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心智模組的酵素模型及其困難

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摘　要

「酵素模型」指的是借用生物學中酵素催化機制的概念，來說明認知科學中「大量模組假說」在計算與功能層次上有關資訊處理與分配之模型。酵素模型的最大優點在於回應了「訊號配置」與「整體計算」兩難題，從而替大量模組假說提供有利的辯護基礎。但本文之目的，在論證酵素模型的這兩個回應並不成立。一方面，酵素模型在避免訊號配置的無限後退時會產生新的困難。另一方面，要說明整體計算至少得滿足兩個必要條件：一是跨模組的訊號交換是可能的、二在於模組能夠不只是針對輸入訊號的語法結構來處理訊號。本文將論證酵素模型頂多說明如何滿足第一個必要條件，而沒有釐清第二個必要條件如何在該模型中實現。換言之，酵素模型對兩難題的回應不成立。因此，酵素模型無法用以支持大量模組假說。

關鍵詞：酵素模型、酵素計算、大量模組假說、訊號配置、整體計算

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Why the Enzyme Model of Modularity Fails to Explain Higher Cognitive Processes

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Abstract

The enzyme model (EM), inspired by biological enzyme catalysis, is a computational-functional description of information processing and distribution in modular cognitive systems. It has been argued that EM offers advantages in solving both the allocation problem and global computation and thus may play a role in upholding the massive modularity hypothesis (MMH). This paper, however, argues that EM solutions are untenable, as EM avoids the infinite regress of allocation problem only at a high cost and with several critical drawbacks. Moreover, to clarify global processes, EM needs to satisfy two necessary conditions: first to demonstrate that the EM allows cross module communication, and second to be sensitive to not only the syntax but also the semantics of representations. I argue that EM only satisfies the first condition and thus fails to hold.

Keywords: enzyme model, enzymatic computation, massive modularity hypothesis, allocation problem, global computation.

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Why the Enzyme Model of Modularity Fails to Explain Higher Cognitive Processes*

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I. Introduction

The enzyme model (EM) is a cognitive description of how modules – functionally individuated components that are domain-specific – can access and process input information. The essential feature of EM is its adoption of enzymatic computation (EC) – the information processing strategy inspired by the interaction between biological enzymes and substrates. First proposed by Sperber (1994) and developed by Barrett (2005), the EM is designed to solve Fodor's (1983, 2001) allocation argument and globality problem against the massive modularity hypothesis (MMH). The allocation argument shows that input information can hardly be distributed to specialized modules without assuming a domain-general allocator, while the globality problem indicates that classical sequential computation, given its syntax-oriented processing, cannot handle the holism and flexible nature of the mind. Although Barrett's analogy between substrate/enzymes and information/modules is simply a

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metaphor for illustrating the basic idea of enzymatic computation, the EM itself is a concrete and applicable model. The EM is an alternative to the traditional treatment of information and is regularly cited to refute Fodor's challenge (Carruthers, 2006a; Kurzban & Aktipis, 2006; Machery, 2010; Tooby & Cosmides, 2005; van Leeuwen, 2007) or as an example of modular models that allow parallel processing (Mercier & Sperber, 2009).

Recently, the influence of EM has expanded beyond the debate over modularity to other studies. Some hold that Barrett's EM is useful in dealing with the relationship between literal meaning and explicatures (Capone, 2011) and that EM backs up human domain-specific cognitive systems — the foundation of massive social institutions (Boyer & Petersen, 2012). Some researchers appeal to the EM to explicate why experimental subjects respond faster to the content of a belief than to the contents of public representations, such as maps and arrows (Cohen & German, 2010). Some contend that EM offers partial support for an explanation of how the agency detection module can invent supernatural beings in religions (Bertolotti & Magnani, 2010). In other words, the EM is widely discussed and important model.

In contrast, this paper agures that the EM is untenable because both of the solutions the EM offers to Fodor's challenge are problematic. Section 2 reformulates the EM and its proposed solutions. Section 3 argues that the EM avoids the allocating regress at the cost of several critical drawbacks, including transmission inefficiency and an inability to explain how repeated stimuli can improve learning. Section 4 maintains that to elucidate global processes, there are two necessary conditions: the EM must show that enzymatic modules are unencapsulated and allow cross module communication, and the EC must be insensitive only to the syntax of representations. As the EC satisfies only the first condition, it fails to explain global processing. Section 5 concludes the paper with a discussion of the implications of the findings for future investigations.

II. The EM and its Solutions to Fodor's Challenges

In the debate over central modularity, Fodor (1983, 2001, 2008) poses two challenges to the MMH. One is the allocation problem. According to Fodor (2001), when perceptual representations are input to the central system, there are two possible ways for central modules to get their appropriate representations: information must be allocated either by a domain-general mechanism or by previous domain-specific mechanisms. The first option amounts to conceding that the central system is not completely modular in structure, while the second leads to an infinite regress. If a module's information is decided by its previous mechanism, then how is the information of this previous mechanism allocated?

Another challenge to the MMH is global computation. The MMH relies on computational theory of mind (CTM) to describe how representations are manipulated in the mind. However, according to Fodor (2008), there is an explanatory gap between the theory (CTM) and the phenomenon (the properties of mind). On the one hand, computational process is local — the processing is determined by the syntactic structure of representation itself. That is, whenever a computational device is input p and p→q, it is mandatory that this device be capable of processing the inputs according to Modus Ponens and then provide the output q. The respective contents of p and q are irrelevant to how the inputs should be processed in this automatic procedure. On the other hand, the information processing of the human mind is global — a process c is global if c is not only sensitive to syntactic properties of an input but also to its content and context. Accordingly, there is a gap between the local processing of the CTM and the global properties of the mind, which, as Fodor (2008) pessimistically holds, is unlikely to be bridgeable.

Barrett (2005) replies to Fodor's challenge by presenting the EM. The basic idea of the EM is that the way modules interact with information resembles the way enzymes interact with substrates. Biologically, enzymes are active proteins that can either catalyze inactive chemical reactions or accelerate existing reactions without changing the end result of these reactions. To catalyze a reaction, each enzyme in an organism needs to collide with a kind of molecule called a substrate. Although any substrate can, in principle, collide with any enzyme, only substrates that fit into the binding site of an enzyme (i.e., the *key-and-lock* template) lead to catalysis. Enzyme catalysis is the typical example of enzymatic computation, in which chemical processes conform to Turing's computability (Magnasco, 1997; Shapiro, 2012). The binding site of each enzyme functions as a logic gate (AND, OR, and NOT) with variable input sensitivity, and the output of the catalysis is identified by mechanical procedures. This enzymatic computation illustrates how substrates can be consumed, integrated, and output by an enzyme (Figure 1).

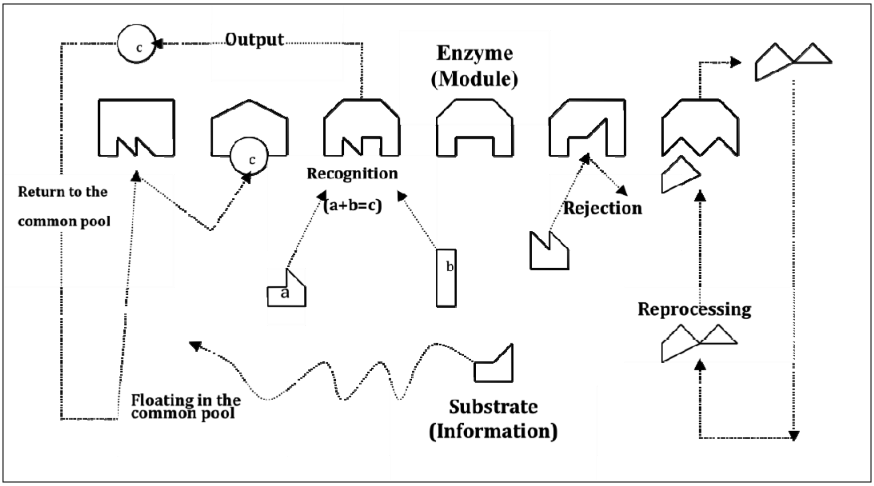

Figure 1. Barrett's (2005) Enzymatic computation

Barrett (2005; Barrett & Kurzban, 2006) argues that the relationship between information and modules is analogous to that of substrates and enzymes. In the EM, modules are specialized computational devices that also use key-and-lock templates as input criteria of recognition in order to identify suitable representations. Sensory representations input to the EM are first put into a *common pool* (or a general bulletin board) that is public to all modules. These representations float in the pool and are tested against different modules until they find the correct modules through chance collision, and the diffusion of modules is thus significant if recognition is to take place. Processed representations are then marked with tags and returned to the common pool to be re-utilized by other modules. Again, all representations can, in principle, be tested with every module, but only those that pass the input criteria will trigger the required processing. This feature is known as *access generality with processing specificity*.

Moreover, the EM is hierarchical and has layers of modules. Each layer has its own common pool and receives only the outputs of modules present on a subordinate layer. At the bottom of the hierarchical structure, there is a central common pool that only takes sensory representations as its input, and deposits outputs from higher layers. This hierarchical structure allows the same representations to be reprocessed by multiple layers of modules.

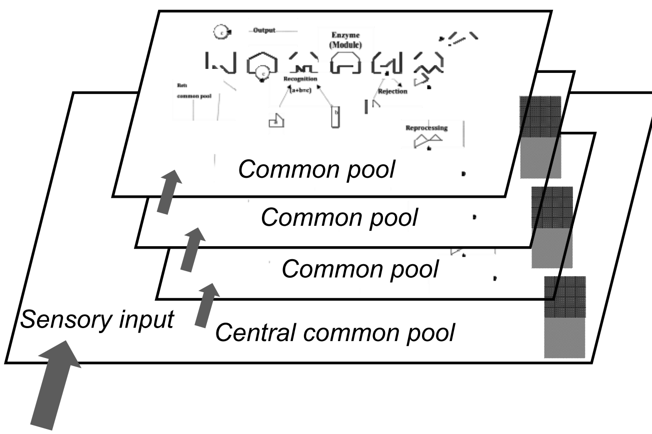

Figure 2. The hierarchical structure of the EM

With the EM, Barrett (2005) contends that the allocation argument cannot threaten the MMH because Fodor fails to recognize an alternate means of information transmission revealed by the EM. For Fodor, information passes from one module to another through a one-way, pipe-like route. Thus, a domain-general allocator is required for this Fodorian architecture to ‘know’ where to deliver information. However, in the EM, the encounter of modules and representations is realized by chance collision, and only representations with the correct shapes fitting into the binding sites can trigger processing. No information distributor need be assumed in the EM. Therefore, the allocation argument is rejected.

To solve Fodor's second challenge, Barrett (2005) denies that MMH has to be informationally encapsulated, as each enzyme-like module could be admitted to more than just a restricted range of databases. He next replaces the CTM with enzymatic computation, arguing that the EM has another feature, *semantic tagging*, which allows modules to be sensitive to content as well. Just as an enzyme may add a tag to a substrate and change how that the substrate is handled by the next enzyme; when a module tags a representation, it changes the shape of the representation, and the new shape may be used as an input criterion by other modules.

This tagging is semantic because it helps a module (i) track the reference of a representation, (ii) control which modules can process the representation, and (iii) couple sensory input to higher-order semantic categories. First, tags help to preserve the reference of a representation. According to Barrett (2005), as preserving truth in computation only applies to fixed sets of information, representations need some identifier for each module to know the restriction of the process scope. Using Barrett's own example, when encountering a lion, the object parser will output a bundle of object properties (size, shape, distance, etc.) This bundle of representation floats in the pool and is tested against various modules. Once this object representation is processed and tagged by a proper module, say, a lion-recognition mechanism, the representation will carry a LION tag throughout various computational procedures. So subsequent modules that are capable of processing the representation will 'know' that the representation is about the lion and add more tags, e.g., a DANGER tag, to the same representation. In other words, as processes are confined to the class that carries the LION tag, references can be preserved.

Second, tagging enables *horizontal* control, which means that a processed representation output by a module may affect another module by switching it on or off. For instance, tags added to a representation will change the shape of that representation, making it unable to fit into the binding site of modules that were ready to accept the original representation as their input. Likewise, tagging also makes a representation available to new modules by changing its shape. This EM is quite different from Fodor's *vertical* architecture, in which representations are passed from peripheral modules up to central modules through isolated and pipe-like routes. There is no way to divert representations from one route to another.

Third, tagging helps modules of the EM to address higher-order semantic properties, making the process of EM sensitive to the content of representation as well. According to Barrett, the mind evolves with specialized computational procedures to address abstract semantic categories such as predators, kin, social exchanges, etc. These semantic categories are unlikely to be derived directly from either raw sensory input or a one-step template, but rather require a series of multiple computational processes. In the EM, each process of a module addresses only a semantic primitive (e.g., a LION tag or a DANGER tag). When an object parser receives sensory input and outputs an object representation to the common pool, this representation may be tagged (e.g., a LION tag) and returned by another module to the common pool to be reprocessed by other modules (for instance, by adding a PREDATOR tag), then higher-order semantic categories (e.g., predators) can be computed indirectly from sensory input. Because EM tagging helps sensitize the processing of a module to more than the mere syntax of a representation, the EM is more promising than the CTM in resolving the globality problem.

III. Information Allocation

The EM seems to avoid Fodor's (2001) allocation problem. However, this achievement comes at the cost of several critical problems. The first drawback is the unreliability of information transmission. Barrett himself notes the risk of losing information in the interstices between modules, but even if this concern is unrealized, the information transmission remains at risk of being extremely inefficient. Barrett insists that "[t]he tagged information is posted on the bulletin board for other mechanisms to make use of; the outputting device does not need to know in advance where to send the information" (2005: 277). However, if we define transmission efficiency in terms of the time and resources a system requires to interpret, transfer, and process data, the potentially long journey of aimless floating unavoidably slows the speed at which information spreads and would pose a challenge to an organism dependent on rapid information flow. As efficiency is an essential component of the MMH (Tooby & Cosmides, 1994; Taraborelli, 2003; Carruthers, 2003b, 2006a), the EM seems to contradict the value it aims to defend.

One possible reply is that, on the one hand, cognitive errors constantly occur in the real world. Humans inevitably make mistakes in everyday life — from lower cognition such as sensory conjunction errors, to higher cognition, such as invalid arguments. Information allocation in cognitive computation not need be infallible; it only requires a certain degree of reliability. As the success of enzyme catalysation in the human body has demonstrated that such information transmission is not unreliable, but rather functions fairly well, the random collision of EM is not untenable. On the other hand, the efficiency of information transmission in the EM can be easily improved. By not taking Barrett's analogy too literally, we can define the modules of a system as restricted to the dataset of their domain, though they can access data that fit the domain. This helps the module focus on only the relevant input, so that a visual module will not waste time on key-and-lock testing with auditory stimuli. Transmission efficiency can be hence revised, so the EM holds.

However, the above rejoinder does not work. Appealing to the success of bodily enzymatic transmission cannot certify that EM transmission is reliable to cognition. In re-evaluating the analogy between representation/modules and substrates/enzymes, it seems that this analogy is not as plausible as it seems at first. The human body contains two control systems, the nervous and the endocrine system, to regulate other systems and to communicate information (Watson, 2005). The endocrine system sends out chemical messages (hormones) into the bloodstream to adjust digestion, metabolism, and growth, etc. Such message delivery is relatively slow, ranging from seconds and hours, to weeks or even years, depending on the hormones produced. In contrast, the nervous system either inhibits or activates the neurons through nerve impulses and the secretion of neurotransmitter substances. This signal conduction is rapid – usually occurring within milliseconds (Watson, 2005; Thibodeau & Patton, 2007). Substrate conveyance among biological enzymes is the same as chemical communication in the endocrine system (both use the key-and-lock fit and similarly diffuse in the body), but the data exchange among cognitive modules involves elements of the nervous system. The human mind needs two control systems because different means are required to achieve different goals. The endocrine system, through its slow chemical transmission, provides effects of a potentially long duration, while the nervous system offers instant responses through a more rapid method of electrochemical conduct (Thibodeau & Patton, 2007). So ten minutes may be fine for a painkiller to take effect, but not for a person to dodge a falling tree. The success of enzymatic transmission in biology does not imply that it would have the same reliability as cognition; the two have different criteria in terms of reliability and speed. Because speed and reliability are significant to evolve the mind (Cosmides & Tooby, 1994), Barrett's extrapolation from enzymatic processes to cognitive computation is unsustainable.

Furthermore, even if Barrett's analogy is not taken too literally, and modules are assumed to be blind to the datasets of certain domains, it remains unclear how the efficiency of information transmission can be improved. Theoretically, a module focusing only on data within its own domain does not mean that the module will not have to confront the task of matching tests with data in other domains. Due to the lack of a direct transmission route, Barrett's (2005) module still needs to spend time in trial and error tests of data outside its domain. A possible solution is to argue that these modules are designed to ignore data outside their domain, but this suggestion violates the core principle of access generality and cannot be adopted by the EM. Consequently, the workload of these modules remains heavy. Experimental studies also demonstrate that modules not only need to negotiate with data outside of their domains, but that their processes are sometimes affected by such data. It has been shown that perception of visual content could be altered by auditory stimuli in subtle experimental conditions (Shams et al., 2000), and that not only can the visual cortex in the blind be activated using auditory stimuli (Kujala et al., 1995; Sadato et al., 1996; Weeks et al., 2000) but also that the auditory cortex in the deaf can be activated using visual input (Finney et al., 2001). Thus, modules are not incapable of testing data from other domains and can process these data as needed. Because the workload of testing data from other domains cannot be reduced by restricting modules' attention to data that fit their domain, the inefficiency remains.

The second drawback results from the inability of EM to explain why learning can improve information transmission. According to Barrett (2005), there is no priority observed in how modules collide and in the testing of particular sets of information. As the only way for modules to find the correct representations is through chance collision, the probability of each module encountering the correct representation is equal. However, multidisciplinary studies indicate that learning can strengthen synaptic connections, create new synapses (Squire & Kandel, 1999), or create new neurons (Kaplan, 2001; Kempermann & Gage, 2002). The repetition of external stimuli increases the strength of connections and alters arrangement, thereby easing neural signal transmission. Of course, the mind is not identical to the brain (Samuels, 1998), but the correlation between stimuli and signal transmission suggests a similar correlation between learning and the information delivered in the mind. In the beginning, the delivery of novel information may have mirrored Barrett's (2005) proposal that each module tests a large number of representations in order to find the correct one. However, when a representation is processed correctly, the feedback should be sent back to some mechanism to record the type of stimuli that is suitable for a particular computational procedure. Chance collision alone is unlikely to explain the relation between repeated stimuli and learning.

EM advocates might argue that learning can increase the diffusion of modules,[1] raising the chance of collision and thus the processing rate. If a module diffuses more broadly as a result of experience, then the module will have more opportunities to collide with these tokens, thereby increasing the recognition rate. Learning, through the diffusion of modules, thus accelerates transmission and processing. However, this raises a question about what happens to the rest of the tokens when the correct module accepts one. In this case, other modules should not process those superfluous tokens, which might lead to a representational contradiction. Thus, other modules should be able to ignore these tokens. When a module receives a token of the right representation, it should somehow instruct other modules to switch off, or to disregard the superfluous tokens. Although Barrett's EM does clarify how a module might switch off another module by tagging a processed representation, it does not clarify how other tokens of the same representation are prevented from activating other modules. A possible explanation is that because EM allows parallel processing, these tokens could be handled by distributed processing of representations of an object, or be used to fortify the decaying signal. That is,

1 Diffusion is important for catalyzing reactions. Barrett holds that enzymes depend on "diffusion in order for molecular recognition to occur" and "[f]or the analog of such a system to be instantiated in the brain, there would therefore have to be a neural equivalent of diffusion, such as massively parallel distribution of information" (2005: 270).

these tokens also collide with, and are tagged by, the first module. However, unless it is shown that *all* of the remaining tokens are processed by the first module, difficulties persist. It is unclear how the required targeting is possible given mere chance collision.

It seems that Barrett and Cosmides both underestimate the role frequency plays in human learning, especially in language acquisition. influenced by Chomsky's (1965, 1981, 2000, 2005) emphasis on instinctive language learning, many evolutionary psychologists believe that language acquisition is largely dependent upon genetic factors (Carruthers, 2005; Tooby & Cosmides, 1992; Pinker, 1994; Sperber, 2002). Recent studies, however, suggest the contrary. Thompson and Newport (2007) explain the abstraction role transitional probability plays in statistic learning of syntax. Weiss and Newport (2006), comparing humans to primates, demonstrate that subtle differences in the statistical learning strategy may help humans acquire language. Temperley (2008) proposes a Bayesian model that can identify and judge music notes in different melodies. Griffiths et al. (2008) conduct a series of experiments to show that iterated learning can reveal the inductive biases of human learners. These examples show the importance of a domain-general capacity of statistical learning — a learning method based on the repetition of stimuli. Because Barrett fails to note this aspect of learning, difficulties arise.

The third drawback is that the EM may not survive a refined version of the allocation problem. Because the EM allows for parallel processing, integrating representations of an object processed by distributed modules is crucial. The only known mechanism for information combination is enzyme-like modules. When representation A and B both carry the similar tags, these tags could serve as a signal for combination and trigger an “A+B→C type reaction” (Barrett, 2005: 269). To achieve the entire representation of an object, a module needs to accept every representation with the proper integration tag, regardless of what domain each representation belongs to. However, this account amounts to admitting the existence of a domain-general mechanism of integration (Figure 3a), so the EM cannot accept it. Alternatively, there could be many domain-specific modules working in a hierarchical way, and each module might only combine representations from a restricted range of input. However, saying that there is an ultimate module taking charge of the final combination is nothing less than saying that this module is responsible for integrating consciousness (Figure 3b). And if there is a module for consciousness, then it is doubtful that this highest module would be domain-specific to any significant degree.

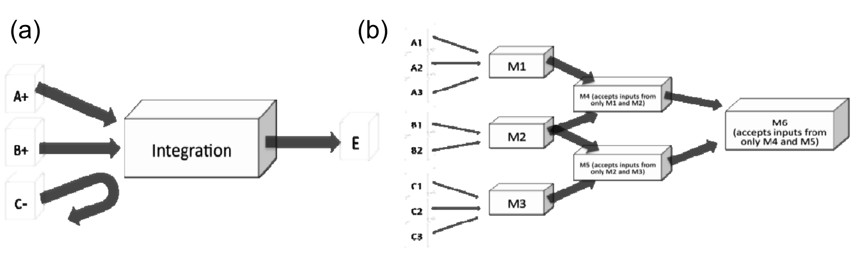

Figure 3. Two possible ways of integration: (a) all representation with the “+” tag will be processed; (b) modules that only receive restricted ranges of input.

IV. Global Computation

To reply to Fodor's globality problem, modularists need to show either that the gap between the phenomena and hypothesis is not unbridgeable, or that such a gap is merely an illusion. Barrett chose the latter[2] position and argued both that enzymatic computation is unencapsulated, and that it is not sensitive to merely the syntax of representation.

Barrett's argument for unencapsulation in the enzymatic theory is relatively uncontroversial, while the argument for context-sensitive computation remains debatable. For instance, information outside the specific domain of an enzyme-like module remains accessible, albeit indirectly, to this module through the common pool. This account is generally acceptable. After all, other modularists also allow cross-module exchange through feedbacks and reprocesses (Carruthers, 2004, 2008).

Conversely, context-sensitivity and the content effect in the EM remain controversial. When rejecting an allocation mechanism to attribute information, Barrett describes a way in which a specialized computational procedure can discover inputs with appropriate content. Using Barrett's own example, when visual input of an object, say, a lion, is returned to a common pool by object parsing modules, this representation will be given a LION tag by a module using a perceptual template. The representation with the LION tag floats in the pool again and is then given a PREDATOR tag by another module using the lookup table of animal tags. The representation with two tags is now

[2] Barrett (2005) argued that Fodor's alleged conflict is not a problem because the computation of the mind is not dependent upon formal logic.

exclusive to specialized processes that are evolved to address a particular content type. In other words, higher-order semantic categories (e.g., predator) can be computed by multiple processes in an enzymatic system. Therefore, tagging in the enzymatic computation helps to "couple information of specific content (semantic) types with particular content-specific computational procedures" (Barrett, 2005: 280).

It is true that a representation could be processed differently when a semantic tag is added, which may be considered equivalent to a sensitivity to extralinguistic information and context. However, the reason why a representation is treated differently is not because a module can detect the *semantic properties* of that tag, but because the tag *itself* has changed the shape of the original representation. That is, the tagging alters the syntactic properties of that representation and hence limits/triggers its computational procedure. Thus, this computation seems to remain syntax-sensitive only, and not content-sensitive.

A way out of this problem is to argue that enzymatic computation is significantly different from the classical computation, especially in that the former has no content-insensitive feature. This is what Barrett (2005) does, first arguing that, according to Wason's selection task, the computation of mind is neither classical nor Fodorian. Rather, whatever computation the mind employs, it should be compatible with Cosmides and Tooby's social exchange hypothesis (SEH), which holds that the mind contains specialized processes for reasoning about social exchange.[3] Barrett then details how enzymatic

[3] Fodor (2001) doubted the existence of the cheater-detection mechanism in the social exchange hypothesis because, in order to distinguish representations relevant to social context from the

computation, via syntactic change (i.e., Tagging), can consider the semantic properties in the social exchange hypothesis, and hence become more sensitive. Before examining the details of the main argument, three quick comments are offered about the strategy. First, if the enzymatic computation is content-sensitive, then the account of coupling tagged representation with a corresponding procedure is redundant in explaining global computation; Barrett can directly use this argument. Second, if enzymatic computation is not sensitive merely to the syntax of inputs, then how it could explain classical processing in conceptual and linguistic reasoning is obscure. Third, a tag is nothing less than a representation. A tag is the information with semantics and syntax that is stored in the database. Appealing to a second representation to explain why a process can reflect the semantic properties of a first representation will result in another question —how can the second representation be selected from a web of databases?

To disprove classical computation, Barrett appealed to Wason's selection task to demonstrate that the mind has content effect[4] and does not obey the rules derived from formal logic. Next, Barrett (2005) argues that the content effect can be explained by the SEH, which can in turn be explained in the EC with tagging by comparing the following conditionals as examples:

(W) If a card has a vowel on one side, it has an even number on the other side.

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irrelevant ones, a system requires a domain-general mechanism to access representations in different domains, which is nothing more than assuming an allocator. However, since no allocation device is assumed in Barrett's EC, Fodor's worry is dismissed.

4 While admitting the content effect, Pollard and Evans (1987) argued that scenario (context) is more important than content.

(G) If a person is drinking alcohol, then this person is over 20.

The reason (W) and (G), despite their identical syntactic structure, are processed differently is that they trigger different algorithms. The representation of (G) is tagged as social-related and is returned to the common pool for further processes; when the representation bumps into the correct modules, it will trigger the algorithm for social exchange. By contrast, the representation of (W) lacks this tag, so it has no privilege to be computed by the dedicated processing. In other words, it is the tagging that facilitates the category shift from normal process to specific treatment and helps the mind to behave sensitively to content in different categories. Consequently, the EC explains flexible computation better than do other MMH theories.

To see whether Barrett's strategy succeeds, it is worth taking a closer look at the claim against the CTM and the evidence supporting it. Barrett compared the logic of the mind and that of CTM in conditional P→Q:

> For formal logic, P and Q are syntactic categories that can take any propositions as input, but for whatever logic the mind is using, that is not true— the tags that P and Q carry influence how they are processed (2005: 282).

Accordingly, we may define the thesis of CTM, with the special interest in its algorithms for reasoning, as (C):

(C) The computation of the mind relies on the rules derived from formal logic.

Thus, Barrett's view can be considered as the negation of (C), which can be further divided into a strong version, (S), where the computation of the mind does not rely on the rules derived from formal logic at all, and a moderate version, (M), where the computation of the mind, in large part, does not rely on the rules derived from formal logic. However, it seems that both readings result in difficulties for the EC.

If what Barrett has in mind is (S), then it seems that (S) is too strong to be held up by Wason's selection task because the fact of illogical behavior does not imply that such behavior's processing has to be illogical. A logical process may result in illogical output, as seen in the heuristic process of search engines on the Internet; the result is not always reliable but is still based on classical computational process. Thus, even if all the participants in Wason's tasks responded illogically, the result would not mean that human reasoning obeys no rule of formal logic. Moreover, according to Cox and Griggs (1982), although participants' responses are illogical, the mind may still follow the rules of formal logic. In their experiments, a high percentage of participants reasoned according to inferential rules, albeit on different contents. They showed that logical reasoning occurs only when certain conditions are satisfied, rather than directly proving that human reasoning does not follow logical rules. Thus, it is doubtful that (S) holds.

Instead, if what those selection tasks support is (M) and not (S), then the EC is confronted with other difficulties. First, if it cannot be ruled out that in some cases the computation of the mind depends on the inferential derived from formal logic, then it is unclear how the EM can explain these cases. Does it mean these cases are inexplicable by the EM without the CTM? If not, does it mean the EM has no problem in explaining these cases as well, and how? Furthermore, there is another worry about whether the SEH and EC can work together well. The EC is provided to explain information allocation and flexible computation in the MMH. Like Sperber (2001), who supports a strong version of MMH, Barrett (Barret & Kurzban, 2006: 630) seems to also hold that the mind consists entirely of functionally individuated modules. Conversely, Cosmides' (1989: 194) SEH is proposed within the context of moderate MMH. It is not impossible for a strong theory to use the hypothesis successfully in a strong theory, but because the strong MMH confronts more difficulties than the weak MMH in explaining computational flexibility (Carruthers, 2003a; Samuels, 2006), the EC has the burden of showing why the SEH is good for it. After all, the SEH appears to function very well without the assumption of tagging (Tooby & Cosmides, 1992, 2005). Therefore, while some versions of MMH might be correct, the EM is unable to support them, and neither can the EC demonstrate that the CTM is wrong.

V. Conclusion

We have seen that the ECM faces a series of difficulties. On the one hand, although the enzymatic solution indeed assumes no allocation mechanism and avoids the allocation regress, it does so at the cost of several critical drawbacks. Barrett is aware that information can sometimes get lost in the common pool and trigger no process in the corresponding module, but even if it can find the right module, the potentially long journey will reduce the efficiency of transmission and result in potentially costly delays. This conflicts with the basic idea of both evolutionary psychology and the MMH. Moreover, random collisions are incapable of explicating why learning can improve information transmission.

On the other hand, an argument for modular unencapsulation is insufficient to elucidate global computation. It has to be shown that Barrett's semantic tagging helps an enzymatic procedure to consider semantic properties of representations with relevant tags. To prove that the influence of tagging is more than syntactic, it is necessary to show that computation in the enzyme theory is not understood traditionally, and that tagging is not merely changing the constituent structures of representations. That is, the CTM fails to hold and can be replaced by the EM. However, because Wason's selection task is insufficient to demonstrate that the CTM is wrong, adding a tag to a representation is nothing more than altering the syntactic properties of that representation. That is, the alleged "semantic tagging" can only affect the constituent structures of representations and thus remains content-insensitive. Therefore, the EC fails to explain global computation. Therefore, the enzyme model is unable to explain higher cognitive process.

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