Summer '84 - FILE UNDER Tom - "MODULARITY" Bever

Furniture by Fodor

It has long been recognized that every sentence in a human language has several natural levels of representation such as sounds, words, syntax and meaning. How to relate these levels in a linguistic description has been more controversial. Thirty years ago, the conventional wisdom was that the levels could be interrelated in an orderly way, moving from the most peripheral (e.g., the sounds) to the most abstract. The guiding principle was a version of behaviorism - the requirement that each level of description be determined only on the basis of information at more superficial levels. This conformed to the empiricist constraint on how knowledge is internalised, and also implied a straightforward model of language comprehension: sentences are understood by first analysing the individual sounds, then the words, then the syntax, and finally the meaning.

The taxonomic program in linguistics continually foundered on the many instances in which a higher level of representation was needed to determine the characteristics of a lower level. The corresponding theory even failed as an account of speech perception. George Miller demonstrated that sentence comprehension must have a computational component such that the processing of syntax can actually facilitate recognition of lower levels of representation. He found that the perception of words in a sentence is far better than recognition of the same words in isolation. A notorious series of experiments proved that this effect holds even when the sentences do not make much sense. With such demonstrations, Miller gradually convinced many of his colleagues that sentence structure is actively computed during comprehension - since the number of comprehensible sentences is very large, a <u>theory</u> of the sentence is a neccesary part of the theory of language understanding. (FOOTNOTE This phenomenon has been convincingly shown to be 'on-line', rather than a post-sentence effect. For example, one can shadow sentences more accurately and quickly than random words ( ); one can also recognize the initial portion of a word faster when one knows what sentence it is in (Bever, 1982).

Fodor's response: Any task involves use of central systems. We need theory of the task. If you have such a theory of mom becomes tractable

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Generative grammar offered such a theory, and thus was born an influential movement that emphasised the role of structural computation in ongoing behavior. Chomsky also elaborated certain direct empirical implications of the grammar, inependent of its role in behavior. He argued that the grammar is a representation of the speaker's knowledge. Such knowledge is only abstractly related to data a child could observe, a fact which lead to the claim that the capacity for grammar is specifically innate. In this spirit, Comsky proposed that research into the nature of language should be guided by the metaphor that it is like the study of an 'organ', the mental equivalent of a liver or eyeball. This research metaphor distills several different kinds of properties that are claimed for language, innateness, coherence within the mental world - distinctness from other kinds of knowledge; a unique internal structure that does not share structures or principles with other mental organs. Chomsky also generalized the notion to other psychological systems, e.g., object recognition.

The grammar that emerged eschewed any behaviorist constraints on the relationship between different levels of representation. In fact, it became a part of linguistic theory to postulate precise and intricate constraints on each level of representation and on their interrelations. While specific theories have evolved over the years, a basic claim has remained constant: understanding a sentence must involve recovery of the correctly interrelated levels of description assigned to it by a grammar. Since the grammatical levels of representation are themselves abstract, the claim that they are behaviorally relevant has sparked considerable interest. Indeed, numerous researchers have assumed that there is an autonomous linguistic perceptual system that computes representations independent of beliefs about the world.

Mom appears to work out the implications of the organ metaphor for a general model of behavioral processes, while emphasising speech perception as the main empirical example. Mom extends the organ metaphor with specific properties that bear on the physical and temporal activity of "modules", psychological entities that process the levels of representation differentiated in such an organ. Among these properties are speed, localization, informational encapsulation, a "vertical" organisation of resources limited to each module. What we shall show is that Mom does not present a processing theory that has any more substance than the organ metaphor on which it is based: first, Mom unceremoniously gives up the vertical constraint; in maintaining the informational encapsulation constraint, Mom re-introduces the problem of taxonomic linguistics - how to explain the behavioral facilitation of one level of representation by another. In any case, data that would support the hypothesis about informational encapsulation would also support a theory that assumes computation of independent levels of representation within the same module.

Thanks for the memories

Mom proposes that capacities that are usually thought of as general are actually dispersed separately within each module. The most central of these is "memory", the flagship topic of current cognitive psychology. Mom argues that each module has its own kind of memory built into it.

There is a notable consequence of this claim. As in the organ metaphor from which they derive, modules do not share internal properties: hence, the memory

system of one module is only accidentally like the memory system of another module. There are no general laws of memory that hold across modules. This is a tremendously strong claim, one that would undercut current cognitive psychology and would force new interpretations of the various memory phenomena that have been taken to hold across modality - e.g., serial position effects, temporal and conceptual grouping effects, recoding effects, special phenomena such as the von Restorff effect. Essentially, Mom claims that the basis for these effects differs in each modality, and that it is only fortuitous that they seem to be the same effects. Such a claim must take the breath away from most cognitive scientists; this, in our opinion, does not invalidate the claim ipso facto. Indeed, it is one of the claims that makes Mom interesting.

Not for long. When facing up to various consequences of the vertical hypothesis, Mom ~~first~~ weakens it, and then appears to give it up entirely.

- [illegible]

Making mountains out of modules

The other property that makes Mom more than a mere behavioral instantiation of the organ metaphor is the claim that modules are "informationally encapsulated". Mom proposes that each module computationally maps an input onto an output, without any recourse to other modules. Inter-modular interactions are mediated by the non-modular "central processor" that can compare the output of several modules, but that does so very slowly. For example, a contextually unlikely sentence will first be understood in the normal way, and then occasion an oddity response: conversely, the fact that a sentence is contextually likely cannot increase the efficiency with which it is understood. Mom argues that all the alleged facilitating effects of probability actually involve a retarding of responses to unlikely stimuli, not a speeding of responses to likely ones.

In its strictest sense, this constraint would lead to very strong predictions. For example, it would predict that facilitation of word recognition could not occur simply because the words are in a sentential framework. Yet it was just such phenomena that forced psychologists to accept the behavioral importance of linguistic structures. Is Mom arguing that this was a mistake, fortuitous perhaps, but a mistake nonetheless?

Not for long. Mom has a way of dealing with such phenomena - whenever one module appears to facilitate the operation of another, it is taken to be a demonstration that the two modules are part of the same (super)module. For example, the findings by Miller and others simply demonstrate that sub-modules within the larger speech perception module can facilitate each others' processing.

This theoretical move opens up many possibilities for circularity, vis a vis empirical disconfirmation of Mom's proposals. Worse than potential circularity is the confusion it causes about the representational languages which serve as input and output of modules. Each perceptual module must be able to report directly to the central processor, presumably in the lingua mentis, the slow, cumbersome language of undifferentiated reason. But sub-modules within a larger module must be able to communicate with each other in languages appropriate to each kind of input/output relationship. Clearly, there is a deep problem here.

If the normal flow of perceptual processing is "upward", say from phones to syllables to words to phrases to sentences to meanings, then the system can operate in an orderly way, each module taking as input the output of the preceding one. But, if there are interactive effects among the modules all bets are off - one must envision that one module can indeed interact with the internal operation of another. Limiting such interactions between modules to those within a 'super-module' does not solve the problem, because the problem is not which modules can interact; rather, it is how their internal computational processes can interact.

It is a bit surprising to find this problem in an enterprise that draws on generative linguistics. One of the arguments in favor of a rationalist approach to the description of language was the failure of taxonomic linguistics. Nevertheless, Mom starts out implicitly accepting the taxonomic constraint as applied to perception - it then must face the same music that drowned out the taxonomic grammarians and their pet psychologists.

A word is in order about the nature of the top-down within-module effects. Indeed, as Mom points out, they are not demonstrations of a strong "new-look" theory. That is, they are not examples in which belief-states determine percepts. Rather, they are examples the influence of structural knowledge on lower level computations. This is the problem that Miller's research set, and one of the problems that Mom leaves unexplained and untouched.

[redacted] The Whole Iguana

The impenetrability of within-module processes is the paramount empirical claim that Mom makes. Hence, demonstration that it is false would destroy the fabric of Mom's case. There are numerous cases other than Miller's that would appear to invalidate the claim that modules are informationally encapsulated; indeed there are even some cases that appear to show the impact of current beliefs on modular activity. Empirical matters, however, are slow to be resolved, and ad hoc re-interpretations easy to construct. Accordingly, it is a useful exercise to stipulate that there are no interesting cases of higher- to lower-level facilitation of perception. Would this unambiguously support Mom's particular version of informational encapsulation?

Definitely not. Informational encapsulation is a property that Mom relates to the rumor that modules operate speedily and have a neuro-geographic location. While such phenomena are not defining features of modules, the fact that Mom spends time on them indicates what the notion of informational encapsulation really is: modules are computationally and neurologically dissociated from each other. This view is further supported by the otherwise gratuitous and quaint discussion of Gall's theories. According to Mom, the theory of Gall is divided into three parts, a theory of mind, a theory of the brain and a theory of the skull. Mom rejects only the last third. This further supports the interpretation that modules areboth mental and physical entities, giving a literal notion of what encapsulation refers to.

Such a view is not uniquely supported by the absence of intermodular interactions during processing. That fact (if true) would support a much simpler interpretation of the organ metaphor as a processing model. If each

module computes a particular linguistic level of representation then it must have an internal computational language that is appropriate for that level; for example, phonological analysis must proceed in terms of acoustic entities, syntactic analysis in terms of categories, and so on. It follows directly that modules cannot interact during their processing: one kind of representation cannot interact with another in a well-formed way. On this view, only the output and input of modules can interact, via the lingua-mentis: understanding a sentence, for example, would involve the matching of multiple levels of representation each computed by a separate module specific to that level.

This may seem very similar to Mom's model. Indeed it is, except that it is an unadorned mapping of the organ metaphor onto a perceptual model. It has as an automatic consequence the inpenetrability of each module. Therefore, the facts that Mom cites as favoring a particular notion of informational encapsulation would support a more direct mapping of grammar onto behavior. In fact, it would support a view that seems non-modular in spirit. On this view, the lingua mentis in fact carries out the computation of each level of representation all in the same location (say, somewhere in the left hemisphere): levels can interact only as they are coherently represented: hence the computation of each level ordinarily proceeds independently of the computation of other levels, until complete representations are available at each level for comparison. Mom might counter this with the claim that the lingua mentis is too slow. But that, too, is only a rumor, in this case based on some allegations about how slow science is to progress.

Mom must show that the informational encapsulation postulate is not compatible with the assumption that the mapping operations are carried out by the language of the central processor. This follows from the fact that it is the special nature of the language of each module that accounts for its speed. It would also appear to account for informational encapsulation. If each lingua modularis is of a unique kind then it follows that its operations will be unaffected by other linguae.

We address the issue of speed below. The prior question is whether there is a model consistent with the few facts that Mom cites in favor of informational encapsulation that does not assume distinct linguae modulariis. We show that there are such models in two stages. First, we show that it follows from the organ model that each level of representation interacts with others discontinuously; second, we show that the operations of each module can be stated in the lingua mentis. This demonstration leaves the only argument that the lingua mentis is not the language of individual modules to be one of speed - we finally show that rejection of the lingua mentis as the language of modules because of their speed is based on a specious argument.

Following the organ metaphor, Mom assumes that understanding a sentence involves computation of each level of representation, and their interrelation. The perceptual model in Mom achieves this by separate within-module computation of each level, and interrelation of the output of all modules. That is, each module computes a level of representation and transmits it to the central processor, and to the next level. The distinct levels of representation associated with a single sentence are the output of each distinct module. (They are interrelated within the central processor (or some 'final' module - Mom is

unclear on this). The main data which Mom cites to demonstrate the distinct computation of each level of representation is the absence of 'top-down' effects, demonstrations of the effect of a higher level on the internal operation of a lower level of representation. Bottom-up effects are presupposed in the model, by definition.

There is a non-modular implementation of the organ metaphor that would predict the same facts. We give an example, not because we have unique positive evidence, but as an existence proof of alternatives to Mom's model. As it should be, it is a notational variant of Mom's model except for the particular claim about the modular basis for informational encapsulation. We will call our model, the perceptual soup model.

The soup model replaces computational operations with a redundant set of "learned" n-tuples. Each member of an n-tuple is a template at a particular level of description, linked to other levels of description. The simplest instance of a soup model is one in which every n-tuple pairs an acoustic representation with a phonetic one (th,e,d,o,g) or a lexical one (THE DOG) or a syntactic one(NP). These parallel acoustic-to-linguistic-level mappings involve multiple imperfect strategies; for example, using specific local cues for the phonetic pairing, word envelopes for lexical pairing, intonational and other cues for syntactic pairing. As in Mom's model, A sentence is understood on this model, when it receives a set of consisent levels of representation, e.g., when the phonetic analysis, lexical and syntactic analysese are consistent.

The soup model does not require separate or ordered computation of the distinct levels of representaiton. Nevertheless, it is a consequence of the model that top-down effects will be excluded: they cannot exist, by definition, since levels are interrelated only when there are complete representations at any two levels. For example, /d,o,g/ can be related to DOG, but /d,o/ cannot - hence, the fact that /d,o/ is the beginning of the word DOG cannot help the perception of the initial fragment, even in contexts that predict the occurrence of the word /DOG/. Similarily, perception of /THE DO/ cannot be helped by independent information that a complete nounphrase is about to occur.

There are many tokens floating around of each template, and this is not clear (aren't there?)

We call this the perceptual soup model, because all of the mapping templates could co-exist in the same physical location (say a vat of glial cells) and still exhibit the lack of priming effects. The model may seem implausible because it depends on such multiple representation of direct mappings from the acoustic level to each of the other linguistic levels. Intermediate models, in which there are also templates that pair one level of representation and another, are entirely consistent with the model, and predict a lack of top-down effects. In fact, there is even a biological model for how such multiple mappings from one kind of information from another could occur - the antigen system, in which pathogens are paired with a template for destruction by other systems (e.g., white blood cells).

This model allows each inter-level pairing to be stated as a unique passive template. The pairings, however, could be computational with the same implications for top-down effects. Basically, it is the mere fact that each level of description uses distinct kinds of units that guarantees the absence of an effect of a higher (incomplete) unit on lower-level processing. But the

uniqueness of the units at each level of description is a property of the organ metaphor in all of its processing manifestations, not just in Mom.

If the inter-level mappings are computational, then they are stateable. If they are stateable, then they are statable in the lingua mentis. This means that, in fact, the operations themselves could be carried out directly in the lingua mentis, so far as computational demands are concerned. This makes crucial Mom's argument that the lingua mentis is slow, and that the modules are fast, because it is only the speed of the modules that appears to disqualify the lingua mentis as their internal language. We turn next to the evidence that the lingua mentis is in fact slow.

There is a set of problems pertaining to the central processor and its investigation. First, the technique of using the progress of science as a way of studying the operation of the central processor is circular. If there is anything we know about what counts as science, it is that it must be hard to do. Immediately apparent truths do not count as scientific truths, until they have been laboriously integrated within symbolic artefacts known as scientific theories. Accordingly, it is by definition the case that scientific theorizing is slow and erratic when looked at as a whole. A further difficulty is that individual developments in science may be very rapid - indeed the oft-reported sequence of events in a scientific discovery is that there is a rapid 'intuitive' phase in which the solution is perceived in a flash, followed by a phase of proof and integration with existing theory. Thus, science too may move in rapid fits and starts: it seems slow only because of the requirement that it be communicable to others, and hence couched in appropriate external form.

Among other things, science must be communicable, at least in principle. This means that every scientific theory is itself statable in English, a point which the author of Mom notes in an earlier book (TLT), for other reasons. Modules are by definition the subject of a scientific theory, including their internal operations. This means that the internal operations themselves are statable in English, itself in a strong mapping relationship with the lingua mentis - that is, the internal operations of modules could be carried out by the lingua mentis: accordingly, the only evidence that postulated modules are not stated in the lingua mentis is that they operate rapidly. This makes more poignant, the fact that the basis for deciding how fast the lingua mentis ordinarily operates is by definition a slow enterprise.

Apparent support from related disciplines

One of the most obvious aspects of Mom is its topicality: it is clearly one of the top-ten of cognitive science for 1984. Part of the reason for this is its obvious brilliance; another part is that it encapsulates and articulates an otherwise largely inchoate viewpoint shared by many researchers. Finally, it seems to offer a rationale for many related intellectual enterprises, such as the study of word perception and deliberations about the best kind of programming language for computers. Below we discuss two such examples, to point out that the issue of modularity as a mental principle is distinct from such other empirical matters.

Modularity justifies a current empiricist renaissance.

Let us turn the clock back to (sigh) 1965. It is a dark and stormy night in Lexington Kentucky. The author of Mom (in a much younger manifestation) and other infantile associates are locked up in a motel with many major representatives of the then current establishment in human "cognition", actually verbal-learning, the study of how word-lists are memorized - Underwood, Schulz, Postman, Deese, Osgood, Maltzman, Kendler and others, especially Jenkins, who had just Converted to the New Syntactic-structures faith. The confrontation lasted for a week in a dry state, mitigated only by the liquorish ingenuity of the conference organisers, one of whom was particularily notable because of a recent divorce and scratches from a present ocelot (or so he claimed - the motel purveyed soft-porn movies that put everybody on a different edge.) The old guard of verbal learners knew that something was up and they were actually trying to deal with it in an honest way. But the new guard had the goods on them: a theory of grammatical relations within sentences that rendered irrelevant the question of inter-word associations. That is, the old guard was still concerned with such questions as the effect of stimulus-presentation-rate, or whether adjacent words were presented in capitals and/or lower-case letters, or whether the presented words were homonyms or not. The future author of Mom was heard to say, "these guys are incredible: I just heard one of them say to another 'I use three-in-one oil in my memory-drum, what do you use?' "

The basic point was simple: the new linguistic theory made it possible to give theoretical force to sentential structures and relations, such as subject, predicate and object: hence the argument of verbal learners became irrelevant, that it was first necessary to understand the effect of inter-word associations before understanding more complex phenomena like the meaning of sentences. They had been saying for a long time that in the sweet byenbye all problems would be solved. But, the jig was up.

The victory was secure: the hearts and minds of future graduate students were captivated by a few examples of the "psychological reality" of grammar. The importance of grammatical relations, and the irrelevance of inter-word associations was completely demonstrated. The verbal learners were self-consciously and vigorously despondent - they knew the end was at hand: the sweet-byenbye theory had been shown up and found out for the fraud it was: the study of inter-word associations would be of no avail in understanding the nature of grammatical relations.

Then, gradually, psycholinguistics grew up: the distinction between formal theory and behavior became clearer (in part due to the efforts of Mom's author). After numerous false starts, the general principle was formulated: the relation between a grammar and behavior is "abstract". Rather than viewing speech behaviors such as comprehension as direct implementations of the grammar, special-purpose recoding systems were postulated that used grammatical distinctions in the aid of behavior. For example, automatic strategies were proposed for sentence comprehension, that mapped sequences of lexical items onto grammatical and semantic relations: while outside of the grammar, such a comprehension system still addressed the problem of the perception of sentential structures.

This way of conceiving of the comprehension problem made precise a question about local ambiguity: are words and phrases assigned all possible syntactic categorizations or only the one that is appropriate for the current context (or guessed context when necessary)? This question has provided the rationale for a major investigation of Lexical Access, the recognition of a word and its abstract categories. The issues in Mom emphasise the importance of this line of research: it is crucial to Mom that the initial stage of lexical access, however it works, is automatic and uninfluenced by higher levels of linguistic representation. Hence, the study of lexical access would seem to have a high and topical priority.

Closer examination of what is actually happening in the field, however, gives one pause. Partly because of the applied nature of many recent research grants the study of lexical access has been largely isolated from sentential contexts: though some studies embedd the words-to-be-accessed within "sentences", the sentential cloak is usually monotonous, drab and ignorable. What delights the hearts of this brave new wave of researchers, and their sponsors, is the parametric investigation of the properties adjacent to lexical access, its speed, definiteness, dependence on other lexical items. These investigations include studies of variation in presentation rate, orthography relations between one word and another, homonymy, color, voice, and so on. The dominant "theory" of how one word influences another is "spreading activation", essentially an hydraulic leaking of activation from one word to another via memorized canals.

The concern should be clear: We have returned to the Bad Old Days of the study of isolated words, and the associative relations between one word and another. The study of sentential relations, other than association are set aside. No doubt, there are exceptions, and individuals who see the folly of what they do – but even they espouse a new version of scientific straightjacketeering: Once we understand interword association during perception (they say) we will be in a better position to address those interesting questions, like the perception of grammatical relations. The pie in the sky shines on.

The fundamental underlying issue, as always, is recidivist empiricism. The nasty feature of generative linguistics for psychologists has always been that it is incompatible with the naive empiricist view that all forms of content are discovered by the child in the world. This view has surfaced again in Gibson, and the corresponding behaviorist methodology dominates the study of lexical access: as the author of Mom once put it, trying to stop psychologists from being empiricists is like giving lifejackets to lemmings. I would put it a little differently: despair springs eternal.

The fact remains that Mom could appear to give aid and comfort to the behaviorist investigation of lexical access, by emphasising the importance of the questions about how many meanings are primed at lower levels of linguistic representation. But Mom raises this question as it pertains to the comprehension of sentences, not to the accessing of distinct words – indeed it is not a necessary part of Mom's main theses that words *are* separately accessed during real sentence comprehension. The best that can be said for the current line of lexical access research is this: Perhaps inter-word associative priming exists, now show us that it exists in a way relevant to sentence processing.

But to do that, one must have a theory of sentence processing. Here we go again.

The modularity of programming languages.

There is a separate easy mistake to make about the notion of modularity, especially in relation to issues in computer science. Recently, there has been a war over what kind of programming language is best, a linear one such as basic, or a modular one such as pascal. The current fashion among computer scientists is to argue in favor of a modular language. There are many reasons why this might be so, most notably the economic and pedagogic advantage of having programs that are easy to talk about and easy to sub-contract. It might seem that computer scientists and modular psychologists could take mutual comfort in their respective theories. It could be argued that cognitive science has shown that thinking really is modular, hence justifying the use of a corresponding kind of programming language. This, however, would be a mistake; in fact, it would be nearly the opposite of what one ought to conclude. Programming is clearly not a modular skill in Mom's sense. Hence, programming

depends on the central processor. But the central processor is non-modular by definition. Hence, nothing follows about whether programming should be made to be modular or not - at least nothing follows from Mom's modularity.

Something does come to mind from the pun on the word modularity between computer and cognitive science. It exemplifies the allure for psychologists of theorizing on the basis of the latest information processing technology in a culture. When introcuding modularity and its relation to the theories of Gall, John Marshall pointed out that the history of mental theories has paralleled the history of technology in a rather direct way. This is well documented by many of the arguments in Mom - in particular the entire metaphor that the modules operated in 'compiled' sub-languages makes sense only in the context of computers. Of course, there is no reason to believe that this has anything to tell about biological thinking. It does, however, cast some perspective on Mom's final conclusion that psychology of modules is the best cognitive psychology there ever will be, limited as it is. This seems rather like the argument in favor of Pascal as a programming language - it allows one to divide and conquer. We do not suggest that Mom is blindly imitating the arguments in computer science. But we do suggest that insofar as Mom's conclusion has appeal, it may be simply because of the current prevalence of the corresponding strategy in the pursuit of cognitive theory.

In brief, Mom appears at first to be a substantive implementation of the organ metaphor as a processing model. Careful examination shows that Mom gives up one substantive claim, while its other substantive claim is either false or irrelevant. But the view is invigorating.]