

Abstract

How is the brain organized? Is the brain a general purpose machine? Or is it highly specialized? The basics of Jerry Fodor's Modularity of Mind Thesis will be discussed as well as other avenues for understanding mental structure.

The now dishonored Franz Joseph Gall (1758-1828) believed strongly in the idea that the brain has specialized structures, but he lacked the necessary technology to test this premise. He believed that the brain was not one big general-logic device. Not to be held back, Gall went about testing his thesis in the only way he thought possible - studying skull shape. Although his work is not considered to be science by most people today, he did make a necessary leap forward. The brain does in fact have many specialized structures that accomplish for us very necessary functions. The nature of these structures is presently a hot debate. The topic of discussion here will be a particular theory of structural specialization of mind known as "Modularity". Modularity of the mind as described by modern theorists is quite interesting and logical, but is not yet complete. An attempt will be made here to describe the present theory and then to propose a few additions so that mental phenomena may be more accurately explained.

In order to make sense of this discussion certain definitions are needed. The brain / mind will be made here. "Brain" will refer to physical matter (i.e. neurons, etc.), and "mind" will refer purely to thought (i.e. knowledge, computation, etc.), whether conscious or not. Taking a metaphor from Computer Science, the concepts "analog" and "digital" are also important. "Analog" will refer to quantities that modulate as continuous functions. "Digital" quantities on the other hand have discrete allowable values. These two concepts are important because the brain is primarily a collection of circuits that exhibit an analog nature, but our minds are certainly capable of simple logic which requires digital values. "Complexity" will refer to the mathematics of Complexity as it has to do with Information Theory (e.g. does a given structure have

enough Complexity to encode a specified amount of data...). “High-level” structures will refer to the greater structures of the mind - the overall architecture in gross resolution. “Low-level” structures will refer to a very small part of the mind’s architecture in relatively fine resolution. “Computation” will refer to the action of predictable processes that take input and produce output. Computation is also a transformation of data that can be modeled mathematically. Cases of mind processes that are computational but cannot be mathematically modeled are probably somewhat analog in nature or are not sufficiently understood. “Conscious guess” will refer to the conscious mind inserting a possible value into a computation. “Unconscious guess” will refer to a similar action done by a process not accessible from the conscious mind. These guesses may or may not affect the computation of other processes. The “shape” of a mental module is defined as the superposed states of all neural pathways therein. Finally, “Mind processes” will refer to any mind activity, be it modular or non-modular, “horizontal” or “vertical” (as defined in Fodor, p10-23), conscious or not.

The present understanding of Modularity (as proposed by Jerry Fodor) comprises nine basic postulates. These will be discussed here along with some amplifications. The module is basically an “organ” of the mind. Of course the analogy of module to physical body organ shouldn’t be taken very far. This is only a way of thinking that helps one comprehend concepts such as input, output, encapsulation, and autonomy. The mind may seem digital in its conclusions, but we are primarily analog. It may be that bundles of brain circuits reach a certain threshold and then the mind is able to conceive a digital quantity. Whatever the mechanics of quantitative cognition, it certainly cannot be said that the brain acts with the certainty of a computer or Turing Machine (Fodor, p36). Words like “computation”, “input”, and “output” should be taken to be inexact representations of reality. The chasm between reality and the terminology we use to describe it is of great relevance in Cognitive Science. The same phenomenon can be seen in physics. To speak of an electron as being in a given location is an extreme simplification, but such a statement is useful in certain discussions. It is closer to the truth to make a second statement: the wave function that describes an electron in free space under non-relativistic conditions is:

$$\psi(x, t) = Ae^{\frac{i}{\hbar}(px - Et)}$$

When necessary, valid conclusions can be made from this equation. When dealing with the earlier, simpler statement, one must be cautious when drawing conclusions. All statements here concerning modules should be treated with the sensitivity appropriate for a simple statement. A distinction made by Fodor that should be considered here as well is the difference between “transducers” and “input systems”. “Transducers” are the first level of perceptual information manipulation. No information is lost in this step - only rearranged. “Input systems”, on the other hand, throw away much information. Such a process can be very useful when the world around us is far more stable than the output levels of transducers (Fodor, p55-60). The modular activity discussed below will describe attributes of “input systems”, and a few output systems as well.

1. Modules are domain-specific (Fodor, p47). Each module is useful only within a specific domain. Each of the senses has a module or modules associated with it.. Modules take in data from our hearing, vision, touch, taste, and smell, and present it in a digested format to the rest of the mind. Within each of these domains are subdomains, their exact delineations always under debate. It has been theorized, for instance, that the human-facial recognition module may be used by some people to recognize automobiles. Cars can be said to fall under the same domain as faces because they are symmetrical and have facial qualities such as headlights (eyes), and a bumper (mouth). The definitions of domains and modules are separate questions, but they affect each other undeniably. Some think that there are domains of computation within the mind that are not directly associated with perception. Language is tied to perception, but is a unique case that will be treated below in greater detail.

2. The operation of modules is mandatory (Fodor, p52). That is to say that the action of a module in the presence of stimulus is insensitive to task demands (Fodor, p91). Under normal conditions, one cannot look without seeing objects in 3-D space. One cannot listen to his or her native language and only hear the sound waves that

make up speech. The language module will present parsed speech to the conscious mind. It cannot be hindered by mere choice.

3. Modules allow only limited central access to interlevels of input representation (Fodor, p55). Inevitably in any computation there are more than just the two levels of input and output. The central processes of the mind, such as consciousness, only have access to the output of a module (as a first approximation). The module can be said to be a “black-box” of sorts, or even one of Searle’s “Chinese” boxes. We do not see most of the inner workings. Such a simplification is necessary. If higher levels of mind operation had access to all the data that goes into all our modules we would never have time to think anything useful. The simple output of modules allows our consciousness to rise above the frame problem. We do in some cases have access to greater detail if it is desired. Such detail comes at the cost of speed and uses more memory resources.

4. Modules are fast (Fodor, p61). “Fast” here is meant relatively. We have a module that is able to discern low numerosities - 1, 2, and 3. The effect known as “subitizing” allows us to count 1 or 2 objects in our visual field in about 600ms. We can count 3 objects in about 700ms, while the recognition of any number that is higher than three requires two to three hundred milliseconds per unit. The graph starts off flat and slopes upward rapidly after 3 (Dehaene, p67). 700ms is considered fast when contrasted with the almost 2 seconds that someone might require to count up to 7 objects. When listening to clicks, the human ear cannot distinguish single clicks if they are played at 20 per sec, but humans can understand speech that has been sped up to 50 phonemes per second (Pinker, *Language Instinct*, p161). The sounds that make up speech must therefore be processed by a module.

5. Modules are informationally encapsulated (Fodor, p64-). This concept is contrasted with the concept of feedback. There are some examples of feedback affecting the output of modules, but most modules have a given input set that cannot be willfully changed and is not changed by the module itself except in cases of ambiguity

which will be discussed later. The input to modules can be seen to be dissociated from other input streams in certain cases of cerebral impairment. Subjects suffering from *left-neglect* (because of a specific right-hemisphere deficit) cannot see objects in their left field of vision. However, sign-language speakers who suffer this ailment can still use their left field for the purposes of signing syntax. In a similar ailment a subject is incapable of voluntary facial movement in one half of the face, yet if the subject is a sign-language speaker they can still use all their facial muscles for the purposes of signing (Jackendoff, p151). Informational encapsulation may be a key to understanding much about neural architecture in general (Fodor, p99).

6. A module is an encapsulated analyzer with shallow outputs (Fodor, p86). This is to say that modules deliver only basic categories (Fodor, p96). If one looks out a window and sees a middle-aged Canadian woman with a Rhodesian Ridgeback tied to a leash, the average person might say, "There's a woman walking a dog." One would not say, "There's a human walking an animal". It is hard to visualize just "an animal". We speak and think in so-called "Basic categories" because they are efficient and useful. When more detail is necessary we are able to access it, but not as quickly. If modules are encapsulated processors, it follows that they are limited in their possible outputs (Fodor, 91).

7. A module is associated with a fixed neural architecture (Fodor, p98). Cerebral lesions were the first evidence used to support this claim. If a module has been identified, and a subject with a specific lesion is found who exhibits an inability to use the given module, it can be said that the module incorporates at least the affected area of brain substrate. More could be involved, of course, and more cases could lead researchers to a conclusion in the future about any given specific module. One example is hemiachromatopsia. A specific lesion in one region of the right hemisphere can cause a subject to lose all color perception in their left field of vision (Hoffman, p109). The same specific relation between a mind function and brain substrate can be seen with visual processing of motion. When healthy subjects are exposed to Transcranial Magnetic Stimulation to their V5 region, they lose the ability to perceive and cognize

motion (Hoffman, p141). The magnetic fields inhibit function in that specific section. It is important to note that the correspondence may or may not go in only one direction. A module is enacted upon a fixed set of brain substrate, but it is not yet clear that any given neuron can be an element in the substrate of only one module.

8. Modules exhibit characteristic and specific breakdown patterns (Fodor, p99). This statement follows from the above examples. When the brain substrate corresponding to a module or the substrate that supports a module is injured, the function of that module is negatively affected.

9. The ontogeny of modules exhibits characteristic pace and sequencing (Fodor, p100). Each module develops according to a predictable schedule. Its original organization prescribed by genetics, each module proceeds to greater complexity as it incorporates what it learns from perceptual input. The language module will mature to its fullest extent only if it receives proper input during a critical period. Its development is surprisingly similar among subjects, and can be studied in great detail, even if each subject attains each milestone at a different rate. Many experiments on the visual systems of animals have shown that modules need input during the critical period. After that period is past, no amount of input will be incorporated by the module.

Now that the present understanding of modularity has been defined, it is worth mentioning that which is not modular. This category would obviously include all mind process which do not fulfill the above definitions. Central cognitive processes, in general, are not fast and are very accessible and consider an unlimited amount of different types of input, and are therefore not modular. Conscious guessing is not modular. Again, it is a slow process which can take into account any number of inhomogeneous factors. The brain is very efficient in its use and interaction of both encapsulated and unencapsulated systems. Both are necessary. Some mind processes fulfill some but not all parts of the above definition. These semi-modular processes will be mentioned later.

The rest of this essay is a foray into an augmented definition of the modularity of mind. Although some aspects of the following five concepts are included inherently in the writings of other theorists, they merit specific mention as being primary statements in the definition of a module.

1. Modules are computationally autonomous. Gall was the first to postulate this (Fodor, p21). Dehaene said that modularity was “The compartmentalization of mathematical knowledge within multiple partially autonomous circuits” (Dehaene, p139), and described each network of neurons as “performing its own simple, automated and independent computation” (Dehaene, p138), and that modules “function automatically, in a restricted domain, and with no particular goal in sight. Each of them merely receives information in a certain input format and transforms it into another format” (Dehaene, p202). This says, in essence, that our modules operate completely in parallel - they do not compete for resources. As with earlier statements, this is a first approximation. If we consider only those modules which are informationally mono-directional, the only two resources to consider are perceptual data and oxygenated blood. Blood is not often of great concern because brain activity causes vessel dilation. Ironically, the amount of oxygenated blood available to any given neural region relates directly to its activity. Intuition would predict the inverse, but the brain’s arterial system appears to overcompensate (Dehaene, p210). The brain consumes far more resources than the rest of the body by weight, but it’s worth it. It can be said that different modules may compete for perceptual data, such as listening to music and language simultaneously, and there are some modules that are not mono-directional (e.g. feed-forward in visual systems), but even with these complications, each module is relatively able to effectuate computation without drawing on the *computational* resources of other mind processes.

2. Modules operate serially on successive complete sets of input. It is already understood that a module receives input and produces output. It may not naturally

follow, however, that one module cannot in parallel dedicate equal resources to two dissimilar input sets. Starting with a simple example, the Koffman figure (Hoffman, p27), there are a few most probably modular systems that encode the following ideas: 1. A straight line in an image represents a straight line in 3D, 2. If the tips of two lines coincide in an image, they coincide in 3D, and the more general principle, 3. The image does not represent a unique view - that is to say that if the viewed object were moved or turned slightly in 3D space, its image would not qualitatively change except in the slight manner that would be expected (Hoffman, p27-). This statement explains why the Koffman figure is usually taken as a 2D arrangement of lines and not a cube. This complete set of input produces a 2D output from the visual modules in question. An example that differs in one minor detail is a Necker cube. We interpret it as a cube because the tips do not coincide, but more importantly we believe that it is not merely a "lucky" occurrence of lines in a plane that resembles the projection of a cube. Our inability to easily influence our mental pictures in these cases shows modular encapsulation. The Necker cube is mentioned here specifically because it can be interpreted as facing "up" or "down" (depending on which face you interpret as being closer). One can see the cube as being in one state or the other, but not both. Such action would follow naturally from this augmented understanding of modules if one includes guesses as modular inputs. Looking simultaneously at two Necker cubes one can see another interesting phenomenon: it is not natural to see the two cubes in different states of "up" or "down". They are either both up or both down. This visual example indicates that there is only one 3D module that interprets such cases and it operates serially on complete sets of input. Since the two are visually identical, they are two complete identical sets of input that produce identical outputs from the module in question.

Conscious guessing in this case can cause the cubes to flip, but they tend to flip simultaneously. One explanation of this strange dual-flipping comes from the slowness at which guesses are made, whether conscious or not. A guess acts as one input into the module (assuming that this module is not completely informationally encapsulated), and will affect the output just as any other input would. The difference is that guess-input is much slower and cannot be produced as quickly as perceptual data is received

from the transducers. When our 3D visual modules are finished processing the first cube and focus on the second cube there is no time (or perhaps no need) for a new guess to be generated. The previous understanding affects our understanding of the second cube. This same explanation can be applied to the parallel flipping of two ambiguous instances of a word within a single sentence (e.g. "Tom can drive and Mary can drive"). Additional words can dissociate the two incidences of "can", but then we are no longer waiting for input from a guess. Clarity can speed semantic parsing considerably precisely because there is less need for guessing. Another example would be the old party trick in which one attempts to rub his/her stomach in a counterclockwise circle while moving his/her foot in a clockwise one. There seems to be a modular nature to our production of circular motion. Studies on the specific neurons of monkeys in the MIT Brain and Cognitive Science department have shown that conscious production of movement has more to do with spatial coordinates than to do with the angles of our joints or actions of specific muscle groups. There could be one module for circular motion creation and it takes direction (either as clockwise/counterclockwise, or "handedness") as input, and it outputs a set of directions to our muscles to carry out in 3D-space. I witnessed this effect firsthand in high school when I learned to spin a pencil on my hand by flicking it with my thumb and middle finger. Being right-handed I practiced only with the right hand for weeks. Once I had finally reached semi-perfection I started working on the left. Although it felt less comfortable, I was successful on the first try. The learning time on my weak hand was extremely short because of the modular nature of this type of learning (physical movement). An adjunct field of research, perception of ambiguous or contradictory inputs, discovered what is known as the McGurk effect: Researchers found that dubbing a sound such as "ga" over a close-up video of a mouth saying sounds such as "va", "ba", "tha", or "da" will result in the subject hearing the sound the mouth actually made rather than the sound they heard (Pinker, *Language Instinct*, p159). The conclusion can be made that visual input effects auditory perception. When a phoneme within a recording of a word is replaced with a non-linguistic sound such as a cough the listener still hears the word in its entirety. The cough sounds as though it is only in the background (Pinker, *Language Instinct*, p184). The unconscious guess fills

in the linguistic hole and forms the output in such a way that our conscious mind cannot tell the difference. When a module does not have a complete set (as the module itself understands “complete”), it fills any hole with an unconscious guess. The same effect can be “seen” in our inability to see our retinal blind spots just over the optical nerve bundle and perhaps is why we see ghosts in the dark attic and hear monsters in the woods at night. One final example that shows the serial nature of modular processing is that of calculating. There is evidence to show that counting involves linguistic modules (having more to do with the sounds of number words than their symbolic visual representations). If modules operate serially on successive complete sets of input, then it would make sense that calculating interferes with our ability to recite the alphabet aloud. It is indeed difficult to do both at the same time.

3. Modules develop from a genetically predetermined structure of limited complexity which matures in a sufficiently rich environment. This does not mean that there is a gene or set of genes for any given module. Modules are derivative in nature. It can only be said that because of certain genetically determined factors a given brain structure is capable of maturing to the point where it acts as a module. This statement does not preclude that some people may have a “chess module”. Arguments could be made for the existence of a chess module without there being a “chess gene”. Most mind processes considered to be modules are far more mandatory than chess ever could be. Vision, for instance, gets a lot of help from its genetic design. Genetically predetermined maturation in chickens and ducks leads to a fear response from a specific shape - the simplified silhouette of a hawk. No fear response is incurred from the same shape if it’s flying in the opposite direction because in that case it resembles a Goose (Hoffman, p9). Evidence shows that these responses are not learned. This is deeply perplexing because there are countless ways to interpret the light levels that reach our retinas (Hoffman, p13). Computer vision designers were among the first to conclude that our visual modules make many important assumptions in order to be able to see as well as we do. Similar problems are faced and easily overcome by children learning to speak. Mathematically there are many more ways to understand language than children actually consider. Children learn to speak with relative fluency long before they’ve

heard enough to make mathematically defensible conclusions about their grammar. We say they are fluent because they speak like us. Their brains were inclined to ignore the vast majority of possibilities, as were our brains at the same age. There are only so many ways the module can mature and these possible “shapes” are often referred to as Universal Grammar (UG) (Chomsky, p19-). Although the topic of UG is indeed useful in many contexts, it should be remembered that UG is only a derivative concept. There is no brain that exhibits all of UG in maturity. It is a collection of possible states. It should be treated as E-language (External language - the disembodied collection of grammatical concepts commonly utilized within an ideal speech community) is treated, “[E-language] is now regarded as an epiphenomenon at best. Its status is similar to that of other derivative objects” (Chomsky, p25). A possible understanding of Plato’s problem of poverty of stimulus comes naturally from this augmented definition of modules. Information theory would say that within any given physically fixed set of neurological substrate there exists an upper limit on its realizable complexity - entropy cannot decrease forever. The representation of digital information upon an analog structure implies bundles of analog circuits dedicated to each digital value with its digital quality being expressed through a threshold. The total number of bundles can only be divided so many times. Any given module therefore has limited learning capabilities. It would follow then that those concepts which are not exhibited in UG represent patterns of neural pathways which are not physically possible. It could be said that these “shapes” are not possible results of maturation. Even Plato, in the example where he taught Meno, knew that we have something inside is already. None of us is a *tabula rasa*. Jerry Fodor claims that Chomsky considers innate intelligence to come in the form of knowledge which interacts computationally with perceptual data, but “knowledge” may be too strong a word. The fact that certain shapes are not realizable by maturing modules implicitly prunes the tree of mathematical possibilities.

4. A module is accessible by a limited number of mind processes. This statement refers both to input and output. Any given module can only accept input from a limited number of sources and its output is readable by a limited number of processes. The input modules as described by Fodor have only perceptual transducers

for input (along with a few exceptions for feedback), and their output is available to the conscious mind. There is some evidence that visual data may influence auditory perception (such as locating an unfamiliar sound - Mere geometry allows the source of any perceived sound to lie anywhere on a circle in space), but this influence could come just as easily from the conscious mind instead of directly from the visual modules. Limited inputs and outputs are part of what makes modules fast. They neither consider all possibilities nor communicate in a way that any mind process can understand (physical connection may be more of a factor in this matter than so-called “language of thought”). Computer models of thought have brought many of these ideas to light, but such models are insufficient in many ways (Fodor, p36). When biological restraints are cast aside there can be too much freedom. The conclusions drawn from such systems may help determine an upper limit on the ability to process information, but do not help much in understanding exactly how our mind works.

5. The location of a module as a node within high-level mind architecture is determined by genetics and maturation. When describing the mind the logical location of each function is more important than the physical location of each corresponding set of brain substrate. The logical location of a module determines its inputs and outputs. One function of Wernicke’s area is to look up words and funnel them to other areas. Whether or not Wernicke’s area represents a module will not be argued here, only that it represents a mind process enacted upon a specific substrate which relies on its genetically predetermined and maturationally developed location within overall mind architecture. This process would seem to adhere to some if not all parts of the definition of a module. The high level structure of the mind is not as plastic as other mind qualities, but there is some limited plasticity. Such plasticity is not consistent in all subjects and appears to be dependent on genetics. Left-handers and right-handers who are related to left-handers have a higher probability of recovering from certain aphasias (Jackendoff, p152). This data is applicable here only if the described recovery involves rerouting high-level pathways. This line of research should prove enlightening in the future.

Also worth mentioning here are some semi-modular activities of the mind. Perhaps this is where the playing chess and other learned abilities fit in the picture. Such processes may be relatively fast but not as fast as perceptual modules. Within the overall mind they might be relatively encapsulated and computationally autonomous. Perhaps such semi-modules are enacted upon substrate that would otherwise have been dedicated to general logic. Brain usage or lack thereof affects the strength of synapses. Constant use over time may transform such brain sections to be effectively like the substrate of a module, and therefore act more like a module on the mind level. Another semi-module could be emotions. “The amygdala ... receives not just simple signals ... but abstract, complex information from the brain’s highest centers. The amygdala in turn sends signals to virtually every other part of the brain, including the decision-making circuitry of the frontal lobes” (Pinker, *How the Mind Works*, p371,2). Though the emotional semi-module is not limited communication-wise as are other modules, it does seem to be a unique mind process that produces a useful simplified output that takes into account more variables than perhaps any other mind process.

In conclusion, this augmented definition of the modularity of mind leads to many implications. When more is known, predictions can be made, for example, about how modular complexity in the modules that govern linguistic grammar “switches” may impact second language acquisition. Perhaps the first language’s switches will prove stronger and bleed into a subject’s use of their second language. Perhaps their connections to second language words are slower because Wernicke’s area is already matured in compliance with the native language. Whatever the case may be, if the above definitions prove to be true, researchers would be able to ask a whole slew of new questions. Questions are at the heart of any scientific advancement. If Sir Isaac Newton had never asked why the apple fell from the tree, would we know about gravity? He did ask that question, and perhaps it corresponded to a bump on his head.

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