

Theoretical Arguments for and Against Massive Modularity -- Review of Buller, David J., *Adapting Minds*, The MIT Press, Cambridge (Massachusetts), London (England), 2005.

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Introduction

In chapter 4 of his book, **Adapting Minds**, David Buller argues against Evolutionary Psychology's Massive Modularity thesis. In the first section of this chapter Buller focuses his attack on the theoretical arguments for massive modularity, while in the the second part he focuses on the empirical evidence for the theory. In this paper we will discuss the *first* section of the chapter; the theoretical arguments for massive modularity and Buller's proposed alternative.

Massive Modularity

Massive Modularity (hereafter referred to as MM) is the thesis that the human brain is largely composed of evolved psychological mechanisms a.k.a. *modules* that are **a)** computational in nature and **b)** are adaptations shaped by natural selection to be ready-equipped, at birth, with innate knowledge of specific problem domains consisting of domain specific bodies of data. The modules are moreover, informationally isolated so that in general each module cannot “see” the data inside another module, nor is any one module equipped with any innate knowledge of the domains acted upon by other modules.

An example of a module is Vision. We have an area of our brain dedicated specifically to processing data that is input via the sensory receptors in our eyes. We do not need to learn how to see since this module is more or less fully functional at birth, or at least only very shortly after. In other words it is equipped with innate knowledge of the problem domain. The vision module responds *only* to light waves of a certain frequency (approx. 10^{11} to 10^{15} Hz), which are its domain specific body of data. Vision, moreover is unaffected by our beliefs or our desires or our emotions or what we know about the world through our other senses or what we know about the world through other means; vision is informationally isolated, that is. Optical illusions confirm this. E.g. even though I know the road doesn't actually taper off to a point somewhere in the distance, the fact that I know this doesn't affect the fact that this is what I see, and I have no way of telling my vision module to see something else.

We can argue along similar lines for each of the five senses and denote different modules for

each of them. Proponents of Evolutionary Psychology (hereafter referred to as EP), however, believe there are more modules than just these ones. For EP, our brains are *massively* modular. We have modules for language, spatial reorientation, cheater detection, theory of mind, and so on; literally hundreds, if not thousands of modules in the mind.

This stands in contrast to the traditional empiricist view of the mind; that the mind consists of a blank slate and a few general rules for organising the data that comes to us through the senses and for “writing it down”, to use a crude analogy. On the traditional empiricist view, all of our knowledge is learned from experience and none of our knowledge (save for the few general rules mentioned above) is innate.

Arguments For MM

The evolutionary psychologists Leda Cosmides and John Tooby give three arguments in favour of MM and against the blank slate.¹² First: “For a domain-general system to learn what to do, it must have some criterion of success and failure; trial and error learning requires some definition of error. But there is no domain independent criterion of success or failure that is correlated with fitness. This is because what counts as fit behaviour differs markedly from domain to domain.”

E.g., to procreate we must have sexual intercourse, thus sexual intercourse is vital to our fitness. But from that it doesn't follow that it is context independent. Sexual intercourse with siblings, for example is not likely to increase fitness – in fact incest has a fitness cost. Likewise it would not increase fitness to have sexual intercourse in the middle of a busy highway. Still it's not clear why a domain general mechanism couldn't do something along these lines:

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if (object is your sibling) then
    don't have sex;
else if (speeding truck is bearing down on you) then
    don't have sex;
else if (object is a lion) then
    don't have sex;
else if (object is a lion and there is a truck bearing down on you) then
    don't have sex;
else if (...) then
    ...
else if (...) then
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¹ Cosmides and Tooby, pp. 91-94

² In the discussion that follows note that I am presenting these arguments in a different order from the way they are given in Cosmides and Tooby, in a way I think flows more smoothly from one to the next.

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...
else
    have sex;
end if

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This brings us to the next argument for MM¹ : “A domain general evolved architecture is defined by what it lacks; it lacks any content, either in the form of domain specific knowledge or domain specific procedures ... a domain general system must evaluate all alternatives it can define.”

Now the more complex the problem the more potential alternatives there are. To take a simple example, the number of distinct combinations in the truth table for a logical expression in sentential logic is 2^X , where X is the number of elementary propositions. As we add propositions this number gets very large, until e.g. with thirty-two propositions we have $2^{32} = 4,294,967,296$ different alternatives to consider. Since the mind is domain *general*, it cannot pick just a subset of all its inputs and evaluate these in isolation; since every piece of knowledge has the potential of bearing on every other piece, it must consider *everything it knows* even to solve the simplest, most constrained problems, and due to combinatorial explosion it is unlikely a domain general mind could solve problems fast enough to be adaptive.

But even if a domain general mechanism *could* do this fast enough, it's impossible for it even to get all of the data it needs to perform its' computations. The reason being that for a blank slate, all knowledge must be derived through learning from experience, and as Cosmides and Tooby put it²: “Many relationships necessary to the successful regulation of action cannot be observed by any individual during his or her lifetime ... Adaptive courses of action can be neither deduced nor learned by general criteria alone because they depend on statistical relationships between features of the environment, behaviour, and fitness that emerge over many generations and are, therefore, often not observable during a single lifetime.” Natural selection, however, can “observe” these relationships over many generations, and then design specific mechanisms to solve these problems, in the form of domain specific modules specialized for specific problem domains.

Neuro-plasticity

Cosmides' and Tooby's argument for MM, then, is essentially that it's extremely unlikely that a

¹ Actually Cosmides' and Tooby's third listed argument

² Their second argument listed

domain general mind could work at all much less evolve under selection pressure, therefore the only alternative is MM. To answer this Buller must take up the challenge posed by EP that a domain general mind could not have evolved by actually describing one that *could have* evolved. Along the way he will try to show not only that his account is more explanatory than MM, but that MM is in fact implausible as a theory.

Buller begins the discussion by pointing out what he sees as a problem with EP's account of how modules historically proliferated in the brain. According to EP, each module was at some point in our history added to the mind and then subsequently shaped by selection into its present form. Buller says, and EP agrees, that since modules are very complex, a single gene mutation isn't likely to be enough to add more than one module to the mind. Rather we should expect that there would be *at least one* gene for every module; likely very many more. But a very significant proportion of our genes are dedicated to building our sensory receptors. “fully 4 percent of the genes involved in brain development are concerned with building the sensory cells inside the nose. We can assume that roughly as many are concerned with building sensory cells in our ears and on our tongues, but that many more are involved in building the cells in our far more complex eyes and all the sensory cells in our skin.”¹

Now if all of these genes are dedicated to something *as simple* as sense perception, imagine how many must be dedicated to our *higher* cognitive powers. And if we add up all the brain cells we need for our thousands of modules we quickly use up our supply. Buller concludes that there simply is no correlation whatsoever between number of genes and brain complexity, and to illustrate this he gives the example of the house mouse which has just as many genes, if not more than we humans, but no “higher cognitive powers”.

But it isn't clear why his statement: “our sensory receptors are surely less complex than the brain systems devoted to higher cognitive functions.”² should be true. Buller doesn't actually specify what he means by “higher” here. He does seem to be distinguishing, however, between these “higher” functions and the more mundane sensory systems. So I suppose we can make for ourselves a working definition of “higher” as something “more central” or “inner” to the brain as opposed to something peripheral like a

¹ Buller, pp. 130

² Buller, pp. 130

sensory system. By “central” I mean some part of the brain that is not *directly* dependent on any sensory stimuli. But just because something is “higher” in this way does not entail its construction is more complex. Rather, in this case at least, it seems to me that the opposite must be true; for our sensory systems must take in information from the highly variable, rarely predictable *outside world*, whereas our “higher cognitive powers” take as their input stuff that comes from *inside* the mind. I am not saying that the inside of the mind is less complex in a *functional* sense than our sensory organs. What I am saying is that in the case of our “inner modules” there is no need to *translate* external inputs into the “0s and 1s” that the mind uses to communicate internally, hence much of the complexity that is needed to perform this translation in our sensory modules is not needed in our inner modules. So even though each of EP’s proposed higher modules operate on domain specific data and are informationally isolated, presumably they at least *speak the same language*, since they must be able to communicate with each other somehow, and speaking the same language simplifies the interfaces quite a bit I would imagine. So it’s certainly plausible that we don’t need quite so many genes as Buller thinks we do to account for higher cognitive function, and I don’t see it as a problem for MM if our sensory systems are specified by a significant number or even the majority of our genes.

This is analogous to the case with computers. The input to a computer program is usually alphabetic characters, e.g. ASCII (though it could in principle be anything: sounds, images, etc.). Inside the computer itself information is represented simply in binary. It takes quite a bit of complexity to do this translation, and whole devices such as keyboards, mice, digital cameras, etc. along with their drivers (software that interfaces the device with the computer’s operating system) are dedicated to facilitating this task (device drivers, in particular are notoriously hard to program). Once the input is received, however, the relative complexity of the hardware and software required to process the information is much lower, and interfaces between internal components such as main memory and the CPU are much simpler (typically just a bus).

But let’s move on. Since Buller rejects the view that our brains might be genetically specified, he must account for our brain structure in some other way, so to start with he divides the brain into two main subdivisions: the ventricular zone which includes the limbic system and midbrain, and the

neocortex (the subventricular zone), which carries out higher cognitive function. A problem with this division is that Buller lumps the midbrain and the limbic system together into the same category (the ventricular zone), but this is misleading. The midbrain *is* a part of the ventricular system. But the limbic system *is not*. Like the neocortex, it constitutes a part of the *cerebral cortex*. Perhaps Buller's confusion stems from the fact that the limbic system is *located* close to the brain stem and ventricular system, probably owing to the fact that it is the evolutionarily oldest part of the cortex. But Buller sometimes speaks as though the cerebral cortex (minus the limbic system) and the neocortex are one and the same thing, and this is just not the case. The neocortex is the grey matter surrounding the cerebral cortex. This is hardly the whole cortex.

But to move on, in the midbrain and limbic system, Buller states: “cell production ... builds brain structures by adding cells to already existing layers of cells, in much the way that other parts or organs of the body are formed.”¹ Since this is the case, Buller sees no reason to doubt that this part of the brain is under “very rigid genetic control.” But for the neocortex, cell production follows a different method: “cells produced in the subventricular zone ... must actively *migrate* to their final destinations in the brain, wending their way through a thicket of other cells. Once they reach their final destinations, they grow branching axons that form connections with other cells.”² This process is also under strict genetic control, since the major brain structures in the neocortex are the same for all people no matter what their environment. What's *not* under genetic control, says Buller, is the subsequent *fine-grained* brain development. As the neocortex is developing, many neurons *compete* for control over connections to, for example, muscle fibres. So in a young brain many motor neurons may be connected to one particular muscle fibre, and as the brain develops, the weaker connections eventually break and the isolated neurons die. So the brain overproduces neurons (an additive process) which are then selectively eliminated (a *subtractive* process). It's analogous to a potter heaving a hunk of clay onto his potter's wheel and then shaping the clay with his hands into a salad bowl or a cup.

Now there are two factors that help decide which cells win the competition: environmental stimuli and spontaneous neural firings internal to the brain. To Buller, environmental stimuli are

¹ Buller, pp. 131

² Buller, pp. 132

primary, since even for parts of the brain that are not directly connected to the senses, their connections eventually lead there and so environmental stimuli have an effect on them too. He says: “In short, environmental inputs to the brain shape the more fine-grained cortical structures by determining the outcome of cell competition.”¹ But this is too strong. All he's really shown so far is that environmental stimuli have *some* causal role in shaping our cortical structures. It's a little bit of a jump to go from there to saying that they *determine* the outcome of cell competition, as though they were the *only* relevant factor. It's obvious that the environment plays a role in brain development; EP admits as much. The argument is over *how much* of a role environmental stimuli have in brain development. And the amount of innate knowledge we have encoded in our brain structures will help answer this question.

So to summarize Buller's view, gene expression determines the raw material that makes up the coarse-grained brain structures, which then are *shaped* by cell competition, which is driven by the environment, into finer-grained structures or modules. He calls this process “proliferate and prune.” And the process does not stop after childhood, but continues (though perhaps at a lesser rate) throughout later life.

Now since the modules don't have any innate structure, but instead are shaped by the environment in an ongoing process, it entails that different regions of the brain should be able to take on different functions at different times; in Buller's words, an *Adapting* mind, not an *Adapted* one.

And this is what we actually see, according to Buller. He gives several examples: “If a finger is lost, the cortical region that used to respond to its input will decrease in size and the neighbouring regions will expand until nothing is left of the functional brain area at all. The converse is true as well. If a digit is overstimulated for a while, its corresponding area in the cortex increases in size. ... Indeed, it appears that our brains change enough over our lifetimes that, by the time we are old, we use regions in our brains that are different from the ones we used as young adults to accomplish the same tasks.”² Other examples he cites are: severing the medial nerve of the hand, phantom limbs, how our brains deal with vestibular disturbances, cross-modal connections between sight and smell, and between sight and speech.

1 Buller, pp. 133

2 Buller, pp. 137-138

So here is a model of mind that has some of the characteristics of empiricism's blank slate, while at the same time accounting for some form of modularity, though Buller's version of modularity is different from EP's version; Buller's modules are not fully informationally isolated or domain specific. Buller says, in fact that his modules are not domain specific but domain *dominant*. I.e. each module does one thing *primarily*, however it does do other things at the same time (due to the cross-modal connections), and moreover can switch to doing one of these other things primarily if the need arises. So the blank slate is the initial overproduction of neurons, of which those with the strongest connections are selected for to form functional modules. The modules are determined by the environment and they are not static, but dynamic, or *plastic*, and can change as the environment changes, taking on new functions or ceasing old ones. He uses the immune system as an analogy¹. The immune system itself is not adapted to any particular pathogen, however it is adapted to be *adaptive* enough to create different antibodies for different pathogens on demand.

And with his model Buller is able to meet Cosmides and Tooby's objections to domain generality. He defeats the domain-dependence and combinatorial explosion objections since even though his model is domain general in one sense it is modular in another and therefore it can deal with domain specific problems in the same way that MM can. His modules are less informationally isolated than EP's modules, but they are isolated enough to avoid combinatorial explosion. All that remains is the last objection, that a domain general mind cannot have innate knowledge and cannot learn everything it needs to know to solve any particular adaptive problem in only one lifetime.

For this last objection, Buller does not really need to answer it, since there is no necessary relationship between domain generality and lack of innate knowledge, so it is a straw man anyway. And he does in fact allow for some innate knowledge. He admits, albeit a little reluctantly, that we must have innate knowledge of language. But for most other knowledge, e.g. face recognition, we can get away with initial biases. Sort of like innate "clues" about what we should be paying attention to, or nudges in the right direction.

But for all of this Buller doesn't deny that *some* of our behaviours do have their origins in the

¹ Buller, pp. 140

evolutionarily older parts of the brain (the limbic system to be precise), and thus would be under stricter genetic control than behaviours originating in the neocortex. Certain sexual and emotional responses, he admits, might be adaptations. However it wouldn't follow that our *higher* cognitive functions are. “certain sexual and emotional responses may be more like the liver or the kidneys than like antibodies, the result of selection's having acted on genetic differences between individuals ... Consequently Evolutionary Psychologists may be right about some of our more basic emotional adaptations, but nonetheless wrong in its claims that we possess a lot of *cognitive* adaptations devoted to very specific forms of problem solving.”¹

But this seems like quite an odd statement to make. Most of EP's proposed modules have to do with exactly these types of behaviours, i.e. *emotions and sexual responses*. Even for something like “cheater detection”, how we *feel* about situations has a lot to do with how we *behave* when we are faced with them (Just saying the word “cheater” arouses certain emotions in us). Evolutionarily Psychologists readily admit that we don't *think* about cheater detection. In fact this is exactly what they are trying to show when they say it is a module. It's not that we have some module that is adapted to *think* a certain way; this is *not* what EP is saying at all. EP tries to explain our *behaviours*, not our *thoughts*, and behaviours are directly or indirectly influenced by *emotion*, which originates in or is at least directly influenced by the *limbic system*, which is under *strict genetic control*. This point is driven home if we take a moment to survey some of the functions the limbic system actually performs in the brain²:

“The limbic system includes many different cortical and subcortical brain structures that differ depending upon which book is referenced. For ease of interpretation, this is a list of all the regions generally considered to be part of the limbic system:

- *Amygdala: Involved in **aggression and fear**;*
- *Cingulate gyrus: Autonomic functions regulating heart rate and blood pressure as well as **cognitive and attentional processing**;*
- *Fornicate gyrus: Region encompassing the cingulate, hippocampus, and parahippocampal gyrus;*
- *Hippocampus: Required for the formation of **long-term memories**;*
- *Hypothalamus: Regulates the autonomic nervous system via hormone production and release. Affects and regulates blood pressure, heart rate, hunger, thirst, **sexual arousal**, and the sleep/wake cycle;*
- *Mammillary body: Important for the **formation of memory**;*
- *Nucleus accumbens: Involved in **reward, pleasure, and addiction**;*

¹ Buller, pp. 142-143

² Source: Wikipedia (https://en.wikipedia.org/w/index.php?title=Limbic_system&direction=next&oldid=35732411), emphasis added

- *Orbitofrontal cortex*: Required for **decision making**;
- *Parahippocampal gyrus*: Plays a role in the formation of **spatial memory**.”

On the other hand, Buller's examples of plasticity in the neocortex: losing a finger, severing the medial nerve of the hand, phantom limbs, vestibular disturbances, all have to do with mechanisms that receive and process *sensory inputs*. And as I argued earlier, it is plausible that hardware mechanisms designed to deal with sensory data are *more* complex, not less, than those that are not, and perhaps plasticity evolved as an answer to the variable, unpredictable nature of the sensory data which we receive through our senses. And yet the more “primitive” *inner* parts of our brains, the parts of the mind that EP is actually *concerned with*, would still be genetically determined. I see no reason why this could not be the case.

Before ending this chapter, Buller makes one last theoretical argument against MM. He attributes this argument to Jerry Fodor¹ and it is known as the *input problem*. Suppose we have two modules, M1 and M2; each of which is (only) activated by the inputs: P1 and P2, respectively. Question: what is the procedure that *assigns* the inputs to M1 and M2? Is it domain general? If yes then this undermines MM. If no, then it must be yet another module. But what procedure assigns inputs to *that* module? If we continue down this road it leads to infinite regress. Hence there must be a domain general mechanism at some point down the line, and MM can't be correct.

Murray Clarke, in his book *Reconstructing Reason and Representation*, has what I believe to be the correct answer to the problem²: “If there is a cheater detection module, then thought, conscious or not, is not required, because the module is triggered *automatically* by the contextual cues in the environment.” (emphasis added). However Clarke doesn't specify *how* the module would be “automatically” triggered. Fodor or Buller could quite reasonably answer in fact that this is exactly their point; you can't specify *how* it would be done because there is no way it could be done short of having some domain general mechanism to “sort out” the environmental cues.

Perhaps we can shed some light on the issue by considering an everyday example. Consider a cocktail party³ where many of the guests are of different nationalities, so that each and every

¹ Fodor, pp. 71-78

² Clarke, pp. 22-25

³ Source: Phoneyworld.com (<https://web.archive.org/web/20050907153439/http://www.phoneyworld.com/technology/>)

conversation in the room is being carried out in a different language. You open the door to enter the room, and all you hear is *noise*. As you walk further into the room, however, you pick out a couple who are speaking english. This is something you understand! You approach them and join the conversation.

There is no domain general mechanism assigning inputs to you here; no hostess to lead you to the right conversation; rather, you have picked out something in the morass *that you can understand* and have keyed in on it. More significantly, you *still hear each and every one* of the other conversations going on in the room, but since you can't understand them; they become background noise; you can just discard these inputs altogether. This is no mere thought experiment. This is the way things are actually done in radio communications. To save bandwidth, a technique called *multiplexing* is often used; where many radio signals, each intended for a different recipient, *are combined into one* more complex signal. At the receiving end, the receiver must have some way of separating out the signal intended for itself from the others, even though it “hears” everything simultaneously. In one multiplexing technique (Code Division Multiple Access or CDMA), a distinct *code* for each intended receiver is generated and applied to each signal. The signals are then combined (i.e. multiplexed) and then transmitted together. At the receiving end, the receiver de-multiplexes the signals and applies its own code to all of the signals it receives; at the end of this process only one signal is intelligible; the others remain as noise and are ignored, as in our cocktail party example. I see no reason why our modules could not work in a similar fashion, if data from our senses were combined or multiplexed in the brain in this way before being given to the modules. Such a process would be simply additive and would not need to be very complex. There would be no need for a domain general mechanism to separate or “hand out the inputs”, to the modules, so to speak.

But if this multiplexer is adding codes to the data in order to direct it to specific modules, isn't this just the same as a domain general process differentiating the inputs? No. The multiplexer's job is not to encode the inputs. It simply combines them. The codes are applied *before* this step. In the case of the brain, the codes would be *in the environment*. Similarly for the de-multiplexer, which is located in the receiver, or in our case the *module*. It does not need to know any of the codes. It just has to de-

combine the signals by the same simple rule that was used to combine them. Even after de-multiplexing, none of the signals has any meaning yet. It is only after applying its code to each of the signals in turn that the module is able to pick out the one that it can understand. None of this to say that this is actually the correct model of how MM works, rather I am simply showing that it is *possible* for a module to be triggered, to use Clarke's words: “automatically by the contextual cues in the environment.”¹, and here is one way it could be done.

But what if it's not clear what the environmental signs are that a module needs to key in on to become activated? Buller gives the female mate-preference module² as an example. EP proposes there is a module in females designed to produce attraction to high status males. But high status is very variable across cultures, “the range of things that can bring status in different cultures and subcultures is astonishing. making beads, making music, delivering sermons, delivering babies ...” But since signs of status are so variable, it should be difficult for a module to pick them out, thus we should need some domain general mechanism to combine knowledge from say, the “religion domain”, or the “obstetric domain” to determine who is the best preacher or best baby deliverer. And if a domain general mechanism can do this, why do we need the modules “to do the easy jobs after a domain general mechanism has done the hard jobs.” ?

But this is not an *in principle* problem. As long as we can find some signs that are consistent and detectable even in the context of differences in culture, then we can dispense with the domain general mechanism since a module could have adapted to key in on just these signs. Granted this is difficult, but just because it's difficult doesn't mean it isn't possible. Strangely, Buller himself mentions one such sign that might arguably might signify high status males, in the very next chapter of his book. Quoting Bruce Ellis, he writes, “In general, the higher a male is in status, ... the greater his ability to control resources across many situations ...”³. This would be true for our bead-maker, our musician, our minister, and our obstetrician.

Conclusion

¹ Clarke, pp. 25

² Buller, pp. 159

³ Buller, pp. 206

Buller has not succeeded in showing MM to be fatally flawed, and I think it's clear from the discussion above that this is so. Nevertheless, he has succeeded in presenting an alternative domain general account of mind that is able to answer the objections Cosmides and Tooby give against such a mechanism. Even given the problems that we were able to point out in his account, it's still possible that he is least partly right about how brain processes work; the jury is still out on exactly which cognitive functions belong to which parts of the brain. That said I think I have made it clear that MM is still the more plausible account.

EP's a priori arguments against domain generality are weak; and the proof of this is that even this problematic hypothesis of Buller's can knock them down so easily. Unless EP can think of any better theoretical arguments in favour of MM, we will have to satisfy ourselves with judging its merits based on the empirical evidence. Unfortunately that is beyond the scope of this paper.

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