the sciences can be connected under one larger, ontologically consistent explanation.

In order to have any form of knowledge we must first make ontological assumptions, and, since the way that we know requires these assumptions, the most important ones must be taken on a sort of educated guess or faith. For example, God is an ontological assumption because the existence of such a being could never be proven. Religious people use this assumption to understand the world in an act of faith. Similarly, causation and time are ontological assumptions that are necessary for science. We cannot do science without making these assumptions about the world even if there is no way to test them. Ontology necessarily precedes epistemology although, ideally, it is updated by new information. Therefore, in order to follow a truly scientific ontology we require an explanation for the mind in which it plays a causal-yet-caused role in an unfolding universe that can be understood by us to at least some degree. By grounding knowledge in multimodal experience rather than amodal representations the mind is no longer an impersonal mental entity, but rather the mind is part of the body and the world.

4.2.1.2 Biological Plausibility

Taking it a step further, multimodal theories deal directly with the brain rather than abstract representations. This means that it is possible to actually study the mind empirically rather than indirectly through artificial intelligence and postulation. “One [of the] strengths of grounded cognition is its natural fit with the brain. Because grounded cognition rests in the modalities, knowledge of how the brain implements the modalities informs grounded cognition” (Barsalou, 2008a, p. 635). The idea that the brain processes knowledge using neuronal activity seems intuitive enough, but this idea has encountered much resistance from cognitivist theorists. These theorists insist that the brain is the ‘hardware’ which runs the ‘software’ that is the mind. By this interpretation studying the physical brain will not tell us about the mind (Pinker, 1997). Multimodal theories, on the other hand, place the brain in the center of our understanding of the mind, and recent developments in neuroscience have enabled us to study the brain like never before. Simulation and the direct relationship between perception and action are examples of interpretations stemming from research in neuroscience. Indeed, neuroscience could arguably be considered the missing link between the cognitive sciences and biology.

4.2.2 Modular Weaknesses

4.2.2.1 Unscientific

Despite the position of modular theories, they have a number of glaring problems. The first issue concerns their methodology. As noted above, an obvious strength of modular theories is the overwhelming explanatory power they have. Indeed, *anything* can be explained by simply adding new modules or systems post hoc. This strength is at the same time its weakness. To solve a problem one simply hypothesizes a module that would solve it. For example, the supposition-generator module hypothesized by Carruthers (2003b) is a system proposed for no other reasons than to fill an explanatory gap. In order for a theory to be considered scientific it must be refutable or falsifiable. The way in which we come to knowledge in modern science is through a process of testing *against* the hypothesis (Shermer, 2002). Modularity cannot be decisively disproven therefore it cannot be considered truly scientific.

The supposition-generator example also highlights another key problem. Where is this conjectured system located? Most scientists operate under the assumption that in *some* way the brain plays a role in the mind. Therefore there must be some kind of neural correlate for this activity. It is insufficient to simply state that some proposed system is in the mind; there must be some kind of explanation to back such a claim. Indeed, there are no neural correlates for any modules except the overly course-grained neural divisions recognized in the cerebral cortex for the sensory modalities and the collection of neural structures that compose the language system, both of which exhibit so much interaction with the other. Even these brain regions are not as easily distinguishable as commonly conceived because of the phenomenon of brain plasticity in which often-used cortical areas "appropriate" the neural space utilized by unused or rarely used cortical areas, and the connection between perception and action discussed in Chapter 3 (Gibson, 1979; Garbarini & Adenzato, 2004). Without identifiable neural correlates of some kind there is simply nothing tangible to study, and this ultimately makes such theorizing groundless.

4.2.2.2 Non-Ecological

Returning to the ontological issues mentioned above, modularity and cognitivism in general are not friendly to a fully dynamic conception of the mind. Modularity focuses on the detached agent, and this is something we should avoid at all costs when explaining the mind (Clark, 1997). The basic premise is almost blatantly Cartesian: the body collects impressions which are transformed into a non-material form. A homunculus then appraises these ephemeral representations and makes a rational decision before sending out motor commands to the muscles. Although many cognitivist supporters might take exception to such a description, their contentions would be based on qualifications that would not change the actual process. Even a massively modular system with no internal executive still utilizes this stepwise process which Hurley (2001) aptly called the "sandwich model" of cognition.

As mentioned above, cognitivism is in many ways antithetical to consilience of the sciences. It puts a limit upon what we can know about the mind because if the mind cannot be understood by studying the brain then the science of the mind cannot be connected to a science of the physical universe. Indeed, Fodor (2000) explicitly argues against such a consilience saying that traditionally sciences do not fit together and therefore the entire venture of trying to achieve scientific consilience is flawed. "It simply isn't true that all the sciences are mutually relevant… Quite the contrary, most sciences are quite strikingly mutually irrelevant… It's generally hard work to get theories in different sciences to bear on one another" (p. 83). He uses as an example the relationship between astrophysics and botany which he claims have no bearing on one another. Furthermore, Fodor (Fodor, 1983; Fodor, 2000) claims that the nature of the mind makes it difficult if not impossible to understand. He makes the very pessimistic assertion that, "we're currently lacking some fundamental ideas about cognition and that we're unlikely to make much progress until somebody has the fundamental ideas that we're lacking… No doubt somebody will have them sooner or later, and progress will ensue. Till then, I think we are well advised to plug on at the problems about the mind that we do know how to think about" (2000, p. 99). While most modular theorists (Pinker, 2005; Carruthers, 2003b) disagree with Fodor on these points, as evidenced by their continued investigations, this sad conclusion is not inconceivable under the cognitivist paradigm.

4.3 Choosing sides

Now that I have given both sides a thorough treatment and have compared them side-by-side, I am in a position to clarify my own position. Despite the difficulties with a multimodal mind, the ontological elegance of this grounded interpretation is decisive. I will argue that the mind is multimodal rather than modular.

4.3.1 Reasoning

The primary reason for my decision is the attractiveness of the parsimonious ontology supported by grounded theories. Obviously, such an ontology is a boon to scientific understanding of the natural world. Everything makes sense in relation to everything else, and the same laws that govern the activity of particles in the center of supermassive black holes also hold sway over the ghost electrons that are continuously popping into and out of existence. There are fixed orderly laws that govern an elegant universe. These laws may be known through careful testing and observation, and they can be manipulated in order to improve our lives through technology.

Additionally, because multimodal theories are grounded in the modalities they are grounded in the brain which can be studied through neuroscience. Being grounded in the brain makes these theories grounded in the natural world. An understanding of the mind in the natural world means that sciences that study the natural world can inform and be informed by sciences that study the mind. In this manner, consilience could (and should) be possible. After all, astrophysics does teach us about photons, and photons are the fuel for photosynthesis in plants. The more we know about photons the more we know about the metabolic processes of plants. Therefore, in a very real sense astrophysics is relevant to botany.

4.3.2 Future Considerations

4.3.2.1 Explanatory Pluralism

There is a tendency toward radicalism whenever a new theory is presented that challenges the old one. This revolutionary rhetoric, however, is often overstated (Barsalou & Prinz, 2000; Bechtel, 1996). In this debate, for example, the issue has been polarized between grounded and cognitivist conceptions of the mind. The disagreements have been heavily discussed and many advocates on both sides have taken extreme positions that necessarily exclude the others. It should be noted, however, that grounded cognition is actually the synthesis of two other preceding paradigms, behaviorism and cognitivism (Chemero, 2009). From behaviorism it draws on neo-empiricism and the direct constitutive link between perception and action. From cognitivism it draws an interest in the mental states that behaviorism lacked as well as a plethora of experimental techniques. Grounded cognition should not be seen as antithetical to cognitivism, but rather it is cognitivism's natural successor.

Upon closer examination this becomes apparent. Some of what seem to be major disagreements are not actually as major as they might seem. Often it is simply a difference in terminology that divides the two paradigms (e.g. representations, simulation, etc.). In such cases language can create oppositions where there are none. However, this kind of realization is the way of progress. For example, the description that the mind computes information is actually not wrong. No one can deny that our minds aid in negotiating the world by taking in information, processing it, and producing a phenomenological and behavioral result. The problem is simply in the description. Saying the mind computes is like saying that trees provide shade. Yes trees do provide shade; however, a better description might be that trees spread their leaves wide in order to absorb sunlight. Similarly, the mind enacts an experience is a better description than saying that it computes information because the information being processed is only one part of our engagement with the environment. Better to say that the mind generates a meaningful experience in the context of its opportunities for action in order to negotiate its environment in pursuit of its goals. Neither description is decisively incorrect; and they share the same underlying assumption that the mind can be explained without reference to the supernatural, and the same goal in trying to explain it (Fodor aside). Because of these simple disconnects in language and description I would advocate for explanatory pluralism (Dale, Dietrich, & Chemero, 2009), or at the least explanatory tolerance. For example, although we now know that perception and action are so intimately linked that the typical distinction between them is flawed, we will, nonetheless, continue to distinguish the two for heuristic purposes.

Similarly, modules are functional entities, which means that they could be interpreted as multimodal systems that are domain specific but not informationally encapsulated. By this definition the difference between the two architectures, modular and multimodal, concerns only the level of description involved. For example, when discussing complex abilities like language it is possible to group together all of the relevant modalities and simply refer to it as the language module, although a word like 'system' or 'network' might be more appropriate. Like a module, this functionally circumscribed system is domain-specific. The benefit of calling this collection of modalities a module is that it allows for communication between different cognitive scientists and philosophers and different disciplines. Terminology should not get in the way of knowledge, so allowing for flexible definitions elevates the underlying ideas above the petty squabbling regarding which word is a superior description.

4.3.2.2 Theoretical Completion

An important goal for the future of multimodal theories is to develop experiments that do more than suggest that they are correct. "Transitioning from demonstration experiments to analytic experiments is a natural trajectory in science and it will undoubtedly occur in grounded cognition" (Barsalou, 2008a, p. 635). It is one thing to show evidence that a theory might be true, but it is another thing entirely to use that theory to explain a phenomenon. In the future, the theories that I have described in the previous chapters must be utilized in analytical experiments in order for these theories to be instrumentally acceptable.

Previously I discussed the weakness of the introspective modality. This is an issue that needs to be addressed because without this important aspect of experience we have merely a very complex version of behaviorism. As I pointed out, cognition does not seem to belong in the introspective modality. Additionally, the distinction between affect and motivation seems arbitrary. One solution might be to reduce these phenomenal experiences to basic elements, or psychological primitives (Duncan & Barrett, 2007). These primitives can then be grouped together in specific combinations which, in turn, produce the phenomenal experiences of affect and motivation. Therefore, rather than natural kind emotions like anger, sadness, and fear being the fundamental units of affective experience, combinations of psychological primitives like valence, arousal, and confidence are combined into the phenomenologically experienced natural kind emotions and motivations. Furthermore, affect in general is underrepresented in our conception of the mind, but it could be the missing link that explains top-down effects in cognition. The somatic marker hypothesis discussed in the previous chapter, for example, highlights the role of affect in our normal decision-making (Damasio, 1994; Bechara, Damasio, & Damasio, 2000) which might possibly help do away with the mental homunculus – that is, the view that there is a mental agent that resides in our heads which impassively takes in sensory input and spits out motor output – altogether. Enactive cognition especially might benefit from integrating affect into the sensorimotor system on equal terms. This synthesis has been attempted by Columbetti (2007), however she proposes that affect is a product of appraisal which means it plays an instrumental role in experience. In order for affect to be enactive it must play a constitutive role in experience like the sensorimotor system.

4.4 Summary

Both paradigms have much to offer in our pursuit of a scientific explanation for the mind. Modular theories have an intuitive appeal due to their position as the dominant paradigm, and they provide powerful theories for the workings of the mind. Multimodal theories, on the other hand, are plagued by the inconsistencies and incomplete ideas that necessarily occur in new theories. Currently they are descriptive, and they could never become the dominant paradigm without analytic experiments. However, multimodal theories are friendlier to a naturalistic ontology. They could be seen as a step towards consilience of the sciences because they connect the cognitive sciences to biology through neuroscience. A lack of consilience is especially salient in the modular mind. It features a computer-like sandwich model of cognition that cannot be correlated with activity in the brain. Additionally, modular theories are not scientific because they cannot be refuted and can always be modified post hoc.

After considering both sides I have suggested that the multimodal view of the mind is superior because it is supported by neuroscience and friendly to an eventual consilience of the sciences which makes it a more fecund theory. This decision does not denigrate the modular view however. After all, most modular theorists see modules as functional rather than ontological entities (Carruthers, 2003a; Pinker, 1997). In other words, both theories are simply descriptions of mechanisms, and even multimodal theories feature functional mechanisms and systems in their classifications. I believe that over time cognitivism will be gradually phased out, but until then we should not completely discount it and “throw the baby out with the bathwater”.

In the future experimental techniques must be developed to actually utilize our multimodal understanding of the mind. Additionally, I hope to see a further fleshing out of the introspection modality which I consider incomplete. Finally, I insist that the homunculus must be exorcised completely. We have the mechanisms, descriptions, and conception of our place in the universe to remove this anachronism once and for all. The last issue once again deals with the importance of descriptions to a theory. The computer metaphor is inadequate and needs to be revised. One possible metaphor is the Watt's governor, which achieves complex behavior as an emergent property without the need for a mental homunculus and elaborates the dynamic nature of cognition. A better metaphor for a multimodal mind might be that it is like a recipe book (Barrett, 2009). It is a small collection of modalities that serve as ingredients for a variety of different results depending on how they are combined.

5.0 Conclusion

5.1 Modularity

According to modular theorists, the mind is a system of modules shaped by natural selection (Pinker, 1997; Carruthers, 2003a). Each module has its own job in information processing, cannot be interfered with by cognitive meddling, and operates quickly and automatically using algorithms that determine responses (Fodor, 1983; Prinz, 2006). Whenever sensory information arrives is gathered by sensory organs and arrives in the brain it is transduced into amodal sentence-like representations. These representations can then be used to form propositions and beliefs which further determine actions (Carruthers, 2004; Fodor, 2000; Pinker, 2005).

According to some supporters for modularity, the mind consists entirely of modules for every cognitive operation including reasoning and imagining (Pinker, 1997; Pinker, 2005). Others believe that the complexity of human cognition could not be handled by a completely modular mind and therefore insist only peripheral sensory and motor modules exist. Uniquely human abilities are handled by a central non-modular system (Fodor, 1983; Fodor, 2000). Still others prefer hybrid approaches where certain modules, language for example, are flexible enough to perform the functions that other modules cannot and can therefore function as a central, functionally non-modular, system (Carruthers, 2003a).

A variety of problems have been found with modularity by theorists such as Fodor (1983) who insist that modularity cannot account for the flexibility of human cognition, creativity, and the ability to infer to the best explanation. Other theorists such as Carruthers (2003b) have endeavored to show that these abilities can be explained using adapted modules and functional mechanisms created from other modules. Despite their differences, all of these theories collectively support modularity of the mind. Tied to modularity through a theoretical alliance are other positions such as adaptationism, computationalism, and cognitivism in general.

5.2 Multimodal

According to multimodal theories the mind is composed of the concerted activity of the basic sensory modalities. The basic modalities are the sensory modalities, the motor modalities, and the introspective modalities. Whenever sensory information is received it is constructed into an intelligible perception using information from the other modalities in addition to the sensory modalities. The motor modalities add spatial dimensions and affordances for actions to vision, and the introspection modalities add salience and significance to what is perceived. Collectively these modalities take raw sensory impressions and try to generate a meaning that fits into the context of the situation (Barsalou, 2009; Columbetti, 2007; Torrance, 2006; Varela, Thompson, & Rosch, 1991). This meaning generation is not a passive reaction to the environment, but rather it is the way that we negotiate our environments in pursuit of our goals. Rather than reacting to an experience we are enacting the experience itself.

The mind does not represent beliefs and proposition with amodal representations. Instead knowledge is represented in the brain using the same modalities that receive and construct it (Gallese & Lakoff, 2005). Whenever sensorimotor neurons are activated they store certain configurations of activation in association zones or CDZ's. Parts of these zones can be reactivated by activity similar to the original activations that were stored (Damasio & Meyer, 2009). The neurons in these zones are examples of neural control structures, or conjunctive neurons (Barsalou, 2008c), which Clark (1997) describes as internal directors whose specific job is to regulate the activity of other neurons. Other examples of conjunctive neurons are somatic markers which are CDZ's that deal with affective content and its relationship to the other modalities, and cogs which are neural control structures that selectively inhibit parts of firing patterns in order to situate cognition and produce abstract knowledge.

An important part of many multimodal theories is simulation architecture. Simulation is the activity of the brain's modalities which collectively create a modal representation (Barsalou, 2009; Barsalou, 2008a). Whenever the mind simulates it reenacts previous experiences. The simultaneous reenactment of different modalities dealing with a stimulus produces the knowledge that is a concept (Barsalou, 2008c; Gallese & Lakoff, 2005). This simulation is automatic, mostly subpersonal, and plays a constitutive role as the *stuff* of knowledge; however, visual imagery and imagination are examples of simulation that can be used instrumentally to understand ideas or plan actions (Michael, In Press). These simulations are situated according to the situation rather than fixed activation patters. "Knowledge has no existence separate from process, but is instead embedded in, distributed across, and thus inseparable from real time processes. From this perspective, there is not a fixed and separate representation of anything" (Barsalou, Breazeal, & Smith, 2007, p. 20).

There are number of seemingly disparate grounded theories. What these theories have in common is the relationship between perception and action, a rejection of cognitivism, and a desire to replace the computer metaphor with a dynamic description. There are linguistic theories that explain the very framework of thought and the ability to abstract by appealing to fully embodied metaphors that relate to our perceptions and motor possibilities (Lakoff &

Johnson, 1999; Gallese & Lakoff, 2005; Aziz-Zadeh & Damasio, 2008). There are theories of representations and memory that use simulation architecture to explain how knowledge and memory are both parts of a multimodal system (Barsalou, 2008b; Barsalou, 1999; Conway, 2009; Damasio, 1994). Finally, there are multimodal and simulation based theories that deal with social cognition and how we know other minds (Goldman, 2006; Rizzolatti & Craighero, 2004; Damasio & Meyer, 2008).

5.3 Finale

In this thesis I have endeavored to form an opinion regarding the architecture of the brain. The two options I have examined were theories featuring a mind composed of modular systems whose workings are largely independent of one another and multimodal theories wherein the mind consists of the interactions between a few basic interconnected systems composed of sensory, motor, and introspective modalities. In both cases I began by examining the proposed neural architectures that support mental modules and multimodal integration. Afterwards, I examined the underlying ontological commitments implicit in the respective paradigms that support modularity and multimodality, cognitivism and grounded cognition.

My exposition regarding modular theories of mind featured three different versions of the theory which are espoused by Fodor, Pinker, and Carruthers: peripheral systems modularity, massive modularity, and moderately massive modularity respectively. I also reviewed the self-identified problems with modularity as well as the proposed solutions to them. In my analysis of multimodal theories I discussed a variety of grounded theories that use a multimodal architecture for the brain along with neo-empiricist simulation to explain concepts, representations, memory, and social cognition.

Finally, I compared the two theories directly before advocating the multimodal architecture and providing my reasons. My decision was influenced greatest by the unscientific nature of modular theories as well as the explanatory fecundity of multimodal theories and the possibility of scientific consilience they may offer. Along with my decision came suggestions for the improvement of the theories themselves and for assimilation and eventual replacement of the cognitivist paradigm altogether.

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