



ISSN: 1817-6798 (Print)

Journal of Tikrit University for Humanities

available online at: <http://www.jtuh.tu.edu.iq>
JTUH
 جامعة تكريت للعلوم الإنسانية
 Journal of Tikrit University for Humanities

A Cognitive-Functionalist Interpretation of Modularity

A B S T R A C T

Dr. Ismael F. Hussain AL-Bajjari

PhD in Linguistics, Lecturer, Department of English Language, College of Education, University of Mosul, Mosul, 2013

Keywords:

Modularity
 Module
 Massive Modularity
 Functionalist Modularity
 Fodorian Modularity

ARTICLE INFO

Article history:

Received 6 Feb. 2020
 Accepted 18 Feb 2020
 Available online 22 Apr 2020
 Email: adxxx@tu.edu.iq

Modularity has been the subject of intense debate in philosophy, psychology, and especially, in the cognitive sciences since the early 1980s, due to the publication of Fodor's ground-breaking book *The Modularity of Mind* (1983). However, in most cases of such modular views of the mind, misunderstandings have impeded an access to a more conceptually plausible account of modularity; a case that concerns us most here. This paper identifies the most striking arguments in the relevant literature, with special attention on the modularity argument proclaimed by J. Fodor (1983) that has been either limited in scope and depth, or misconceptualized by proponents. In particular, it reviews briefly the most modular assumptions made in this argument; those related to the cognitive architecture of the mind, and the perceptual-linguistic processes that are structured in terms of modules, or "organs". It is proposed here that modularity, clearly defined, may provide a useful framework for directing research works about human cognitive system, in general, and cognitive systematic processes of language use, in particular. Modularity might prove indispensable for understanding the structure of the mind, and offering insights into those mental mechanisms of human language processing as well. To that end, the paper, largely following the stance of **Modern Massive Modularity**, proposes a **hierarchically cognitive-functionalist model** of the modularity of mind, whose biggest claim is to argue that the architecture of the mind is more pervasively modular than the Fodorian perspective permits, and that the line of modularity might be drawn, not only up to the high-level systems responsible for thought, but also at the low-level systems (sub-systems) underlying perception and language.

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DOI: <http://dx.doi.org/10.25130/jtuh.27.2.2020.23>

تفسير ادراكي وظيفي لمنظومية العقل

اسماعيل فتحي حسين جامعة الموصل كلية التربية للعلوم الانسانية

الخلاصة:

لقد كانت ومازالت منظومية العقل موضوع نقاش حاد في الفلسفة ، وعلم النفس ، وفي مجال العلوم الإدراكية على وجه الخصوص منذ عام 1980، وتحديداً بعد نشر كتاب الفيلسوف والعالم اللغوي الأمريكي جيرى فودر الموسوم "منظومية العقل" (1983)، الذي فتح آفاقاً جديدة في هذا الصدد. إن سوء

الفهم في معظم وجهات النظر المتعلقة بمنظومية العقل قد أعاق التوصل إلى منهج إدراكي منطقي لتناول هذه المنظومية، وهذا ما يهمنى هنا كثيرا. يتطرق هذا البحث الى التعريف بأهم الأطاريح المتعلقة بهذا الشأن مع التأكيد على إطروحة المنظومية التي قد أعلنها جيرى فودر (1983) والتي إما أنها قد كانت محدودة في مداها وعمقها أو قد تم استيعابها بشكل خاطئ من قبل مؤيديها. من خلال هذه الدراسة يستعرض البحث وبشكل مقتضب تلك الفرضيات المرتبطة بالهندسة الإدراكية للعقل مع التأكيد على العمليات الاستيعابية واللغوية المبنية على شكل وحدات منظوماتية أو "أعضاء". ويقدم البحث اقتراحا مفاده أن منظومية العقل بتعريفها الواضح ، قد توفر إطارا مفيدا لتوجيه البحوث حول النظام الإدراكي البشري بشكل عام، والعمليات الإدراكية النظامية المتعلقة باستخدام اللغة بشكل خاص. إن منظومية العقل ربما تكون أساسية لفهم بنية العقل وأنها قد تقدم أيضا نظرة فاحصة لتلك الميكانيكيات العقلية المرتبطة بتقديم واستيعاب اللغة البشرية. وتحقيقا لهذه الغاية ، يقترح البحث منهجا إدراكيا وظيفيا ذا بنية هرمية لمنظومية العقل من خلال إتباع منهج المنظومية الشاملة الحديثة. إن من جل اهتمامات هذا المنهج هو توضيح أن البنية الهندسية للعقل لا بد وأن تكون أكثر اتساعا في منظوميتها مما قد يسمح به منهج فودر. ويحاول هذا المنهج في جوهره أن يمد حدود منظومية العقل، ليس فقط إلى مستوى الأنظمة عالية المستوى المسؤولة عن الفكر ، ولكن أيضا إلى الأنظمة ذات المستوى المنخفض (الفرعية) الكامنة وراء الاستيعاب واللغة.

1. Modularity of Mind: Introductory Remarks

The concept of modularity has been utilized largely in philosophy and psychology since the early 1980s, following the publication of Fodor's book *The Modularity of Mind* (1983). During the twenty-eight years since the term 'module' was first used in the field of cognitive science, the conceptual and theoretical orientation of modularity has been changed dramatically. Apart from the Fodorian conceptualization in this particular area, some post-Fodorian theorists, like Carruthers (2006), have argued that the architecture of the mind is more pervasively modular than the Fodor's view indicates. As Fodor (1983, 2000) claims that modularity covers the low-level systems underlying perception and language, Carruthers (2006) has proved that the mind is modular through and through, including the high-level systems responsible for thought. In this regard, the present paper tries to bridge the gap between the Fodorian and post-Fodorian perspectives (namely, Massive Modularity) of the concept of modularity, and presents a more comprehensive as well as plausible functionally cognitive perspective that draws the line of modularity, not only up to the high-level systems responsible for

thought, but also at the low-level systems (sub-systems) underlying perception and language (see section 5, below).

In a general sense, the notion of "modularity" is concerned with the degree to which an article or system is made up of relatively independent, but interlocking components or parts. More specifically, it is concerned with the question that how a complex mental process can be divided into meaningful modular parts. In essence, it is based on the principle that a network of interactions is called modular if it is subdivided into relatively autonomous, internally highly connected components (cf. Wagner et al. 2007). Cognitively oriented, it reveals that the mind has some internal architectural structure which is systematically modular, and that mental phenomena arise from the operation of multiple distinct processes rather than a single undifferentiated one (cf. Barrett & Kurzban 2006).

As the concept of module, a specialized encapsulated mental organ evolved to handle specific information types of enormous relevance to the species, has markedly been invoked in different contexts with different purposes and orientations, various kinds of modularity have appeared in literature; *Biological Modularity*, *Diachronic Modularity*, *Developmental Modularity*, *Morphological Modularity*, *Evolutionary Modularity*, *Neural Modularity*, and *Cognitive Modularity* (cf. Pinker 1997; Gunter et al. 2001; Sperber 2005). Especially noteworthy in this regard has been the development of a cognitive model of modularity, whose proponents; chief among whom is Jerry Alan Fodor, as he argues that the architecture of the mind is schematically modular (see section 2, below).

The term modularity, taken from the lexicon of computer technology, is based on the ground that sub-systems can be separated with regard to their specific tasks and independent functioning, viz. 'Modules'. In neuro-science, it refers to the idea that the brain is divided into cells, layers and regions which share the task of information processing in various ways (cf. Bates 1994; Prinz 2006). In linguistics and cognitive science, the term 'module' refers to a stronger and more controversial claim. In linguistics, namely, in Government-Binding Theory, language system itself is believed to be highly modular consisting of specific subsystems (or modules) that interact in regular principles(cf. Chomsky 1980; Crystal 1997). In this sense, Chomsky (1980) conceptualizes the notion of modularity in the context of grammatical regularities that are not governed by general cognitive systems, rather they are governed by principles that are specific to language. Thus, grammar, as a part of linguistic competence consisting of grammatical competence,

conceptual competence and pragmatic competence, is viewed by him (*ibid.*) as a module with a set of autonomous sub-systems, each of which has its own criteria for well-formedness. In language acquisition, the concept of 'universal-generative grammar', developed by Chomsky (1957), is based on the view that there is an underlying 'language acquisition device' structure in the brain. This device is postulated to be autonomous and specialized for learning language rapidly; a module (*cf.* Chomsky *ibid.*, 1965, 1988; Fodor 1983).

In cognitive science, especially in J. A. Fodor's works (1983, 1985, 2000), it is proposed that the mind is modular in the sense that it contains a number of different systems (modules) each with its own distinctive properties, such as the language system and the vision system (also see Crystal 1997). He (1983, 2000; also in subsequent works) has conceptualized modularity basically as the structure of the cognitive systems that are composed of modules whose functions can be characterized individually and independently from each other.

2. Fodorian Cognitive Modularity of Mind

Following Chomsky (1957; 1965; 1988) and other evidence from linguistics as well as implications from philosophy of mind, J. Fodor (1983) has remarkably developed and widened further the idea of the modularity of mind in the 1980s. According to Fodor (*ibid.*), a module, located somewhere between the behaviorist and cognitivist views of lower-level processes, is defined as an information-processing unit which encapsulates knowledge in one domain (such as language, vision, physics, number, etc.) and the computations on it. It is, in essence, an input unit (responsible for language processing and perception) that domain-specific representations can be fed into. Moreover, a module can be an output unit (responsible for action) where central processor feeds information back down into. Modules in general are bottom-up, data-driven, fast, autonomous, mandatory and automatic (*cf.* Fodor *ibid.*, 2000).

Fodor (1983) describes reflexes that are said to replace the mind, according to the behaviourists' point of view (*cf.* Barrett & Kurzban 2006), as encapsulated (cognitively impenetrable or unaffected by other cognitive domains) and non-inferential (straight pathways with no information added); *viz.* high level processes. Low level processes are unlike reflexes in that they are inferential; thus, necessitating some form of computation (*cf.* *ibid.*). In contrast, the view expressed here, following the cognitivists' point of view, looks at lower level processes as continuous with higher level processes in their being inferential and cognitively

penetrable (influenced by other cognitive domains such as beliefs) (cf. Sperber 2001; Sperber & Wilson 2002). Eventually, Fodor (1983) arrives at the conclusion that lower level processes are inferential like higher order processes and encapsulated in the same sense as reflexes. He (ibid.) adds that 'lower level' cognitive processes are truly modular, whereas higher level cognitive processes are not modular since they have dissimilar properties. Elaborating on this argument, Fodor (ibid., 1985) defines modules as cognitive systems (especially perceptual systems) that meet nine specific criteria (or properties). The first five criteria describe the way that modules process information. These include, briefly, *encapsulation* (it is impossible to interfere with the inner workings of a module), *unconsciousness* (it is difficult or impossible to think about or reflect upon the operations of a module), *speed* (modules are very fast), *shallow outputs* (modules provide limited output, without information about the intervening steps that led to that output) and *obligatory firing* (modules operate reflexively, providing pre-determined outputs for pre-determined inputs regardless of the context). The other four ones pertain to the biological status of modules. These are *ontogenetic universals* (i.e. *innateness*; modules develop in a characteristic sequence), *Neural localization* (i.e. modules are mediated by dedicated neural systems), *pathological universals* (i.e. modules break down in a characteristic fashion following some disorder in the system) and *domain specificity* (i.e. the requirement that modules deal exclusively with a single information type) (Fodor 1983: 87-103).

A further idea of Fodor's modularity is that of the distinction between modular and non-modular systems. The first type is concerned with the mental processing in specialized systems that carry out restricted operations on a limited type of input; such as the parsing of visual array in the visual system. The second type is the one found in the central processor (i.e. a cognitive clearing house in which concepts are deployed, beliefs are formed, inferences are drawn, decisions are made, etc.) (cf. Fodor 1983, 2000).

The essence of Fodor's classical account of modularity, is based on the fact that mental architecture is a three-tiered system, composed of *sensory transducers*, *input-output system modules* and *the central processor*. According to Fodor (1983: 101–103), the sensory transducers are the system that draws information (auditory, olfactory, kinaesthetic, visual, etc.) from the external environment and transforms it into symbols or formats that can be processed by the input system modules. The input-output system modules, being vertical, inflexible and representing the unintelligent part of the brain, are responsible for converting

transducer symbols or formats into representations accessible to the central processor (i.e. responsible for perception and language-processing). Finally, central processors are the systems responsible for higher level conceptual activities such as reasoning, problem-solving, belief-fixation, hypothesis-generating, inference-drawing, and decision-making. Their major function is to organize or integrate representations, taken from the input system modules, with one another and with the memory, and hence, accept, reject or revise them in formulating beliefs. These processors are said to be free in communicating with each other, and in exchanging information with the input and output modules, viz., they can reach all kinds of information in the cognitive system. They feed information back down to the input system modules, which in turn, become output system modules. They are different from input-output system modules, since they are horizontal, unconscious, informationally unencapsulated and open, slow, optional, and general-purpose (see Fodor (ibid., also Fodor 2000; for the details).

Though it has encountered stiff resistance over the years, Fodor's minimal peripheral-system Modularity (notably, 1983), sometimes known as the 'Classical Modularity Hypothesis', has launched a great deal of research referred to as Post-Fodorian Modularity that deviates with various degrees from the general orientation of Fodor. In the coming two sections, an overview of the most striking Post-Fodorian Modularity hypotheses that concern us most here, is briefly given; namely, Functionalist Modularity and Massive Modularity.

3. Functionalist Modularity

Using a diagnostic checklist for modular systems: *encapsulation, inaccessibility to consciousness, speed, shallow outputs, mandatory operation(automaticity), fixed neural localization, characteristic breakdown patterns and domain specificity* (section 2, above), Fodor (1983) introduced his concept of modularity. However, Fodor himself has emphasized that these are neither necessary nor defining features of modules, and that modularity is a matter of degrees and that a system being modular means that it is modular “to some interesting extent” (Fodor, 1983, p. 37; see also Barrett & Kurzban 2006). In the Fodorian sense, modularity is considered a natural property with the association of certain features; the most essential one is encapsulation. The question raised by Barrett & Kurzban (ibid.) is: 'Is modularity something to be diagnosed via a checklist, or a natural property?'. According to many evolutionary psychologists (cf. Sperber 1994), the nature of modularity, like other natural properties, is

something to be discovered, and its concept should be grounded in the notion of functional specialization, rather than any specific Fodorian criterion. They, following biologists, contend that structure reflects function, but that function comes first (cf. *Ibid.*, see also Sperber 2005). In short, they, with their functionalist stance looking for specialization in cognitive processes, argue that modules should be defined by the specific operations they perform on the information they receive, rather than by a list of necessary and sufficient features. In particular, an empirical investigation which reveals that a particular system lacks one of Fodor's (1983) properties of modularity does not imply that the system is not modular (cf. Sperber 2005). This is the case even if one uses Fodor's own views, as he concedes that systems can be modular to a greater or lesser extent (cf. Coltheart, 1999).

To sum up, Functionalist modularity is principally interested in the ways (or mechanisms) in which functionally specialized systems (i.e. modules) are instantiated, and triggered to carry out their functions. In other words, functional modularists, and so does the present paper, view modules, apart from Fodor's diagnostic checklist, as those systems in the mind which are functionally specialized information-processing. More importantly, they propose that, contrary to the Fodorian view that only 'peripheral' systems such as vision are modular, most information-processing systems in the mind are modular as well, including what Fodor has called 'central' processes, such as those underlying reasoning, judgment, and decision making (see Sperber, 1994). This proposal is sometimes known as the 'massive modularity' hypothesis (cf. *Ibid.*, 1996; Pinker, 1997, 2005; Carruthers, 2005). This paper also asserts that a notion of modularity broader than the one Fodor advanced is possible, viz. modularity based on the notion of functional specialization, rather than Fodorian criteria such as automaticity and encapsulation (section 5, below).

4. Massive Modularity

According to the Massive Modularity thesis, developed by proponents of evolutionary psychology (Cosmides & Tooby 1992; Sperber 1994, 2002; Pinker 1997; Carruthers 2006, *inter alia*), the mind is modular (in some sense) through and through, including the parts responsible for high-level cognition functions like belief fixation, problem-solving, planning, and the like. Apart from Fodor's anti-Darwinian view, this thesis, in its traditional version, typically embraces the tenet of 'evolutionary adaptation' (cf. Sperber 1994, 2002).

Regarding their 'Massive Modularity Hypothesis', evolutionary psychologists contend that the human mind is composed largely, if not entirely, of innate, special-purpose computational mechanisms or 'modules.' The four central tenets of evolutionary psychology are: *computationalism* (the human mind is an information-processing device that can be likened to a computer made out of organic components rather than silicon chips); *nativism* (much of the human mind is taken to be innate); *adaptationism* (human minds are the mosaic, evolutionary product of a great number of adaptations to challenges posed by the environment of 'evolutionary adaptation' in their accumulative past); and *massive modularity* (according to which the human mind contains a large number of 'Darwinian modules,' comprising both peripheral systems and central capacities such as reasoning) (see Cosmides & Tooby 1992; Samuels 1998, 2000; Sperber 2002). In the light of these four tenets, the brain is viewed to be composed of a number of dedicated modules, each outfitted to deal with an adaptive problem. In other words, cognitive entities in the brain consisting of Darwinist modular system have many cognitive modules that are domain-specific, innate cognitive structures whose features are universal and largely determined by genetic factors, and they are a species of computational mechanism. Consequently, learning, in general, and the acquisition, generation, and perception of language, in **particular**, are not a general-purpose process (or domain-general), but rather, they are a special-purpose process (or domain-specific). In this regard, massive modularists agree with the Fodor's argument concerning the acquisition, generation, and perception of language; in that, Fodor, echoing Chomsky, thinks that language is one of the modules of mind (domain-specific) rather than part of the central processor (domain-general). This goes with the essence of his modularity which is based on "**information encapsulation**", viz. some of the information outside the module is not accessible from within (Fodor 1983, p. 71). For details, see Cosmides and Tooby (1992, 1994), Pinker (1994, 2005), Sperber (1994, 1996), among others.

In its modern version, Massive Modularity Hypothesis has reasonably proclaimed that mental processes consist of multiple specialized systems, rather than a single general purpose one. The proponents of this hypothesis argue that a large number of functionally specialized information-processing mechanisms are likely to perform more effectively and efficiently than a small number of systems with more general functions (cf. Carey 1985; Tooby & Cosmides 1992; Pinker 1997; Carruthers 1998, inter alia). For this reason, natural selection is said to go in harmony with developmental systems that give rise to function-specific cognitive

mechanisms (cf. Pinker 1997). They also argue that the problems such as the frame problem, or the problem of relevance, and combinatorial explosion, faced by information-processing systems, result from the fact that systems making inferences and decisions (like the human cognitive system) face the problem that the possible inferences given by data are essentially boundless (in perception, for example, sense data have an infinite number of possible interpretations) (cf. Tooby & Cosmides 1992). To avoid such problems, mechanisms with narrow functions can embody information about the computational process to reach the desired goal. To that end, natural selection is largely to prefer specificity in the kinds of information handled by computational mechanisms (ibid.). In short, the proponents of Massive Modularity explicitly assert that functionally specialized mechanisms with formally definable informational inputs are characteristic of human cognition and that these features should be identified as the signal properties of modularity. Therefore, concepts like function, specificity, specialization, cognitive mechanism fitness, domain specificity, or functional specialization, are highly significant in conceptualizing modularity properly.

The main thing to note here is that the operative notion of modularity differs significantly from the traditional Fodorian one. In particular, 'Module' here does not mean 'Fodor-module,' and the properties related to 'Fodor-module' like *proprietary transducers*, *shallow outputs*, *fast processing*, *significant innateness* or *innate channeling*, and *encapsulation* are struck out. Modules, for massive mental modularists, are isolable function-specific processing systems, all or almost all of which are domain specific (in the content sense), whose operations aren't subject to the will, which are associated with specific neural structures, and whose internal operations may be inaccessible to the remainder of cognition (cf. Carruthers, 2006). Of the nine features associated with Fodor-modules, massive modularists-modules retain only five: *dissociability*, *domain specificity*, *mandatoriness*, *localizability*, and *central inaccessibility*. Informational *encapsulation*, the feature most central to modularity in Fodor's sense, is remarkably absent from the list (ibid. p. 12). Relying on these features, modern massive modularists defend the modularity of central cognition, taking for granted that the mind is modular around the edges. Thus, they claim that input systems are modular in a strong sense, and that central systems are modular, but in a considerably weakened sense (cf. ibid. ; Sperber 1994, 2002, inter alia). (see section 5, below)

To sum up, the insights of the modern Massive Modularity Hypothesis (that concerns us most here) claim that in human mind there is substantial modularity

extending over central systems (i.e. central modules), and peripheral input and output modules as well. In essence, it contends that the mind is modular 'all the way down', viz. information-processing systems exist not only in the peripheral systems but throughout the mind architecture. (Sperber, 1994; see also Carey & Spelke 1994; Spelke 1994; Smith & Tsimpli 1996; Carruthers 1998, and Cosmides & Tooby 2001; Tooby et al. 2005).

In the light of all those highly convincing arguments and principles presented in the Massive Modularity Hypothesis discussed so far, the paper attempts in the following section to develop a hierarchically cognitive-functionalist model of the modularity of mind, taking into consideration all the bright sides of Fodor's Modularity, but not the dark ones. More specifically, the proposed model tries to fuse positive insights from these both theories, (i.e. Massive Modularity and Fodor's Modularity), in order to offer an innovative account of cognitive modularity (section 5, below).

In this model, the functional cognitivists' point of view based on global modularity is adopted that is perfectly consistent with the computational psychologists' view that the mind is computationally realized in mental processes operating via algorithms or programmes constituting inter-module and intra-module encapsulated- processing systems that make the mind massively modular through and through, including the parts responsible for high-level cognition functions (i.e. the central processors) like belief fixation, problem-solving, planning, and the like. My view, then, is that the modular information-processing systems exist not only in the peripheral systems but throughout the architecture, applying to all brain systems, from edge detectors (a domain-specific mechanism) in the visual system to a working memory buffer (a domain-general mechanism) (cf. Chiappe & MacDonald 2005) .

These considerations suggest that there is no natural line that separates domain-specific from domain-general mechanisms. Processing information about faces, cars, quantum mechanics, and so on, working memory, unlimited in content, requires functional specialized subsystems with very particular representational formats (the "visuospatial sketchpad," the "phonological loop," and the "episodic buffer") that together constitute working memory (Baddeley 2002), whose function is to integrate information. In global information processing, there is always a free access to working memory (i.e. background knowledge). Therefore, it is plausible to think that the working memory constitutes a separate system or module, viz. working memory system (see 5.2, below). Accordingly, unlimited or unrestricted

accessibility to working memory(i.e. globality, informationally unencapsulated flow across computational mechanisms) does not necessarily denote the absence of modularity; rather it denotes that modularity is a matter of gradation, and that a modular system is modular to some interesting degree. The correlation between encapsulation (i.e. cognitive impenetrability) and modularity, on the one hand, and that between globality and modularity, on the other, suggests, as I believe, a significant correlation: the more global the process, the less modular the system that executes it, and vice versa. As a corollary, this massive or central model of modularity takes the signal feature of modularity to be specialization of function; hence, to carry out their specialized functions, modules can be predicted to operate on only certain kinds of inputs or to privilege inputs relevant to that function. Furthermore, it takes the position that functionally specialized mechanisms(based on domain specificity) with definable informational inputs are features of human cognition and that these features should be conceptualized as the signal properties of modularity. In this sense, the model proposes the following specific features that the module must have; these include: *domain specificity*, *mandatoriness*, *localizability*, *speed*, *ontogenetic universals*, *innateness*, *unconsciousness*, *dissociability*, *central inaccessibility*, and *encapsulation*. It is worth emphasizing again that the last two features are interpreted here, apart from Massive Modularity Hypothesis as well as Fodor's' Classical Modularity Hypothesis, as properties of continuum or gradation rather than properties of extreme dichotomous ends; starting from the narrowest-scope and ending with the widest-scope systems, across the intermediate-scope ones (see section 5).

5. Cognitive-Functionalist Model of Modularity (CFMM)

The Cognitive-Functionalist Model of Modularity (CFMM, henceforth) views the mind as an information-processing mechanism and a computational system of knowledge, as well. Building on this, some mental modules are processing systems demonstrating some features of Massive and Fodorian input-output modules; and others are entities of knowledge. Modules, in both forms, are conceived as domain-specific, functionally special-purpose and organized hierarchically on three cognitively interrelated higher systems, viz. '*central processor system*', such as that underlying reasoning, judgment, and decision making; '*working memory system*', such as that related to processing systems of information, language, sensory modalities, creation, memory, etc.; and '*peripheral system*', such as that underlying input-output system modules.

In this regard, the theoretical framework of **CFMM** is based on the assumption that encapsulation, in the present sense of **CFMM**, falls into three kinds: *narrow-scope*, *intermediate-scope* and *wide-scope*. A system is narrow-scope encapsulated, more functionally specific- domain (i.e. more modular), if it cannot draw on information held outside of it in the course of its processing, but it can be controlled or influenced top-down by the central processor system. By contrast, a system that is encapsulated in the wide-scope sense, more functionally general- domain (i.e. least modular), can draw on exogenous information during the course of its processing (it just can't draw on all of that information at once); it can be updated, modified or influenced by the other two systems, viz. the narrow and the intermediate (see also Carruthers 2006). As for the intermediate-scope encapsulated system, more modular than the wide-scope system, but less than the narrow-scope one, information held outside of it can be partially drawn on in the course of its processing that can be controlled or influenced horizontally or top-down by the central processor system.

In short, the essence of **CFMM** is based on the fact that the modularity of the mental architecture is a three-tiered system, composed of *Narrow-Scope System Modules*, *Intermediate-Scope System Modules* and *Wide-Scope System Modules* that can be explained as follows: and *the central processor*.

5.1. Narrow-Scope System Modules : These systems, forming the lower level of cognition, cover all processes performed by *input-output system modules* (and *sensory transducers*, to an interesting extent). Input systems, being modular, mean computational mechanisms that present the world to thought by processing the outputs of sensory transducers. A sensory transducer is a device that converts the energy impinging on the body's sensory surfaces, such as the retina and cochlea, into a computationally usable form, without adding or subtracting information(cf. Fodor 1983). In effect, input-output systems, due to their specific operations they perform on the information they receive, are responsible for translating the formats (or symbols) into cognitive representations of various types accessible to modules in other higher systems; or translating cognitive representations into formats or symbols, in the course of output operations. Having specified input criteria, they handle information in specialized ways; only information of certain types or formats is supposed to be processable by a specialized system (ibid.). They cannot access other modular systems, but they can be accessed, controlled or influenced top-down by the central processor system. In this regard, They normally receive

orders and instructions from other higher systems; particularly from the central processor system. They are flexible, fast, narrowly encapsulated, functionally specific-domain, and properly modular, representing an essential part of human mental architecture.

5.2. Intermediate-Scope System Modules: Intermediate-scope encapsulated systems are those systems that are partially encapsulated, and hence, less modular and more intelligent than the narrow-scope systems, but more modular and less intelligent than the wide-scope systems. These modular systems, getting access into the information offered by narrow-scope systems, can partially draw in the information available outside of them during their processing operations that can be controlled or influenced horizontally or top-down by the central processor system. This second layer of central modularity of human mental architecture is chiefly managed by the working memory module which, in turn, encompasses a set of sub-modules. Working memory, as mentioned above, postulates functional specialized subsystems with very particular representational formats that together constitute its computational framework whose function is to integrate, organize, filterize, correct, etc., the information or formats received from narrow-scope systems, under the control and influence of wide-scope systems. The sub-modules of working memory are functionally domain specific; in that, each one, under working memory manipulations and management, deals with a specific type of information (or symbols) that suits the specialized function it is responsible for. In this respect, mental processes performed inside working memory are supposed to consist of multiple specialized systems, rather than a single general purpose one. Therefore, working memory systems, due to their multiple number of functionally specialized information-processing mechanisms, likely perform more effectively and efficiently than central processor systems having a small number of systems with more general functions. According to **CFMM**, working memory systems consist of the following sub-modules (names of some sub-modules used here are taken from Jassim, 2004):

5.2.1. Language Module: This module is responsible for language processing (i.e. production and comprehension), in the first place, and for other social, cultural, psychological, cognitive, etc., issues related to that processing. There is a strong tendency in the literature towards the independency of language knowledge from other faculties of mind. This tendency is based on the fact that when other mental faculties are impaired or even broken down, Language faculties remain intact and

active, and vice versa. Language processing is highly spontaneous and probably automatic to the extent that language users are fully unaware of the computational complication of the mind.

5.2.2. Information Module: The major task of the information module is to be a mental bank or storage of information; that is to store, paradigmatically in forms of beliefs and utilities embodied as mental models or frames, various types of information such as beliefs, concepts, norms, values, principles, etc. Information module is normally ready to receive or deliver information (or knowledge) of different kinds from or to the narrow-scope system modules, under the working memory module monitoring, whenever necessarily. Metaphorically speaking, it acts as a well-organized record full of sufficient information reflecting the inner reality as well as physical reality of a human being.

5.2.3. Sensory Modalities Module: This module is responsible for processes pertaining to all sensory representations (be visual, auditory, olfactory, gustatory, tactile, etc.), internal feelings, pain, sensations, desires, remorse, etc. The significant role of this module is to interpret, control and trigger these representations.

5.2.4. Theory of Mind Module: Theory of mind (ToM) is a form of connectionism that is neither antimodularist nor antinativist. It is the (meta)theory (i.e. a meta-representational capability) of how people or animals attribute mental states to each other and use them to predict others' behaviour. In other words, it refers to the cognitive capability to predict, interpret and explain others' actions and intentions in terms of their underlying mental states such as beliefs and desires. ToM is explored to be grounded in a cognitive module and its modular capacity, that is cognitively penetrable within the boundaries of working memory modules, needs to be acquired and developed in various ways. One of its characteristics is the ability to reason about false beliefs (c.f. Scholl & Leslie 2001). For further elaborations on 'Meta-Theory' and 'Meta-Modules', see Al-Bajjari (forthcoming).

5.2.5. Memory Module: Memory module is basically responsible for storing various types of information related to visual and auditory sensors, and the like. It is cognitively penetrable by other sub-modules of the working memory.

5.3. Wide-Scope System Modules: These systems, forming the higher level of cognition, cover all processes performed by the central processor module (CPM) that is the least encapsulated, the least modular, and hence, the most functionally general- domain. In this sense, this module is largely penetrable, and thus, it can draw information held outside of it in the course of its operations; it can send orders and instructions to all other modules in the mental architecture, and, in turn, receive updating, modification or influence from them. CPM is, metaphorically speaking, freely moveable, due to its high speed, flexibility, intelligence and accessibility; it can computationally reach all modules all over the mental architecture. Therefore, it plays, with regard to its central task, multiple roles in the global modularity of the mind; coordinator, organizer, integrator, guider, instructor, attention-getter, decision-maker, creator, thinker, etc. Thus, it exercises full control over the other two lower-system modules.

To defend its intelligence, CPM can, in so far as its fast processing mechanism is concerned, provide the right representations/interpretations to the target modules, and associate them at the right time in a very short time. The psychological ground of CPM's intelligence is obviously reflected in the fast mechanism of all its operations, procedures and processes. In this sense, the fast decisions, taken by CPM to organize the information processing and to decide which module to start first (regarding the type of input data received by the transducers) , are highly intelligent, and basically rely on the importance scale. CPM has multiple sub-modules operating within its global modularity. These internal modules include:

5.3.1. Reasoning Module: The reasoning module, cognitively penetrable like the other sub-modules of CPM, contains all forms of logical inferencing (inductive, deductive and abductive), thinking, problem-solving, decision-making, planning, and so on.

5.3.2. Creation Module: This module seems to be very smart with regard to its creative operations. It is essentially responsible for general intelligence, mental creativity, dexterity, and imagination. It deals with all creative instincts and creative abilities in various situations (cf. Cosmides and Tooby 1992). Also, it deals with staples of human cognition such as analogy, metaphor, and counterfactual reasoning, viz. issues in which content or context effects are observed in processing.

5.3.3. Intention Module: The major processing function of the intention module is to determine the highest interest or intention of the individual. To that end, it organizes and arranges the resultant operations within the domain of CPM in an intentional way, so as to reach the target determined by achieving the maximum benefit for the individual.

5.3.4. Awareness Module: This module is specifically concerned with security and safety matters inside CPM and outside it as well. Therefore, the operational work performed by this module falls into two directions. First, *external awareness system(EAS)* is principally concerned with specifying the various sources of danger. Therefore, it puts other modules on alert when there is danger threatening interest or safety. It also gears other modules towards achieving maximum security. Second, *internal awareness system(IAS)* contains a set of meta-rules which are responsible for harmonizing the results of the operations of other modules and organizing their relationships. Meta-rules also specify the time span which a module should take in order to perform the required task. In effect, this system brings general coherence, not only inside CPM, but in the whole mental architecture. Because of the remarkable processing importance of awareness module and intention module, CPM sometimes consults them for a set of instructions for its internal processing.

To summarize diagrammatically the theoretical principles of **CCTM** discussed so far, I have schematized the general framework of **CCTM** in the following figure:

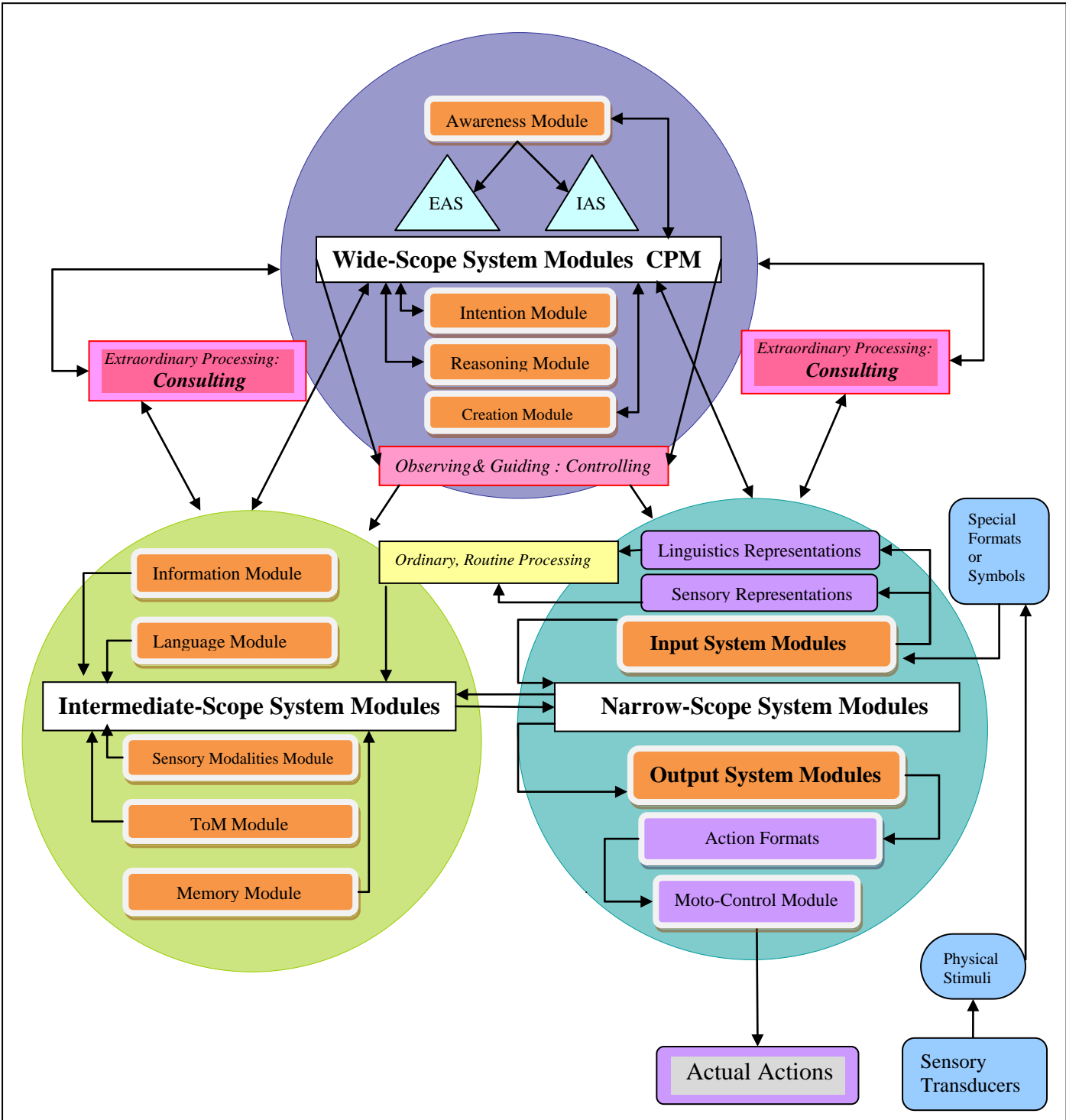


Figure: The Schematic Framework of **CFMM**

Regarding the figure above, there are certain points related to the processing mechanism of **CFMM** need to be clarified briefly. To start from the very beginning

of such mechanism, sensory transducers, an external part of narrow-scope system modules, take in the physical stimuli from the physical world and convert them to special formats (or symbols); then, these formats are translated into linguistic and sensory representations in the input system modules, an internal part of narrow-scope system modules. In the case that the input requires ordinary processing, narrow-scope system modules transmit it to the higher processing system, viz. intermediate-scope system modules, under the full control of wide-scope system with its (meta-) modules; specifically, CPM. On the other hand, in the case that the input demands extraordinary processing, narrow-scope system modules consult CPM directly, so as to get the most desirable results. As shown in the figure, intermediate-scope system modules and narrow-scope system modules are constantly guided with the recommendations and instructions given by wide-scope system modules; notably, awareness module and intention module. When the input processing mechanism comes to the end, intermediate-scope system modules send the processed representations back, as output, to narrow-scope system modules in order to translate them into action formats and send them to the motor-control module which, in turn, translates them into actual actions. Also, the output processing mechanism is submitted entirely to the CPM control and instructions.

CONCLUSION

The massive principles of CFMM, owing to their hierarchically organized framework, have definitely led to further evidence of the flexibility, massiveness, globality and modules multiplicity of the concept of modularity, hence, presented an undeniable argument against the narrow and limited orientation of Fodor (1983) in his 'Classical Modularity Hypothesis' based on modularity of low-level systems underlying perception and language only. CFMM, influenced by modern massive modularists to a certain extent, has contended here that the mind is globally modular to the extent that the high-level systems responsible for thought are included.

CFMM, in its critiques of Fodorian dichotomous view of modularity (i.e. encapsulated systems are modular; unencapsulated ones are not!) which is built entirely on an absolute sense of encapsulation, domain specificity, innateness and the like, has brought an access to a more conceptually plausible interpretation of modularity based on the relativity of such features. In contrast to the Fodorian narrowness of modules' inputs and outputs, CFMM proves, owing to its three-tiered system of modularity, that it is easy to see a role for modules at higher levels of processing, where information from diverse modules (or sources) is integrated. This claim against encapsulated modular processes finds an empirical support in neuroscience. Neuroscientists have found that the activation of multiple brain areas when carrying out a particular task suggests integration of information from multiple sources. In this regard, CFMM has made it clear that multiplicity of modules, flexibility, massiveness and globality are essential properties of the mental modularity, and that there is no modular mechanism being either encapsulated or unencapsulated in an absolute sense; rather, cognitive mechanisms of modularity can be referred to as encapsulated with respect to certain information types but not others. In other words, encapsulation (and hence, modularity) is interpreted by CFMM as a matter of continuum, gradation, or degrees; rather than a matter of dichotomy (or black and white!, metaphorically speaking).

There is also another important concluding remark raised by CFMM pertaining to context effects on modularity. In this respect, processes like the pragmatic comprehension of speech acts, analogy, metaphor, or counterfactual reasoning that usually involve global principles (or central systems) like relevance, interactivity, integration, neural connectivity, are conceptualized by CFMM as properly modular, processed within the domain of CPM; more specifically, within the boundaries of the creation (meta-) module. Unfortunately, this is not the case with other

modularity hypotheses like the Fodorian one which look at these meta-processes as non-modular and as cases for which modularity must be ruled out. Fortunately, CFMM has managed to overcome this pitfall by relying on its global principles that there is a considerable amount of cognitive penetrability among the mental modules; particularly, at the higher levels of modularity. As the figure (p.18) shows, processing modules of intermediate-scope system and wide-scope system, in the course of their routine operations, are cognitively penetrable, or affected by other cognitive modules.

The last remark which is worth emphasizing here is that CFMM has presented cognitive modularity as a tool for thinking about the mental architecture, in particular, and mind in general. More importantly, CFMM, being a cognitive-functional account of modularity, could be helpful to an interesting extent in explaining the systematic relationships between information inputs and behavioural outputs.

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