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Massive modularity? The relationship between context-relevance, information encapsulation and functional specialization

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Abstract
In this article, I discuss the debate between domain-specificity and content-generality in regard to the human mind. My main objective is to argue that the human mind can both be understood as a content-dependent machinery, as well as a general-purpose system that encapsulates information and manifests it accordingly. In evolutionary psychology a strong case is made for the mind's domain-specific architecture but assumptions of domain-general importance could also be taken into account. In evolutionary terms, it is argued that the mind is composed of content-dependent and specialized functions that have evolved in order to help humans deal with adaptive problems. The mind's evolved functionality of domain-specific systems has helped humans not only to survive but also to be creative in their relationships to others and the environment. However, advocates of behaviourist models and learning theories have proposed that the mind is a content-independent device which encapsulates information of a general nature. In this paper, domain specificity will be explained in terms of functional specialization, and content-generality in terms of informational encapsulation. My main aim will be to argue that both assumptions can be viewed in context-relevance to each other.

Keywords: Evolutionary psychology, domain-specificity, functional specialization, general-purpose system, informational encapsulation, innate automaticity, integrative modularity.

Introduction

Human behaviour consists of distinguished mental abilities that relate to complex neural activities (Cosmides & Tooby, 1992; 1994). Abilities, such as mathematical skillfulness, cooperation with others, cheater-detection, navigation in environment, all depend on cognitive structures of specific circuitry (Gelman, 2000). Cognitive structures are domain-specific, modular in function, and refer to the information-processing machinery of the human mind (Khalidi, 2001; Cosmides & Tooby, 2008). Charles Darwin (1859) and William James (1890) were among the first theorists who anticipated the domain-specific explanation of the human mind and its importance for the understanding of human behaviour.

Domain-specificity is not the only field of explanation for the human mind. It has been suggested that domain-generality could also be viewed as significant (Quartz, 2002). Domain-generality understands the mind as general-purpose cognitive system composed of content-independent functions. These functions are modular in nature and feature the structure of the mind with specialized abilities (Karmiloff-Smith, 1992; Fodor, 2000). The case for domain-generality concentrates mainly on behaviourist accounts, such as the issue of learning, and how that is acquired from human cognition (Karmiloff-Smith, 1992). In contrast, domain-specificity explains human behaviour not as an outcome of learning processes but as an outset of specialized cognitive functions. Specialization is context-dependent and dedicated to a content of multi-modular organization (Samuels, 2006). Learning, according to the domain-specificity argument, is not an issue of stimuli coming from the environment, but the outcome of functionally organized modules. These modules are content-central and especially designed for skills and knowledge acquisition (Barrett & Kurzban, 2006; Machery, 2007).

The tug-of-war between the two approaches relates to the interpretation of information and how this is processed by the mind. By information what is explained here is the content of individuals' knowledge, as well as their beliefs, assumptions, fictions, rules, norms, skills, etc. Information is seen in the form of *mental representations* which depict the *material realization* of it in the mind. *Mental representations* become *public productions* concerned with guided behaviours that are transmitted between individuals. *Public productions* can be explained as *public representations*, and include speech, gestures, writing, postures, and etc. Observation and imitation, although they cannot be assumed to be public representations, can still be included here, for they transmit information (Sperber, 2007).

This article will discuss the debate between evolutionary psychology and learning theories in regard to the mind. Is the mind a multi-modular system in terms of structure, or structure-free elements? Is the mind a modular system which explains that adaptive problems can be resolved by the use of a specialized cognitive structure, by the use of general-purpose cognitive machinery, or both?

Presentation of the debate: Issues of informational encapsulation and functional specialization

The domain-specificity/domain-generality debate as to the mind's cognitive architecture originally refers to the epistemological framework of two different approaches:

1. The aspect of *informational encapsulation* (Fodor, 2000), which refers to *the enclosure of the mind's cognitive structures in a massive modularity system*.
2. The aspect of *content-dependent sets of computational processes expressed by outputs - referred to as particular domains - that are functionally specialized* in the mind (Tooby et al., 2005; Stenning & van Lambalgen, 2007).

Both accounts consider the mind as modular in function; however they approach modularity from different starting-points. On the one hand, modularity is understood in terms of causality and functionality, independently processing information across all modules of the mental system; on the other, it is seen as specialized and closely associated to the differing information-processing abilities of each module (Okasha, 2003).

These two accounts diverge from one another, because:

1. The one regards modularity as an outset of independent functions carried through by every single module.
2. The other explains modularity from an evolutionary point of view, where modules are explained as content-focused, in order for adaptive problems to be identified and resolved (Coltheart, 1999).

The domain-specificity argument for the human mind: The case for a content-focus assumption and its relation to informational encapsulation

According to a metaphor (Horgan, 1995), the mind could compare to a Swiss army knife crammed with functionally specialized tools. The mind forms a system of information-processing devices designed by natural selection to solve adaptive problems (Cosmides & Tooby, 1997b; Sweller, 2006). It consists of species-typical adaptations presented in a biological system of incomparable heterogeneity, known as 'the brain' (Richerson & Boyd, 1999; Cosmides & Tooby, 2001).

In cognitive science, brain and mind refer to understandings of physical properties and executive functions (Oatley, 1985; Cosmides & Tooby, 1999). The brain is considered as a system of minicomputers dedicated to generate functionally integrated behaviours (Cosmides & Tooby, 1997b; Portillo & Gleiser, 2009). The mind was designed by natural selection to be composed of domain-specific mechanisms relevant to the physical organization of the brain (Jerison, 1985; Cosmides & Tooby, 2001). Domain-specific mechanisms are evolved adaptations of complicated cognitive architecture explaining the problems hunter-gatherers were facing in our evolutionary past (Cosmides & Tooby, 1994; Kanazawa, 2004). Evolutionary psychology considers the brain's neural circuitry a valuable tool in outlining the modular function of the mind (Cosmides & Tooby, 1999; Bereczkei, 2000).

The mind's composition of a large number of multi-purpose specializations explains that they can distinctively:

1. deal with an information-processing adaptive problem;
2. present neural circuitry equipped with functional particularity as to the specific nature of a problem;
3. apply evolved solutions via specialized machinery engineered to win over an adaptive problem;
4. Integrate knowledge on problem-relevant aspects, in accordance to the evolved design of the mind's specific functions (Cosmides & Tooby, 1999; Kennair, 2002).

The human mind is composed of a large number of domain-specific adaptations because natural selection is a theory of function (Jerison, 1985; Cosmides & Tooby, 1994). For solutions to be applied to adaptive problems, cognitive functions of the mind have been selected for. Adaptive problems and cognitive functions are contingent on each other (Cosmides & Tooby, 1994; Macpherson, 2002). Natural selection forms content-rich cognitive mechanisms able to provide solutions to evolutionarily posed domain problems (Symons, 1992). Content-specific functions of the human mind infer content-dependent problem-solving. That means that problem-solving strategies require specific cognitive preconditions (antecedents) to be in place, in order true or false reasoning concomitants (consequents) to be met (Cosmides, 1989; Becker, 1991; Cosmides & Tooby, 1992).

An example explaining the domain-specificity of the human mind is the Wason's selection task which asks participants to find how the conditional rule of the premise *If P then Q* could be violated (Wason, 1966). Participants are presented with four cards and asked which two they should pick to see whether the rule is violated (Cosmides, 1989; Evans & Newstead, 1995). What participants are actually asked is to falsify the *If P then Q* rule by choosing the cards *if P then not-Q* (Wason & Johnson-Laird, 1972). *If P then not-Q* choice is the logically correct answer, for the selection of the *P* card unravels a *non-Q* value on the other side, and vice versa (Cosmides, 1989; Griggs, 1995).

Social contract versions of this task explain that human mind includes inferential functions at detecting cheaters (Stone et al., 2002); a social contract version of this task could be: *If you mow the lawn I will pay you a fiver* (Eysenck & Keane, 2003). This is because human mind recognizes the reciprocal nature of social exchange by possessing specialized reasoning dedicated to the detection of cheaters (Trivers, 1971; Cosmides, 1985). Laursen and Hartup (2002) as well as Cosmides and Tooby (2005) argued that people look for the adaptively right answer in a social contract environment to detect potential rule-breakers. Social exchange interactions are conditional upon benefits and costs, provided that costs are less than the net benefits gained (Axelrod & Hamilton, 1981; Cosmides, 1989). Social exchange is another form of reciprocal altruism (Trivers, 1971; Axelrod, 1984), which refers to evolutionarily recurring relationships of human interaction (Cosmides & Tooby, 2005; Teboul & Cole, 2005).

The Wason selection task explains evolutionarily recurring relationships in social contract terms regarding conditional rules that have been breached (Cosmides, 1989; Wagner-Egger, 2007). The logic of this task means that the more explicit an adaptive problem, the more vividly specified and improved would be the selection of a mental mechanism to solve it (Williams, 1966). The mind solves adaptive problems via a number of special-purpose capacities, designed to confront challenges (Chomsky, 1980); an assumption which was also suggested by Darwin (1859).

The mind's design of specific cognitive elements explains for evolutionary psychology the functional organization of specialized features towards problem-identification, decision-making, and problem-solving. That means that skills and knowledge acquisition depend on the informational content of the articulation process in order for relevant solutions to be suggested.

However, if this is the case, what about content of information which is: a) cognitively impenetrable - such as auditory or visual illusions; b) difficult to be articulated - such as related or not to reality; c) varied in ways of being processed by the mind as to the context of their constituent parts or d) consists of inputs that have not been fully distinguished by the cognitive system, in order for relative outputs to be produced. From an informational encapsulation point of view it can be suggested that information cannot be processed because of lack, or limited availability, of mental representations produced in the mind (Sperber, 2001; Muis et al., 2006).

The domain-general argument for the human mind: The case for a domain-independent assumption and its relation to content-specificity

Informational encapsulation assumes that the mind is a massively modular system subject to a massive functionality organisation (Fodor, 2000). According to this thesis, only peripheral systems, such as vision, are modular, whilst anything else is non-modular, such as cognitive systems (Fodor, 1983). Encapsulation processes have access to only limited information, excluded from being pertinent to other outputs produced elsewhere in the organism. Cognitive systems are encapsulated in an all-inclusive operation of outputs that are autonomous and totally unrelated to other mental systems (Sperber, 2007).

Informational encapsulation is subject to:

1. The massive modularity view of input systems;
2. The massive functionality organisation of the mind's cognitive systems;
3. General, and not central, cognitive outputs (Sperber, 2001).

To understand the above, it is argued by Fodor (1983) that stimuli operate:

1. As *transducers*, which convert and process signals;
2. As *input systems*, which, in a massively modular way, produce inferences relevant to the sources inputs are admitted to;
3. In association to general-purpose cognitive systems, both in terms of reasoning and external appearance.

Informational encapsulation stands in contrast to domain specificity. It argues that the evolution of human behaviour can be explained in terms of a mind *located* in a domain-general system of content-independent structure (Cosmides & Tooby, 1994; Carruthers & Chamberlain, 2000). A content-independent structure has been proposed by learning theories that see the mind as a general-purpose machine useful for fitness-maximizing (Cosmides & Tooby, 1987; Samuels, 2006). Their main assumption is that the mind is a content-free system offering solutions to any fitness challenge (Cosmides & Tooby, 1994; Veenman et al., 1997).

The human mind as a general-purpose computer traces its origin to the ideas of the 'blank slate' (Locke, 1690; Watson, 1925) and the Standard Social Science Model (Degler, 1991; Tooby & Cosmides, 1992). The human mind's content-generality derives from the environment and the social world. Social processes take place in particular milieus without necessarily being subject to individual transactions (Cosmides & Tooby, 1994; Kaufmann & Clément, 2007).

Researchers describe domain-generality as learning, imitation, rationalization, induction, intelligence (Cosmides & Tooby, 1999; Saffran & Thiessen, 2007). The social world, according to this account, is the external factor and an individual's psychological and physical fitness depend on it (Cosmides & Tooby, 1994; Kaufmann & Clément, 2007).

According to understanding, the social world is alternatively viewed as 'culture' assumed to be maximizing an individual's fitness by:

1. Being socially learnt and passed on from generation to generation;
2. Forming the learning process of one's adult life, for every human mental activity is primarily content-independent;
3. Being represented via intra-group similarities (Berger, 1966; Cosmides & Tooby, 1994).

The general-purpose assumption asserts that, whether an adaptive problem has already been or hasn't been encountered, it is possible for a solution to be suggested (Cosmides & Tooby, 1992; Gratch & Chien, 1996).

However, in the EEA (Environment of Evolutionary Adaptedness), when our ancestors were confronted with adaptive problems, they were making use of evolved cognitive mechanisms (Cosmides & Tooby, 1994; Evans & Zarate, 2000). The use of such mechanisms over evolutionary time assisted them in a consistent way to face different situations (Cosmides & Tooby, 1987; Anderson, 1990). Cooperative interactions, such as helping others, or competitive strategies do refer to information processing of conditionals, regulated by cognitive designs to evoke specialized and content-focused functions (Cosmides & Tooby, 1997a; Wagner-Egger, 2007). One such cognitive design is language: To be acquired there is the need for evolutionarily recurrent mental activity which should be domain-sensitive (Cosmides & Tooby, 1987; Storey et al., 1997). If the opposite is true, it means that communication expectations cannot be met, because they lack functionally distinguished mental architecture promoting the learning of a language (Chomsky, 1980).

The general-purpose machinery of the mind predicts that any activity performed is dependent on functions of experience and familiarity which promote fitness-maximization. Fitness-maximization is the outcome of content-independent experiences, whether these relate to evolutionary adaptations or not (Buller & Hardcastle, 2000; Cosmides & Tooby, 2008). Content-general computation is the case for such an assumption of the human mind, without the need for functional specialization to be involved (Tooby & Cosmides, 1992; Duchaine et al., 2001).

However, if the mind is content-free and independent of any specialized cognitive activity, what about complicated structures, such as face recognition (Bruce & Young, 1986)? Face recognition ability is explained as composed of distinguished specialized structures of content-specific functions in the brain which distinctively recognize a face, facial features, or the ID of an individual (Boyer & Barrett, 2005; Eysenck & Keane, 2005). If the content-free assumption about the human mind is true, then the rest of our biology should also be that way, such as having one sense organ instead of five (Gallistel, 2000).

The example from face recognition supports not only the domain-specificity argument but the informational encapsulation view as well. Physiologically speaking, the term 'encapsulation' can be found in many instances: for example, we say '*encapsulation of tendons in membranous sheaths*'. Face recognition is dependent on a number of neuron cells which *encapsulate information for face recognition through the right middle fusiform gyrus*. *Membranous sheaths* can be found in many parts of the human body including the brain. *Tendons* are enclosed in *membranes*; however, tendons and membranes are not operating in the same way. A tendon functions in association to an inelastic tissue connecting a muscle with its bony attachment; whereas a membranous sheath is the covering sheet operating as an outer layer that protects the tendon.

Although face recognition is the outcome, it may also be the informational encapsulation of a number of different cognitive processes. For instance, not all parts, such as face features or the name of the individual, are located in the same brain areas. Face features and name recognition are found in the *parahippocampal*, *lingual*, and *peri-calcarine areas*, meaning that cognitive abilities do not operate on their own. They operate in association to other brain locations referred to a number of different neural processes. Interestingly enough, cognitive abilities can be found encapsulated in many content-specific neural structures aiming at producing differentiated cognitive operations.

Domain-specificity can therefore be viewed as the content-dependent capability of the mind, however independent of the interaction resulting when information is processed through a number of different outputs (Gallistel, 1999). Having a cognitive system specialized for the A or B domain does not mean that such cognitive system could not stand available or "co-opted" for "evolutionarily novel activities" (Boyer &

Barrett, 2005: 99); i.e. for activities outside the remit of an already content-dependent structure, activities of an encapsulation-informed template.

Discussion: Context-relevance approaches between informational encapsulation and functional specialization

The human mind is not a general-purpose fitness-maximizing computer. It is especially designed for cognitive functions contingent upon domain-specific structures so that adaptive challenges could be faced. Such challenges cannot be statistically systematic in terms of fitness. This is because processes of action on fitness cannot be carefully assessed due to a different representation of genes over succeeding generations. On the other hand, the human mind may consist of content-independent domains as well. Such domains may present a functional modular system of a general-purpose applicability, such as detecting cheaters not only in interrelationships but also in abstract social endeavours (Veenman et al., 1997). As an evolutionary psychologist, though I regard the mind as functionally specialized, I nevertheless consider that such a thesis is one-sided. I would think that what Fodor conceives of as *informational encapsulation* can be related to the issue of *functional specialization*, so that convergence and not divergence is the case.

We know that the precedence of modularity impacts to the generation of information-integrated systems. Information-integrated systems employ independent functions of cognitive architecture in order for elements of behaviour and action to become manifest. This is an important thesis for both functional specialization and informational encapsulation, because 'behaviour' and 'action' are functionally dependent on human cognition. Therefore, domain-specificity and domain-generality are issues of context-relevance to each other.

Context-relevance is the point of convergence between functional specialization and informational encapsulation, for it refers to the aspect of *innate automaticity*. The aspect of innate automaticity explains that information can both be subject to a specific content as well as to modular functions of general-purpose nature. Innate automaticity can also be understood in terms of an internal working process in the mind, where sensory information is processed as an input resulting in particular representations (outputs). Representations are demonstrated via templates of content-specific behaviours. Context-relevance between domain-specificity and domain-generality explains the mind's cognitive architecture in terms of *integrative modularity*. By that I mean that *innate functions* and *external processes* are dependent on one another. They are dependent not only in the form of devices that process specialized informational content, but also in devices of a content-independent structure. The latter refers to the comprehension of the information received which is independent of the content that information 'needs' in order to be processed.

An example to understand the above could be computers that are regarded as entities of general-purpose machinery. Computers need hardware and software for their operating systems, programs, accessories, etc. Next to such general-purpose machinery a number of distinctively characterized sub-mechanisms composed of smaller functional units are attached, all of which assist the operation of the entire system. For, what could be the use of a general-purpose machinery without the need for smaller functional entities, so that the system could be up-and-running? None! All distinct functional units, or modules, depend on the general-purpose machinery, and vice versa.

Modularity of the mind is both domain-specific and domain-general: Human cognition is indeed a domain-general system; nevertheless, it is distinctively divided into units-modules of a special content without which the mind wouldn't be able to properly function. All units-modules are massive in their composition, consisting of even much greater sub-units and modules. Such composition pinpoints to the *massive modularity* argument, for it implies:

1. An 'oceanic structure', as to the constituents of the mind's modular functionality;
2. Components that operate independently to the content of each other.

In such an explanation, massive modularity underlines that both informational encapsulation and functional specialization belong to the same evolved cognitive architecture. Such evolved cognitive architecture was selected for, in order for adaptive problems to be effectively confronted (Barrett, 2008).

The current understanding about modularity, by evolutionary psychology, is approached in terms of information-processing. However, evolutionary psychology needs to re-examine its domain-specificity assumptions, by explaining massive modularity as both functionally specialized and information-encapsulated.

The human mind is composed of domain-specific and domain-general cognitive features designed to deal with the structural content of evolutionarily recurrent situations. That means that the mind by being equipped with a vast number of cognitive mechanisms - context-relevant to each other - is able to apply solutions that can both be content-dependent and content-independent. The human mind is a domain-specific system composed of species-typical adaptations which refer to:

1. Our mental architecture, which is presented with a design that tackles and solves target problems (such as resolving conflicts);
2. The ability to process information that is functionally specific, in order for everyday requisites to be attended (such as satisfying nutritional needs);
3. Natural selection, as the designer of domain-specific mechanisms, consisting of a variety of cognitive specializations, both context and content-oriented (such as helping con-specifics in a time of need).

From an evolutionary psychology perspective, the context-relevance argument in regard to the mind as a general-purpose computational system suggests that:
1. The more significant an adaptive problem, the more vividly natural selection had designed cognitive mechanisms to quintessentially deal with it, such as avoiding predators, or caring for family members.
2. Regulation of action, in a content-dependent manner, is equally important to the general-purpose use of knowledge acquisition. The use of particular knowledge is effective only if the regulation of action is subject to the knowledge gained; such as someone knowing *how* to face cheaters.
3. Human cognition could be both a by-product of imitating the social world, and a domain-specific structure with distinct capabilities. Either way, a solution to a problem such as comprehending costs and benefits in social contract settings is subject to familiarity issues in a given environment.

Conclusion

Evolutionary psychology explains domain-specific mechanisms of the human mind that have evolved to solve adaptive problems. These mechanisms are specialized cognitive activities functionally integrated to face challenges posed in relevant niches. Their functional specialization has been selected for to capacitate and guide human behaviour against everyday difficulties. In contrast to that, domain-general and content-independent assumptions regard the human mind as a cognitive derivative of experiences and socialization, focused on fitness-maximization. The basic hypothesis for such a consideration is that the mind is content-free of any domain-specific mechanism. The main assumption behind context-generality lies with the aspect of informational encapsulation. Informational encapsulation is interpreted as the function of outputs autonomously operating, and totally disassociated from other mental systems.

Although both approaches claim to be divergent, I have shown in this paper that a fruitful convergence between both could also be the case. Such convergence can be understood in terms of context-relevance between informational encapsulation and functional specialization. Both ideas refer to issues of information processing, whether in terms of a mind as general-purpose device or as content-dependent machinery. In this paper I have argued that the mind can be explained both as a general-purpose and content-dependent computer, for it refers to actions and behaviours of specific and general content. Context-relevance between both considerations explains also aspects of innate automaticity and integrative modularity. Inputs and their resulting outputs demonstrate generally- processed information, as well as information being processed by individual parts of human cognition.

Evolutionary psychology, in its interpretation of the mind, needs to consider the context-relevance assumption as valid, in order for a common framework between information encapsulation and functional specialization to be introduced. Evolutionary psychology, by considering the latter, expands informational encapsulation and functional specialization towards an integrative evolutionary approach to the human mind. Such approach could explain the human mind as an operating system of context-relevant circuitry based on a content-relevant general-purpose machinery.

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