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MODULARITY: MYTH OR TRUTH?

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ABSTRACT
Modularity has been an issue of debate in the cognitive sciences for more than three decades. Modularity is a fundamental property of living things at every level of organization; it might prove indispensable for understanding the structure of the mind as well. The concept of modularity (i.e., the degree to which the lexicon, syntax, and other neurocognitive domains operate independently of one another) has played an important role in theorizing about brain architecture and function, both in development and in adulthood. In this paper, an overview of the theoretical and empirical views and arguments germane to modularity such as localization, domain specificity, and massive modularity are presented. It is concluded that although modularity is an accepted view, there are still some controversies on this issue.

KEYWORDS: *modularity, localization, domain specificity, massive modularity*

INTRODUCTION
Generally, questions related to the functional architecture of the mind have been dealt with two different theories (Elman et al., 1996). The first theory can be defined as a horizontal view referring to mental processes which interact with each other such as perception, memory, and judgment which are not domain specific (Sperber, 2002). For instance, a judgment, whether refers to a perceptual experience or to the comprehension of language, remains a judgment. The second theory can be defined as a vertical view since it argues that the mental faculties separated based on domain specificity are genetically determined and associated with distinct neurological structures (Sperber, 2002). This view dates back to the 19th century movement called phrenology and its founder Joseph Gall, who claimed that the individual mental faculties could be associated precisely with specific physical areas of the brain.

In Fodor's (1983) view originated from Chomsky (1965) and the implications of optical illusions, a module is a perceptual input system. According to Fodor (1983), a module is informationally encapsulated; the operations within a module are unconscious; the operation of a module is mandatory; innate modules are localized in particular brain areas; their development is bound to a given time schedule; innate modules are domain specific and they operate exclusively on certain types of input.

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Fodor (1983) argued that a module falls somewhere between the behaviorist and cognitivist views of lower-level processes. Low level processes are unlike reflexes in that they are inferential. This can be demonstrated by poverty of the stimulus arguments in which the proximate stimulus, that which is initially received by the brain such as the 2D image received by the retina, cannot account for the resulting output (for example, our 3D perception of the world), thus necessitating some form of computation Fodor (1983).

On the contrary, cognitivists saw lower level processes as continuous with higher level processes, being inferential and cognitively penetrable (influenced by other cognitive domains, such as beliefs). The latter has been shown to be untrue in some cases, such as with many visual illusions, which can persist despite a person's awareness of their existence. This is taken to indicate that other domains, including one's beliefs, cannot influence such processes. Fodor (1983) arrived at the conclusion that such processes are inferential like higher order processes and encapsulated in the same sense as reflexes. In addition, Fodor (1983) proposed a model of perception and cognition (see Figure 1).

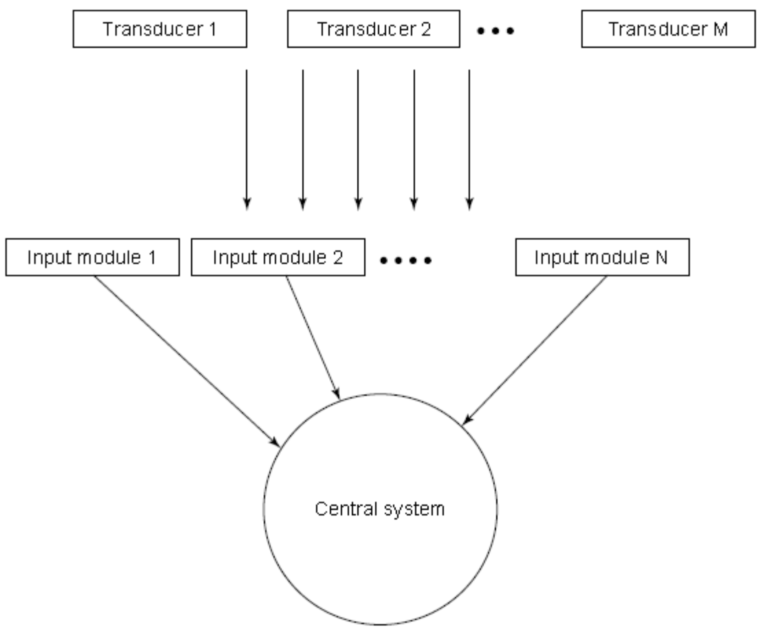

Figure 1: Fodor's Model of Perception and Cognition

In this model three levels are distinguished: the transducers, whose function is to convert physical stimulation into neural signals; the input systems, whose function is to interpret transduced information and responsible for basic cognitive activities such as language and vision; and the central system, which is responsible for more complex cognitive activities such as analogical reasoning, and it is not modular. Fodor is mostly devoted to the input systems and what it means to say is that these are modular.

It is generally accepted that some form of modularity exists in the human brain, but there is little agreement on what exactly it is (Dick et al., 2001). For example, there is little controversy that

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highly specialized areas of the visual cortex selectively process specific dimensions of the visual experience of color and orientation. For higher-level cognition, however, modularity has been controversial. In the following sections, main issues germane to modularity, i.e. localization, domain specificity, and massive modularity are discussed. The last two sections of the paper are dedicated to the arguments against modularity and concluding remarks.

LOCALIZATION: AT WHAT LEVEL IS THE BRAIN MODULAR?

A certain function or domain is localized if it is processed in confined regions of the brain (Karmiloff-Smith, 1998). Empirically speaking, damage in specific areas produces selective functional deficit. However, this argument has been refuted by several findings. For example, in language, agrammatic patients revealed some grammatical judgments, although at a weak level (Wulfeck & Bates, 1991).

For decades, much of neuropsychology has focused on where functions and behaviors are localized. Indeed, far more emphasis has been given to the *where* question without paying attention to the *why* question. Beyond claims of genetic specification, very little is understood about why in default circumstances a region takes on certain functions and not others. An argument can be made that in normal circumstances, Broca's area may become specialized for language processing not because it is specifically designed for language but partly because it is the area with the computational characteristics that are particularly well suited to deal with the requirements of this domain (Elman et al., 1996). In other words, a *domain-relevant* region becomes domain specific over developmental time (Karmiloff-Smith, 1998). Hence, many regions may initially compete for the processing of given inputs, with the special computational properties of one region ultimately winning out. However, a full specification of what those computational properties are is as yet largely unknown. These issues are explained in the next section, on domain specificity.

DOMAIN SPECIFICITY: ARE MODULES INDEPENDENT?

The domain specificity question concerns the extent to which the operations of a proposed module, such as syntax, are special and exclusive to that domain (Elman et al., 1996). Elman et al. (1996) pointed to a number of broad notions of domain specificity. Domains can be specific because they have specific input/output systems: visual cortical areas receive input from the retina, whereas auditory cortical areas receive input from the ears. Specificity may also arise because different problems require different behavioral solutions and/or different computational mechanisms. The important question, however, is the extent to which computational mechanisms of a given domain are exclusive to that domain - i.e., modular - throughout development or in adulthood.

Fodor (1983) argued that modules operate using specialized mechanisms dedicated to handling specific types of input, what he called *proprietary inputs*. The question of whether domain specificity is prespecified in the human brain as a result of evolution or arises during ontogenesis from experience-dependent processes, coupled with self-organizing cortical mechanisms, is still an open one. What is clear, though, is that patterns and regularities in the input can quickly and efficiently lead to progressive specialization of the brain. Evolution is more likely to have given rise to greater flexibility of learning than to increasingly complex prespecified modules (Karmiloff-Smith, 1992).

The idea of progressive modularization challenges the notion that a static model can be used to explain development in both the typical and the atypical case. On the contrary, the developmental process itself is a major contributor to behavioral outcomes (Karmiloff -Smith, 1998). In support of this claim, brain-imaging data from infants and toddlers have shown that over developmental time, there is a pattern of very progressive specialization and localization of important functions for our species, such as face processing (de Haan et al., 2002). In atypical cases, the origins of the behavioral profiles found later in development may stem from differential processing of input and utilization of different strategies beginning early in infancy.

A related hypothesis is that deficits in low-level perceptual mechanisms are contributing factors in developmental disorders. Some possible mechanisms are rapid auditory processing impairment in specific language impairment (Temple et al., 2003). Some have challenged the view that low-level impairment can be viewed as causal in many of these developmental conditions (Rosen, 2003). Because of the fact that such impairments are not found in all cases. The validity of this claim is difficult to assess, for a number of reasons. First, many developmental disorders are diagnosed based on behavioral impairment in a specific area; this sheds doubt on whether it is necessary to look for impairments in other domains, after having *a priori* excluded those whose impairment is less marked. Second, low-level problems need not exist throughout the entire life span. The crucial point is that their presence *early* in development may trigger cascading effects, the *indirect* results of which are found later in development. Third, even if not taken as singular explanatory factors, low-level impairments may play an important role in altering the experience of the child in the environment, providing a possible mechanism by which developmental outcomes are achieved.

In sum, converging evidence suggests that modules are the final outcomes of the developmental process. Furthermore, the progressive development of modules, both in infancy and adulthood, is tightly bound to experience. Even in adulthood, experience continues to play a role in forming brain architecture and processing.

MASSIVE MODULARITY

Massive modularity theory argues that the mind is modular completely, including the parts responsible for high-level cognition functions like problem-solving, planning, etc. The theory has been supported by proponents of evolutionary psychology (e.g., Barrett, 2005; Cosmides & Tooby, 1992; Pinker, 1997; Sperber, 1994, 2002). The worth mentioning point is that the operative notion of modularity differs significantly from the traditional Fodorian one. Carruthers (2006) is explicit on this point:

> [If] a thesis of massive mental modularity is to be remotely plausible, then by 'module' we cannot mean 'Fodor-module'. In particular, the properties of having proprietary transducers, shallow outputs, fast processing, significant innateness or innate channeling, and encapsulation will very likely have to be struck out. That leaves us with the idea that modules might be isolable function-specific processing systems, all or almost all of which are domain specific (in the content [viz. roughly Fodorian] sense), whose operations aren't subject to the will, which are associated with specific neural structures (albeit sometimes spatially dispersed ones), and whose internal operations may be inaccessible to the remainder of cognition. (p. 12)

Proponents of massive modularity have been chiefly concerned to defend the modularity of central cognition. Therefore, this theory for theorists like Carruthers can be best understood as the combination of two claims: first, that input systems are modular in a strong sense (that is, the positive strand of modest modularity), and second, that central systems are modular, but in a considerably weakened sense. In his defense of massive modularity, Carruthers (2006) focused almost exclusively on the second claim.

The centerpiece of Carruthers (2006) consists of three arguments for massive modularity: 1) the argument from design, 2) the argument from animals, and 3) the argument from computational tractability. Each of these arguments is briefly discussed in turn. The argument from design is as follows:

"Biological systems are designed systems, constructed incrementally. Such systems, when complex, need to have massively modular organization. The human mind is a biological system, and is complex. So the human mind will be massively modular in its organization" (Carruthers, 2006, p. 25).

A weakness in this line of reasoning, however, is that even if the mind is massively modular in its organization, it doesn't follow that that the mind is massively modular (i.e., composed throughout of systems that are domain-specific, mandatory, etc.). Another argument which is close to Carruthers' was proposed by Cosmides and Tooby (1992) who put it in this way:

> The human mind is a product of natural selection. In order to survive and reproduce, our human ancestors had to solve a range of adaptive problems (finding food, shelter, mates, etc.). Since adaptive problems are solved more quickly, efficiently, and reliably by modular (domain-specific, mandatory, etc.) systems than by non-modular ones, natural selection would have favored the evolution of a massively modular architecture. So the human mind is probably massively modular. (p. 122)

The force of this argument depends chiefly on the strength of the third premise. Not everyone is convinced, to put it mildly (Samuels, 2000; Fodor, 2000). A related argument is the argument from animals. Unlike the argument from design, this argument is never explicitly stated in Carruthers' (2006). But here is a plausible reconstruction of it, due to Wilson (2008): Animal minds are massively modular. Human minds are incremental extensions of animal minds. Therefore, human minds are massively modular.

Unfortunately for the proponents of massive modularity, this argument, like the argument from design, is vulnerable to a number of objections (Wilson, 2008). First, it is not easy to motivate the claim that animal minds are massively modular. The problem is that domain specificity is just one of five features characteristic of modularity in Carruthers' account, and he presents little or no evidence to support the attribution of the other four features. Therefore, unless domain specificity alone suffices for modularity (which seems unlikely on its face), the argument falters at the first step. Second, even if animal minds are massively modular, and even if single incremental extensions of the animal mind preserve that feature, it is quite possible that a series of such extensions of animal minds might have led to its loss. In other words, as Wilson (2008) put it, it can't be assumed that the conservation of massive modularity is transitive and without this assumption, the argument from animals cannot go through.

Third and finally, we have the argument from computational tractability (Carruthers, 2006). This is probably the least clear of the three arguments, in terms of its underlying logic:

> The mind is computationally realized. All computational mental processes must be suitably tractable…only processes that are at least weakly (i.e., wide-scope) encapsulated are suitably tractable. So the mind must consist entirely of at least weakly encapsulated systems. So the mind is massively modular. (pp. 44–59)

The main problem here is with the last step. Though one might reasonably suppose that modular systems must be at least weakly encapsulated, the converse does not follow. Indeed, Carruthers (2006) makes no mention of weak encapsulation in his definition of modularity, thus it is difficult to see how one is supposed to get from a claim about pervasive encapsulation to a claim about pervasive modularity. At best, what we get is an argument for the possibility of massive modularity, rather than its actuality.

ARGUMENTS AGAINST MODULARITY

Does modularity entail strong nativism?

It is important to identify any commitments to development entailed by modular approaches that differ substantively from commitments that derive from other views of cognitive architecture. Fodor is a strong nativist. This is obvious in his strong nativist position on innate concepts (Cowie, 1998; Fodor, 1997). Regarding modules, Fodor is clear that modules are "presumed innate barring explicit notice to the contrary" (Fodor, 2000, p. 58). This leaves the issue of the particular commitments about development that are entailed by a modularity hypothesis (Tooby et al., 2003). If what individuates a module is functional specialization, then a modularity hypothesis entails that the functionally specialized design features postulated by the hypothesis emerge in each individual, in each generation, during the developmental process by some process of genes interacting with internal and external environments.

Spatial Localization and Dissociations

Two major categories of argument against the existence of modules have been proposed: architectural and developmental. Generally, psychologists agree that because cognitive architecture is instantiated in brain architecture, the two will be isomorphic at some level (Marr, 1982). However, at a larger, macroscopic level, there is no reason to assume that there must be spatial units or chunks of brain tissue that neatly correspond to information-processing units (Smith & Thelen, 2003). Fodor (1983), however, assumed that functional discreteness at the information-processing level would be reflected in discreteness at the macroscopic level of brain structure. Modules, on this view, would be like snap-in parts in an automobile engine. This led him to predict that modules would exhibit "fixed neural architecture" and "characteristic breakdown patterns," for example, following brain injury (Fodor, 1983, pp. 98–100). If modules are spatially localized and discrete, one might expect an injury that could impair a single module and leave all other brain functions intact.

CONCLUSION

It can be concluded that although modularity is an accepted view, there are still some controversies on this issue. In this line, it can be said that terminological discrepancies have hindered efforts to disentangle important issues surrounding the term modularity. In particular, the equation of modular with *fixed, innate,* and *static* is an understandable consequence of intuitions that underpin the term. The interactionist perspective proposes that all cognitive mechanisms are the result of a developmental process that involves genes and environment as both causally relevant, is relatively uncontroversial. It is believed that the view of modularity is essentially logically entailed by a computationalist perspective, which is committed to mechanisms with formally definable inputs and operations. Another potentially controversial aspect is that the genes that play a causal role in the developmental programs associated with cognition have been selected as a result of the functional outcomes connected with the ultimate products of the developmental systems. It is believed that these programs are likely to have been selected as a result of their history of bringing about functionally specific, architecturally modular structures associated with adaptive problems faced by our ancestors. Recent studies imply that behavior in various contexts is influenced by cues that might have been relevant in ancestral environments even though their use in modern contexts makes little sense from the standpoint of canonical models of economics, even those that incorporate preferences beyond self-interest.

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