January 2004

A Lego Model of the Modularity of the Mind

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Abstract. In this paper I propose that the dominant form of evolutionary psychology (which I term "cognitive adaptationism") can be improved by adopting an alternative version of the concept of mental modularity. I suggest a metaphor of mental modules as Lego blocks. The Lego blocks represent a relatively small set of elementary operations that the mind/brain can carry out. These Lego blocks are repeatedly assembled in different ways to execute a wide variety of different functions. These repeated assemblies correspond more closely to the things that cognitive adaptationists have asserted are modules. Arguments in favor of the Lego model include the fact that the localized neural systems identified in the brain appear to carry out elementary operations, rather than higher-level functions, and the fact that evolution by natural selection occurs by the gradual modification of small-level features.

Keywords: evolutionary psychology, modularity, cognitive architecture, elementary operations

The term "Evolutionary Psychology" has been used for over 100 years (e.g., STANLEY 1895) to refer to the Darwinian approach to mental and behavioral phenomena. Since the mid-1980's (TOOBY 1988), however, a group of scholars have claimed this term to refer exclusively to a very specific approach to the evolutionary study of psychology. These "self-proclaimed 'evolutionary psychologists'" (GOULD 2002, p. 1264) meld the cognitive/computational perspective of psychology with the neo-Darwinian/adaptationist perspective on evolutionary biology to produce a set of metatheoretical assumptions or guiding principles for the search for current psychological mechanisms and their evolutionary origins.

This cognitive-adaptationist approach to evolutionary psychology, however, is not the only on-going application of Darwinian ideas to the study of psychological function. A growing chorus of voices seeks to retain the term "evolutionary psychology" for the general project of studying psychology evolutionarily (e.g., CAPORAEL 2001; HEYES 2000; MOORE and MICHEL 1998).

RAUSCHER and SCHER (2003) have pointed out that alternative approaches to evolutionary psychology can be classified or developed by altering or rejecting one or more of the metatheoretical assumptions of cognitive adaptationsim. In the current paper, I will sketch an alternate concept of modularity (the Lego model), and will argue that this alternate view of modularity is more consistent with what we know about the physical nature of the brain and is also more consistent with the complex nature of evolution than is the cognitive-adaptationist approach to modularity.

WHAT IS COGNITIVE ADAPTATIONISM?

Proponents of the cognitive-adaptationist approach to psychology2 (e.g., BUSS 1995, 2004; COSMIDES and TOOBY 1997; DENNETT 1995; PINKER 1997, 2002; TOOBY and COSMIDES 1992) adopt five central assumptions: "(1) Cognitivism: A commitment to a functionalist information-processing model of psychology; that is, to a description of psychological mechanisms in the form of decision rules or computational models without regard to their physical manifestation. (2) Adaptationism: The empirical assumption that complex features of modern organisms are adaptations to selective pressures in the past..., the explanatory assumption that apparent design and the relation of organisms to the environment are the important questions and natural selection the only answer, and the methodological commitment to the use of design analysis to search for these adaptations.3 (3) Modularity: A commitment to a cognitive architecture which views the mind as consisting of many domain-specific and informationally-encapsulated information processing modules. (4) Inclusive Fitness: A commitment to the gene as the unit of selection (i.e., inclusive fitness models of selection), and (5) Species-Typicality: A commitment to the universality of psychological adaptations; a commitment to the search for a universal human nature" (RAUSCHER and SCHER 2003, pp. 9–10; see also LALAND and BROWN 2002).

MODULES IN COGNITIVE ADAPTATIONSIM

Cognitive adaptationists make a strong assumption that our mind is organized into domain-specific modules. That is, that we have a large set of relatively independent modules in our mind that have evolved to solve specific sorts of problems in the environment of our evolutionary adaptedness (EEA; that is, the ancient environment to which modern humans are adapted). Each of these cognitive modules are said to operate according to its own unique set of rules, and to contain its own innate information.4

The idea of a module as conceived within cognitive adaptationism draws heavily on the work of DAVID MARR (e.g., 1983) on vision, of NOAM CHOMSKY (e.g., 1975) on language, and on the general outline of modularity presented by JERRY FODOR (1983). FODOR, in particular, argued for modules that were domain-specific and informationally-encapsulated; cognitive adaptationist modules exhibit both of these features. (FODOR also proposed at least seven other features of modules, but these are generally not emphasized by cognitive adaptationists in their accounts of modularity.)

For FODOR, however, only the peripheral mind was modular in this way: modules operate between sensory transducers and the central, reasoning portion of the mind, but this central system of the mind is, itself, non-modular. A visual perception module, which brings visual stimuli into the reasoning system, and a language module, which carries the results of mental operations out to the world, fit into this conception of peripheral modules.

Cognitive adaptationists, however, do not limit their conception of modules to these sorts of peripheral modules. On the contrary, they propose that the mind is "massively modular" (SPERBER 1994). The massive modularity thesis proposes that much – perhaps all – of our mental processing is carried out by a large number of semi-independent modules.

These modules are cognitive adaptations that evolved via natural selection because they served particular evolutionary functions. Each module operates in a specific domain defined by this evolutionary function. In general, a domain is a subset of the environment in which an organism operates. A domain is the evolutionary problem for which a module is the solution.

Unfortunately, cognitive adaptationists provide little concrete guidance as to how one would identify a domain, and how one would determine if a capacity or function that humans (or other species) are shown to carry out is, in fact, produced by an encapsulated module (cf. MURPHY 2003). Clearly, there are things that humans can do and things that people feel that cannot be the function of unique, evolved modules (e.g., reading, preferences for certain types of cars, computer programming); there simply has not been enough time for evolution to have created a "reading module", a "car preference module", or a "computer programming" module. Demonstrating, therefore, that people can solve a particular kind of problem (e.g., cheater detection problems), or have a particular type of preference (e.g., for high status mates), etc., is not evidence for the modularity of that function. Even if we assume a priori that the mind is modular, we cannot simply assume that any function which intuitively appears to us as if it could arise from an evolved module is, in fact, the result of an evolved module.

IDENTIFYING MODULES

In principle, cognitive adaptationists propose that one can identify modules by identifying domains in the EEA, and analyzing what adaptations should have developed to enhance fitness in each specific domain. But given our current state of knowledge about the nature of the environment in which we evolved, and given the variable nature of that environment (FOLEY 1996, 1997), it is difficult to see how one can carve the joints of the EEA from our modern vantage point (STERELNY and GRIFFITHS 1999; STOTZ and GRIFFITHS 2003).

This is a problem which adaptationists studying non-human species appear not to face. Because of the assumption that the niches of most non-human species have not changed substantially, the niche can be observed empirically. But, one of the major benefits claimed for cognitive adaptationism over sociobiology is the recognition that modern human psychology evolved in response to a long-ago environment, and therefore that modern human psychological mechanisms can be adaptations without being adaptive in our much changed, 21st-century world. This fact makes the task of determining domains, and therefore of determining the appropriate modular grain of a psychological mechanism, particularly difficult.

In fact, if tracing the evolutionary history of the mind requires first breaking it into coherent units, we must begin with knowledge of the current form of the trait. Analysis of what a trait actually does can lead us to determine the various components of the current functioning of the trait. A module can only be identified based on this understanding of its current operation (and, on its anatomy; see below).

This does *not* mean that we should naively assume that the current function is the function for which the trait evolved. However, if we wish to break our mind into coherent units, we cannot do so based on a speculative breakdown of our prehistoric evolutionary niche. Rather, we must use our knowledge of current function to identify reasonable evolutionary modules and then search for the evolutionary history of the identified features.

It is, then, to analysis of known psychological capacities that we must turn. A breakdown of these capacities into elementary operations through task analysis can lead us to understand the low-level steps that a mind must compute to carry out the function under study.

Of course, this is also the way that functional physical anatomy was largely worked out. Cognitive adapatationists cite approvingly the fact that the different organs of the body were identified because they carry out different functions. But this identification, the carving of our body into separate organs, occurred without any concern for specifically adaptive function. In fact, it occurred centuries before Darwin’s birth.

Advances in cognitive science, artificial intelligence, and cognitive neuroscience can provide substantial help to researchers seeking to break cognitive functions into elementary operations, and thereby to map the architecture of the mind. POSNER and ROTHBART (1994), for example, suggest a break down of cognitive tasks into smallgrained elementary operations, “a set of operations that would be sufficient to program or simulate the task being studied” (pp. 184–185). These elementary/mental operations resemble Fodorian modules: They are isolated systems whose processing is opaque to conscious awareness; they take input, perform a computation, and produce an output.

Elementary operations are based on fixed neural architectures. That is, they are carried out by localized neural systems (BECHTEL 2003; BOOKHEIMER 2002; POSNER et al. 1988). This anatomical modularity is further argument for modules to be considered at a small grain. Evolutionary psychology should turn to anatomy to identify what evolved psychological modules might look like. This is in the tradition of paleonthology and other branches of biology that have long used an analysis of the physical anatomy of organisms to identify the organism's evolutionary environment and to determine the proper division of the organism into units whose evolutionary history could be studied independently.

A case for basing the identification of mental modules on anatomical analysis can also be derived from the claim that mental modules are the product of natural selection operating on genes. Genes can contribute to the organism in only one way – by the creation of proteins, which contribute to physical structure. Cognitive adaptationists have made a practice of confining their empirical hypotheses to the cognitive level, and have relied on a commitment to a materialist theory of mind and to the neo-Darwinian theory of biology to span the gap between cognition and the genetic and neuroanatomical/physiological makeup of humans.

This gap in empirical focus has led to hypothesized cognitive adaptationist modules that operate at a grain far larger than can be supported based on study of the brain. The elementary operations carried out by localized neural systems are the best candidates for evolved psychological modules, yet they are at a grain far smaller than typical cognitive adaptationist modules (BECHTEL 2003).

LEGO MODULES

The metaphor of choice for a cognitive adaptationist mental architecture has been the Swiss Army knife. The central feature of the metaphor is the notion that a set of specialized tools, each geared toward a specific function, can best serve to carry out the diverse set of needed activities (for knives and for minds).

I propose an alternative metaphor: Lego blocks. As most readers will know, Lego is a building block toy originally created in Denmark. The pleasure of Lego blocks comes from the fact that a limited variety of building blocks can be combined into a virtually unlimited number of designs. (At various Legoland amusement parks, the Lego company has built a mind-boggling collection of objects out of Legos, including models of Mount Rushmore, Darth Vader, the Statue of Liberty, and the City of Amsterdam.)

In the Lego model of cognitive architecture, the elementary neural modules serve as the individual Lego blocks. These building blocks are assembled as needed to carry out larger-grained functions which give fitness benefits to the organism. The unique combination of elementary operations gives each high-level function (e.g., mate selection, food selection, cheater detection) its unique character. Selection led both to the evolution of the Lego modules themselves, and to the assembly of blocks into functions that lead to enhanced fitness in some selective environment.

Different high-level functions will have some Lego blocks in common. As a result, there may be some overlap in the way two or more functions operate. Additionally, because some high-level functions may be carried out with lower level operations that were not designed specifically for that function, certain functions will not operate optimally.

REPEATED ASSEMBLY

The basic requirements of natural selection are heritable variability and selection. There must be actual differences in the phenotypes of organisms for natural selection to occur. The neo-Darwinian synthesis (and, by extension, cognitive adaptationism) operates as though all the relevant variability originates in genetic material of the organism. Adaptationists make a black box leap from genetic material to actual phenotypic action, acting as if the simple existence of certain genes will lead assuredly to specific phenotypic traits.

In contrast, the Lego model of mental modularity relies on CAPORAEL's (2003; CAPORAEL and BARON 1997) notion of repeated assembly to provide a conceptual framework for the way in which higher level functions are assembled from elementary operations (mental Legos). According to CAPORAEL (2003, p. 75), "phenotypes emerge from constructive interactions among multiple recurrent resources, including genes, cellular machinery, social resources, the reliable presence of critical features of the habitat, and the ongoing results of previous development". A complex interaction of developmental resources must work together to assemble the phenotype (psychological mechanism)5 which an actual organism has at any given time. Repeated assemblies are "recurrent, entity-environment relations composed of hierarchically organized heterogeneous components having different temporal frequencies and scales of replication" (CAPORAEL 2003, p. 77).

This assembly process is heritable to the extent that the phenotype contributes to insuring that the important resources are present for the assembly of the phenotype at some future time. From this perspective, then, the assembly process is the unit of selection. Assembly processes which facilitate their own repetition will become more common.

The repeated assembly idea is related to the developmental systems approach to evolution (GRIFFITHS and GRAY 1994, 2004; OYAMA, GRIFFITHS and GRAY 2000). According to developmental systems theory, "the fundamental unit that undergoes natural selection is neither the individual gene nor the phenotype, but the life cycle generated through the interaction of a developing organism with its environment ... the 'developmental system' is the whole matrix of resources that interacts to reconstruct that life cycle" (GRIFFITHS and GRAY 2004, p. 2).

Developmental systems are repeated assembly processes. Selection operates on the heterogeneous and recurrent resources that go into the construction of a life cycle. From a Lego model perspective, this implies that the various Lego modules are assembled ontogenetically into functional capacities when the matrix of developmental resources are present to elicit the formation of the capacity. The resources include genetic material (DNA, chromosomes) as well as extragenetic material (ambient temperature, childcare, sensory stimulation). When any of the crucial resources are missing, the assembly of the phenotypic capacity will not occur or will occur in a non-normative fashion.

In addition to the ontogenetic capacities assembled over a life-course, repeated assemblies occur over much shorter frequencies. The Lego model makes room for the online assembly of a capacity within a shorter term situation. Thus, we can conceive of a set of elementary operations (Lego modules) assembling at a particular time, in interaction with a particular set of environmental elements, to discharge a particular function, and ceasing to exist in a stable configuration again until the same set of environmental resources are again co-existent.6

HIERARCHICAL ADAPTATIONS

An organism exists as part of a biological hierarchy. Nucleotide bases within a DNA molecule, which is within a cell, within an organ, within an interacting system of organs, within an individual body, within a group, within a species, etc., make up part of the hierarchy that includes multicellular organisms. Lego modules are one level of the hierarchy of psychological features. This hierarchy includes at a lower level individual neurons, neurochemical molecules, sodium and potassium ions, and more; at a higher level it includes the sorts of functions identified in cognitive adaptationist research, and claimed by cognitive adaptationists to be modules.

However, these cognitive adapatationist functions are not necessarily as independent nor as permanent as is implied by the cognitive adaptationist perspective. The lack of permanence of some modules comes about because of the above mentioned possibility of online assembly of functions. The lack of independence comes about because when two functions use some of the same Lego blocks, they will overlap to some extent in how they operate. They may even be able to share information.

LEGO BLOCKS AND THE HISTORICAL QUESTION

The ethologist NIKO TINBERGEN (1963) famously suggested that questions about the cause of a certain trait can be answered from four different perspectives – the proximate cause, the developmental/ontogenetic cause, the functional cause, and the historical cause. Cognitive adaptationism addresses itself predominantly toward the first of these causes. Cognitive adaptationists seek to use an evolutionary analysis to discover facts about current psychological functioning.

To a large extent, historical analysis in cognitive adaptationism serves only a heuristic function. An analysis of the EEA is used to suggest hypotheses about proximate psychological function. Specifically, cognitive adaptationists propose a welldesigned psychological mechanism in response to a problem hypothesized in the EEA. There is a leap from the EEA to the present, with the assumption that somehow the feature proposed would have evolved; there is no effort made to trace the historical path by which the proximate mechanism came to be designed. The Lego model provides a framework for conceptualizing the historical process of cognitive evolution.

Natural selection must work by modifying existing features of an organism to serve new functions. No feature can be created ex nihilo. However, existing features might be combined into a new system, which could serve a new function. If this new function serves to increase the likelihood that the circumstances would be right for the assembly of the function again in the future, then the assembly of the function should be selected for. In the language of the Lego model, this would mean that a new way to assemble existing Lego blocks would result in a new feature.

Another way to evolutionarily construct a new feature would be for one or more existing Lego blocks to be duplicated, and then for there to be modification of those blocks to include new features that are more specialized to new functions. Two functions with duplicated Lego blocks may have a family resemblance in functioning, but we might expect the duplicated Lego block to evolve as well, so that over time the duplicated block and the original block would not function identically.

SUMMARY

Cognitive adaptationists have spurred a major growth in the use of evolutionary concepts to understand human and non-human psychology. However, the specific metatheoretical assumptions made by these evolutionary psychologists should not be allowed to restrict the ways in which we address the evolution of cognition. The Lego model of cognitive architecture is an alternative model grounded in evolutionary theory and in the anatomy of the brain. It proposes a metaphor of Lego blocks for cognitive modules. Each Lego block carries out a low-grain cognitive function, and Lego blocks are assembled to carry out higher level functions in a process of repeated assembly. This model provides insight into the hierarchical nature of psychological function, and into the actual historical process of evolution.

FOOTNOTES

1 I am grateful to FRED RAUSCHER for many fruitful and fun conversations about evolutionary psychology over the years, as well as for allowing me to steal substantial portions of this paper from our previous work together. I am also grateful to EINAR BALDURSSON who supplied the kernel of the idea of the Lego Model, who came up with the name, and who took me to Legoland.

2 This approach has also been called “inclusive fitness psychology” (CAPORAEL 2001) and “narrow evolutionary psychology” (RAUSCHER & SCHER 2003). LALAND & BROWN (2002) refer to this as the “Santa Barbara school”, because of the residence of prominent evolutionary psychologists LEDA COSMIDES, DONALD

SYMONS, and JOHN TOOBY in Santa Barbara, California. Given the fact that COSMIDES and TOOBY began their evolutionary psychology work in Cambridge, Massachusetts, which is also the home of STEPHEN PINKER and close to the home of DANIEL DENNETT, the Cambridge or Massachusetts school seems at least as appropriate.

3 For more on these 3 types of adaptationism, see GODFREY-SMITH (2001).

4 SAMUELS (1998) argues that modules a la cognitive adaptationism ("Darwinian modules" in his terminology) are different from a "library model of cognition" where domain-specific function is carried out by domain-general mechanisms operating on domain-specific information. Nevertheless, cognitive adaptationists do propose that domain-specific modules have innate, specific information. In fact, a domain-specific module would seem to require domain-specific information to operate (cf. SCHER & RAUSCHER 2003).

5 The concept of repeated assembly is equally applicable to non-psychological traits.

6 This distinction between developmentally assembled, but thereafter stable, psychological traits and online assembly of traits seems somewhat forced. It is, perhaps, a legacy of the origin of the genotype/ phenotype distinction in reference to physical traits. "Phenotype" (from the Greek "pheno-", meaning visible) typically connotes a fixed feature that develops from (in part) a specific genotype. (For example, the development of blue eyes from a genotype with two recessive blue-eye alleles). In evolutionary psychology, however, there is a need for a distinction between the relatively fixed feature which develops out of the genotype, and the specific behaviors or psychological states that are produced in ongoing interaction. I propose rheotype (from the Greek "rheo-", meaning "flow") to refer to the flow of behavior and psychological states that are carried out on an ongoing basis. Within this distinction, "phenotype" would refer to the more or less static psychological mechanisms that produce the rheotypic behavior or psychological state.

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