Chomsky and Fodor on modularity[1]

Nicholas Allott & Neil Smith

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Please send any comments or questions you have to: nicholas.allott@gmail.com

1. Introduction: conceptions of modularity

The philosopher Jerry Fodor was a key figure alongside Chomsky in the revolution that led to the renaissance of the cognitive sciences from around 1960. They both argued forcefully for the central postulate of the cognitive revolution: serious study of the mind requires investigation of its internal structures. Both are also vocal advocates of nativism, the view that our mental capacities are to a considerable degree innately determined. And they agree on the importance of Alan Turing's work on computation[2], since it points the way to rigorous theories of mental capacities in terms of computations that manipulate mental representations. [3] Their work was instrumental in the demise of behaviorism and similar views that were dominant in psychology and philosophy of mind in the mid 20th century. However, Chomsky and Fodor differ on Fodor's two best-known contributions to cognitive science. Fodor (1975) argues there is a 'Language of Thought' distinct from natural languages, while Chomsky's view is that much of our thought is conducted in natural language.[4], [5]

In this paper we survey another key difference between Chomsky and Fodor. They have both argued that cognitive science should investigate the mind as a system composed of distinct components; indeed, their views are sometimes

[1] The authors would like to thank Terje Lohndal, Georges Rey, Amahl Smith, Deirdre Wilson and [[to be filled in]] for their very helpful comments on drafts of this paper.
[2] E.g. Turing 1950.
[3] Although Chomsky and Fodor use the term 'mental representation' differently.
[4] The medium of thought might be language's output to the conceptual system, LF, (Smith 1983, 12); or as Chomsky has suggested, at least some thought might also involve representations of speech sounds (Chomsky 2011; for discussion see Smith & Allott 2016, 50–3). Note, though, that Chomsky also sees "language [as] optimized for the system of thought, with mode of externalization [i.e. as speech or sign language] secondary" (Berwick & Chomsky 2016, 75).
[5] A further, related disagreement between Chomsky and Fodor concerns the nature of word meanings. See Glanzberg this volume.

conflated as one 'modularity of mind' hypothesis. However, their notions of modularity differ in ways that derive from their commitments to distinct programs of research.

Chomsky envisages that fruitful study will focus on domain-specific mental systems which are largely innately specified, each of which underlies a particular ability and is characterized by proprietary principles, and that to investigate these systems it is necessary to abstract away from most of the complications in how they are put to use (1975; 1980a; 1980b). Such systems are what Chomsky means when he uses the terms 'module', 'modularity' (e.g. 1980b, 3, 15) or 'modular' (e.g. 1984)[6] – although he generally prefers other terms, particularly 'faculty' and 'mental organ'. They have also been called 'analytic modules' and 'competence modules'. A central example of such a system is the language faculty, a system which, interacting with other mental systems including the sentence parser, memory and conceptual systems, enables our linguistic performance. Other candidates include the number sense[7], moral 'grammar'[8], and the systems underlying intuitive ('folk') biology[9] and physics.[10]

In contrast, Fodor focuses on processing. He argued (1983) that input and output processing, including early visual processing, sentence parsing, and the production of motor commands, are carried out by dedicated, automatic, domain-specific processing units, which he called 'modules'. Crucially, these modules are encapsulated: that is, their workings are insulated from information that is held elsewhere in the mind. The central claim here is that there are some mental processes that work bottom-up and are impervious to influence from above: their output is not affected by the agent's beliefs and desires. When the term 'module' is used in philosophy of mind, Fodor's notion of an encapsulated processing unit is taken as the starting point.[11]

A third use of the term 'module' is common in cognitive science and evolutionary psychology. Here, as in Fodor's conception, a module is a domain- or task-specific mental processing unit which is architecturally distinct from other processing units. But this use of 'module' differs from Fodor's in one key respect: encapsulation from general beliefs is not necessary.[12]

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[6] With obvious exceptions such as Chomsky (2017) where he contrasts his notion with Fodor's.

[7] Dehaene 1998.

[8] Dwyer 2000; Mikhail 2011.

[9] Medin & Atran 1999; Solomon & Zaitchik 2012.

[10] Baillargeon 2004.

[11] E.g. in Robbins (2017), a useful survey article which also considers massive modularity, but remarkably fails to mention Chomsky.

[12] Tsimpli and Smith (1998) proposed calling such modules 'quasi-modules', and reserving the term 'module' for Fodor's conception: encapsulated peripheral processing units. See also section 3.2 below.

An alternative to all these views is that the mind does not have modular structure in any of these senses. In cognitive science this perspective goes back to 'connectionist' work by Rumelhart and McLeland (1996) and it has enjoyed a resurgence in popularity with the arrival of 'big data', especially neurological data (e.g. Plaut 2003; Zerilli 2019).

In this paper we concentrate on Chomsky's and Fodor's conceptions of modularity. We discuss two ways of understanding Chomsky's proposal, in particular how it claims an underlying faculty is related to processing and performance. We observe that Chomsky is largely agnostic on this question; the commitments of his programme are to be found elsewhere.

In section 3, we also review the evidential foundation of all versions of modularity: double dissociation (impairments of one or more mental abilities caused by accidents or other pathology which leave other abilities intact). While there is considerable evidence for modularity, the data currently available are largely neutral, we argue, as between Chomsky's and Fodor's notions.

2. The two programs

2.1. Fodorian modules: encapsulated processing units

Fodor's notion of a cognitive module, influenced by but distinct from Chomsky's (Fodor 1983, 3–10), was set out in his famous monograph *The Modularity of Mind* (1983), and somewhat modified in his *The Mind Doesn't Work That Way* (2000). For him, a module is a discrete processing system, where this discreteness largely comes down to informational encapsulation (1983, 37, 71). That is, in processing an input, a module cannot draw on just any information held in the mind. The classic examples of such encapsulation are optical illusions such as the Müller-Lyer diagram. A belief that the lines are the same length – e.g. because you have measured them – does not stop one of them from 'looking' longer than the other. On Fodor's view, this is evidence that the relevant aspect of visual processing is encapsulated, at least with respect to 'central' or 'person-level' beliefs (i.e. it is not 'cognitively penetrated' – see below).

In addition to informational encapsulation, modules typically also have the following properties (Fodor 1985, 14)[13]:

domain specificity: each module can only operate with a certain type of input. This could be input from one sense – e.g. visual or auditory – or more fine-grained within a sensory modality – e.g. color perception or edge detection –

[13] On the relation of these properties to the essential feature of Fodorian modules, cognitive impenetrability, see Currie & Sterelny 2000, 147–8.

or cross-modal but still domain-specific, as with linguistic parsing, which operates on auditory and visual stimuli.

automaticity and *involuntariness*: modules are reflex-like, triggered into action by input that falls within their domain.

speed: modules are typically fast. Fodor suggests that this is because they are encapsulated, so processing some input does not trigger a lengthy search in general memory for relevant information; and because they operate automatically: a module, once triggered into action, implements a given procedure with no deliberation over what would be the best way to process each input.

functional localization: a module is subserved by a dedicated region or regions of the brain, or, more subtly, by dedicated neural circuits, even if they happen to be quite widely distributed across the brain and/or physically entangled with circuits that do other jobs.

innateness: at least some modules are innately specified.[14] Note that this claim does not preclude environmental effects on the way that modules develop. They may well need suitable conditions to develop, where this obviously includes suitable nutrition, as well as some perceptual input, as in language acquisition. (See Fodor 1985, 35, 36; Sheehan, this volume.)

Working with this conception of modularity, Fodor makes two claims: 1) that 'peripheral' cognition is modular, and, 2) that 'central' cognition, in particular the fixation of belief, is non-modular. Peripheral processing includes perception and linguistic parsing, and central processing is concerned with reasoning and decision making. According to this model of the mind, the senses are connected to transducers, which convert the energy of incoming stimuli into a format that can be used in computation. Their output goes to the input modules, which take care of visual and other perceptual processing and sentence parsing. Some of the outputs of these modules may feed other modules, but others send their output to central cognition where they are combined in all-things-considered belief formation and decision making. For decisions which result in action the model looks the same in reverse: the decision activates an output module or modules dealing with language production or motor action and these send appropriate signals via transducers to muscles.

The task of a perceptual module is to process a stimulus to construct a representation of the aspect of the world that caused it: e.g. an uttered sentence or visual scene. The sensory input underdetermines the representation that the module constructs: there are many arrangements of objects that could have caused any pattern of retinal stimulation, and, given structural and lexical ambiguity, many sentences that could have given rise to any string of speech

[14] Reading may be an example of a modularized ability (fast, automatic etc. in adults) for which there is no dedicated innate component.

sounds. This implies that visual perception and linguistic parsing both involve non-demonstrative inference and that information that is not in the sensory stimulus has to be brought to bear.

Fodor's innovation was to point out that this does not entail that everything known to the agent can be used. Rather, he suggested, each module can only make use of a domain-specific body of information: in parsing, the grammar[15] and some lexical information; in vision, 'assumptions' such as the rigidity principle, which means that a retinal line varying in length is more likely to be construed as due to a rotating object than one growing and shrinking.
There are good reasons for the mind to be this way, Fodor claims. On his account, perception is much faster than it would be if it accessed central beliefs, and it will not ignore evidence for an occurrence because of a prior belief that the event is unlikely. These advantages come with a cost: an increased prevalence of false positives. Fodor argues that price is worth paying: a modular architecture is ecologically rational given that "[p]erception is built to detect what is right here, right now – what is available, for example, for eating or being eaten by" (Fodor 1985, 4).

A number of refinements and caveats need to be mentioned. Although some encapsulation is criterial for a Fodorian module, encapsulation need not be absolute. In particular, some cross-talk between modules is allowed for, as in the McGurk effect, a phenomenon which shows that visual and auditory cues are integrated in processing speech. For example, a video of the face of a speaker saying [b] overdubbed with the speech sound [g] is perceived as [d].[16]

What Fodor's conception of modularity rules out is 'cognitive penetration' (Pylyshyn 1984): information from central cognition cannot become available to peripheral modules 'top-down'., Knowing about an illusion such as the McGurk effect or the Müller-Lyer lines does not render one immune to it. Fodor's explanation is that the beliefs the central system holds about perception do not affect the processing or output of the perceptual modules.

A further caveat about Fodor's criteria is that automaticity need not be absolute. There is nothing incoherent about a module failing to operate because it is in some way inhibited, as is obvious if we compare modules with non-cognitive reflexes. Some of these can be consciously suppressed, including the cough reflex and saccades of the eye. So the claim about automaticity of modules must be

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[15] Fodor suggests that modules of his type draw on Chomskyan competence modules. Unlike Chomsky, though, he understands the latter as databases, collections of propositional representations. See below.

[16] This illusion is just one piece of evidence among many that visual and auditory information are systematically combined in processing of spoken language. Campbell and Dodd (1980; cf. Campbell & MacSweeney 2012) demonstrate that normal language users get up to 50% of their understanding from visual input.

about normal operation in the absence of interfering factors. An analogue is the existence of 'threshold' effects. For instance, a drug may elicit no response at low dosages but, once a particular level – the threshold – is reached may cause significant effects. (Colman 2015).

Fodor's work has been a spur to a great deal of research on whether perception, particularly visual processing, is cognitively penetrated.[17] There have been many claims that top-down effects on perception have been found. For example, there is evidence that it is easier to recognize an object when it is in a context where it would be expected (Bar 2004; 2007). However, a recent review of the literature argues that owing to errors in either methods or analysis "[n]one of these hundreds of studies – either individually or collectively – provides compelling evidence for true top-down effects on visual perception" (Firestone & Scholl 2016, 1).

The crucial disagreements here are not about the data but what they show. In vision, what is processed depends on what one is looking at, and that is under central control. There is ongoing debate about whether other top-down influences are similar or whether they change the *way* in which stimuli are processed.[18] Only the latter would be in conflict with Fodor's conception of modularity. At present the balance of evidence is that visual processing is modular to a considerable degree, even if there is some cognitive penetration.

It is less clear what to say about language processing, Fodor's other example of a peripheral module, given that comprehension includes pragmatic inference, which can draw on any information. Disambiguation, assignment of referents to indexicals and enrichment require inference about the speaker's intentions, what the speaker could have expected the addressee to know etc. Debate has largely focused on whether syntactic parsing is encapsulated. (Pickering & van Gompel 2006 provide a survey.) Ferreira and Nye (2017) have recently argued that reports of the death of modularity in this area have been exaggerated.

If the mind is modular in Fodor's sense then perception and domain-general reasoning are distinct architecturally – obviously a major discovery in cognitive science. Fodor's work was also motivated by wider, anti-relativist, implications (Fodor 1984; 1985, 5). In epistemology it promises to dispel the awkward question raised by a non-modular view of perception: If what you perceive is shaped by what you believe or desire, then why should you trust your perceptions? In philosophy of science a modular view argues for the possibility of a common stock of observational data between those who subscribe to different theories (Fodor 1984, 38, 41–42), contra claims by some that all data are theory-laden and therefore different theories are incommensurable and rational theory-choice impossible (e.g. Kuhn 1962).

[17] See Prinz 2006; Firestone & Scholl 2016; Gross 2017; Robbins 2017, §2.

[18] On cognitive penetration and attention, see Gross 2017.

2.2. Chomsky: competence modules, analytic modules, and mental organs

For Chomsky, a mental organ, faculty or module (1975; 1980a; 1980b; 1984; 1995; 2017) is a cognitive structure underlying performance in some domain: a distinct component of 'mental architecture', with its own developmental pathway and organized according to proprietary principles.

The classic example is the language faculty, a domain-specific mental organ whose innate component, Universal Grammar, both enables and constrains the development of mature linguistic competence, I-language: the 'mental grammar' that underlies use of language. Competence here stands in contrast to 'performance', i.e. episodes of cognition and behavior. (On this idealization, see Allott, Lohndal & Rey this volume.)

For cognition more generally, Chomsky postulates that underlying some human cognitive abilities there are distinct mental faculties, whose mature state is determined to a considerable degree by domain-specific innate endowment: the equivalent of Universal Grammar for each domain. This comes with connected claims about methodology: that it is necessary to abstract away from much of the complexity of performance, since it results from the interaction of many mental systems and is therefore too complex to be captured by systematic theories; that cognitive scientists should focus on computational accounts of mental faculties; and that cognitive science is more likely to discover deep, explanatory theories of domains where there is such an innate faculty to be found.

Note that Chomsky does *not* see such mental organs as collections of mentally represented propositional information (Chomsky 2017, 34–5), although others have taken this to be the essence of his conception (e.g. Fodor 1983; Segal 1996; Knowles 2000). Consider again the rigidity principle in vision. There are two ways that it could work. The principle could (1) be stored as an item of knowledge in a database whence visual processing retrieves it to use, perhaps as a premise in inference, or (2) visual processing could be so constituted that it respects this principle without representing it as such.[19] On the second view, the system is simply disposed to treat stimuli as though they were caused by rigid objects. Compare with the laws of cell division: they are not written in cells; rather they are generalizations that describe the process. Chomsky's view of the I-language is like this. The principles that syntacticians discover are true of it, but not stored as propositional information within it.

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[19] One reason for the widespread confusion is that the term 'represent' is polysemous and Chomsky and other generativists generally use it in a specialized sense (from mathematics) where a system represents a principle or rule just if it is truly described by it i.e. if it instantiates it. Thus, when a generativist syntactician asks whether the Binding principles are represented in I-language she is asking whether they are true and whether they are so in virtue of the I-language organ (rather than e.g. being due to a distinct pragmatic module).

This distinction became clearer with the development in syntactic theory of the Principles and Parameters framework (on which see Alexiadou and Lohndal this volume). Earlier theories had relied on syntactic rules (as an ambition rather than an achievement), but these were now replaced by principles. It's hard to define the distinction rigorously – the terms have been used in several partially overlapping ways by working linguists – but there are two key differences. First, it is natural to see them as architectural features of the system rather than stored data; to say that UG has a particular principle is just to say that any possible I-language will be so constituted as to obey that principle. This is related to the second difference (historically of more importance in the development of syntactic theory): principles are hypothesized to be system-wide, whereas rules are specific to particular constructions or domains.

There was another use of the term 'module' in Government and Binding era generative syntax. Sentences were only well-formed if they conformed to several distinct types of constraint: verbs must have the right number of arguments in the right structural positions; reflexive pronouns must be bound; DPs must be assigned abstract Case, and so on. GB grammars were modular in that they postulated a distinct sub-system within the I-language for each type of grammatical property (Chomsky 1981; Curtiss 2013, 80–90; Hornstein 2013, 398–9; Smith & Allott 2016, 80–93). One of the aims of Minimalism is to account for GB-era generalizations in a framework which eschews such sub-systems. (See Alexiadou and Lohndal this volume) [20]

Returning to the larger picture, there are at least two ways mental organs have been understood, related to different views of the competence-performance distinction. On the first view, claims about competence are completely independent of claims about processing. This is suggested by certain fundamental assumptions of generative grammar. The sense in which a generative grammar 'generates' is mathematical and atemporal.[21] To say that the I-language generates a certain structure by (e.g.) merging *eat* and *cake* and then merging the result with *we* is not to claim that there is a time at which the phrase [*eat cake*] exists but the sentence [*We eat cake*] does not. The ordering of the rules is rather to capture facts about constituency: [*eat cake*] is a constituent of the sentence, while *we eat* is not. (See Adger this volume.) This is in contrast to theories of parsing, which explicitly try to capture the temporal stages in which a representation is built up as a sentence is heard. This might suggest a view of the competence-performance distinction on which theories of grammar do not make any claims about mental *processes* and thus make no causal claims.

There are two problems. The first is that this view is hard to reconcile with the goals and practice of linguists. Linguists say that a certain sequence of words is acceptable (/unacceptable) or has a certain interpretation *because* the I-

[20] In contrast, Curtiss 2013, §5.3 presents evidence for 'little modularity' (as she calls it).
[21] See e.g. Chomsky 2000b, 111-112.

language has certain properties, which e.g. allow or block a certain configuration or a certain kind of movement. This is a claim that the I-language is causally responsible (at least in part) for the (un)acceptability and the interpretations available.

The second problem is that it's not clear that a non-process view of competence is compatible with the standard view in generativism described above, that grammatical rules/principles are instantiated by the system and not in general stored as items of knowledge. A visual processing system can be seen to respect the rigidity principle, for example, because of the way it treats input: roughly it maps certain 'ambiguous' configurations onto representations as of a rigid rotating object. It's hard to see how this kind of criterion could apply to a system that doesn't itself process anything.

A different conception of the competence/performance distinction stresses instead that mental organs like the I-language are mental systems that are accessed in performance by input and output systems such as the sentence parser: "the cognitive system of the language faculty is accessed by such systems, but is distinct from them" (Chomsky 2000a, 117). This view is a better fit with the features noted above of linguists' talk: that the (un)acceptability of a sentence is because it is/isn't generated by the grammar, that it has a certain kind of interpretation because the grammar assigns it a certain structure and so on, and is compatible with the view that some or all grammatical principles need not be stored in a database, but merely instantiated by the dispositions of the I-language system.[22] This view obviously raises the question: what kind of processing do the competence faculties do? See Phillips (2013), Smith & Allott (2016, 152 ff.), Adger (this volume) for discussion and references to recent work in this area.

In fact, Chomsky is mostly agnostic about how the I-language interacts with other systems. His commitments here are just that there is a cognitive system which is the object described by grammatical theory and that it is accessed by performance systems, allowing parsing and production.

The other commitments of Chomsky's faculty view of the mind include the following:

1) That mental faculties are *analytic* modules: distinct cognitive systems that can be fruitfully investigated in abstraction from other faculties and processing

[22] The view that the I-language is accessed by performance systems is compatible with the model which Fodor (1983, 3–10) and Segal (1996) (wrongly) attributed to Chomsky: I-language as a database of propositional rules which the parser consults. As discussed, this excludes what is now largely taken for granted, that rules/principles are instantiated rather than stored.

systems[23]. Compare with Galileo and Newton on falling bodies. They assumed that there is some underlying explanatory structure in nature which can be theorized about, and which is simpler than the phenomena observed. We may never see the system working in isolation, since plausibly all actual phenomena are the result of the interaction of more than one system: e.g. gravity, air friction, wind. Similarly with mental systems: exercise of the I-language may always involve some combination of parsing or production, pragmatic ability, and various memory systems. But it can be theorized about independently of them because it is characterized by proprietary principles. (See Allott, Lohndal & Rey this volume.)

2) There are domain-specific constraints on acquisition. UG allows only a tiny fraction of the languages that are logically possible. (See Crain & Thornton, Crain, Giblin & Thornton this volume) It is not a general-purpose learning device (Collins 2002, 128, 135), but has an innate proprietary vocabulary – e.g. N(oun) and V(erb) – and it construes input in such terms. Likewise for other mental faculties such as the number sense. In each case, the mature adult state of a faculty might be invariant, or could vary depending on the input (as with I-language) or other factors.

3) Such faculties are species-universal. In practice this is important to investigation: it justifies the use of data from individuals across cultures, and such comparisons help to isolate the genetic endowment. It also seems to be true. As far as we know, all developmentally normal children are able to acquire any language with approximately equal facility, and the same appears to be true for the number and moral senses. On the other hand, this property is not fundamental to the concept of a faculty. It's not incoherent to imagine an individual with a unique faculty (or an extra limb), such as the ancestral human in whom, Berwick and Chomsky speculate, "the generative procedure [for language] emerged suddenly as the result of a minor mutation" (Berwick & Chomsky 2016, 70). In principle, one could study the faculties of individuals or sub-species if they varied.

2.3. Comparison of Chomsky's and Fodor's views

As Fodor noted in introducing his conception of modularity, his view is compatible with Chomsky's (Fodor 1983; see also Chomsky 2017, 34). Fodor's claims are about processing; Chomsky's are about analytic/competence units. The language faculty as generativists conceive it is a discrete system that is accessed by both input (parsing) and output (production) systems, and is itself neither an input nor output module: as Chomsky says, no one speaks only Japanese and understands only Swahili. There is no clash with Fodor's claim that

[23] We differ here from McCourt (undated) who defines an analytically modular view as one on which "one simply hypothesizes that there is a cognitive subsystem that exhibits specialized operations and some degree of domain specificity."

central processes are not modular given that the language faculty is not a processing system.

Conversely, Chomsky's programme makes no claim about Fodor's view that some aspects of processing are encapsulated. Linguistic parsing could in principle make use only of domain-general processing abilities such as statistical inference or be carried-out by domain-specific but cognitively penetrated systems, while still drawing on language-specific resources provided by the I-language. [24], [25] Equally, there could be dedicated, encapsulated modules for sentence parsing and production.

Nonetheless there is a difference in emphasis between Fodor and Chomsky's views of language. In contrast to Fodor's focus on parsing, Chomsky's view is closer to a historical tradition in grammar that saw *production* as primary. Indeed he is sometimes interpreted as holding a 'speaker-oriented' view of language. Note, though, that Chomsky distinguishes clearly, as the older tradition did not, between the generative competence which is the focus of his research and production, which is an aspect of performance (Chomsky 2017, 26).

3. Evidence

3.1. Examples

The most persuasive evidence for Fodorian modules, as for Chomskyan faculties, comes from dissociations. (Chomsky 2000a, 121; Collins 2002, 135–6; Smith 2003; 2011). Dissociation does not entail modularity, but modularity does entail possible (double) dissociation (cf. Smith 2003, 89). This is true for both Chomsky and Fodor, although in Chomsky's case where we are dealing with a competence system, accessing the evidence for this parallelism presupposes the operation of a set of (sets of) rules of a kind characteristic of Fodor's position. A difference might arise in principle if it is the mode of access to the knowledge stored in that module which is damaged, not the knowledge itself.

That one can be blind without being deaf or deaf without being blind shows that blindness and deafness are independent senses. Even if both conditions may in certain cases be caused by a defect in or damage to a single organ – the brain – the double dissociation shows uncontroversially that each is independent of the other. A similar simple example is found in aphasia with the independent risk of losing either one's phonological ability while the syntax is unaffected or vice

[24] Chomsky also need not be committed to automaticity – although he has sometimes speculated that all sounds are processed by the linguistic system (including, e.g. the sound of a squeaky door) this doesn't follow from his conception of faculties.
[25] The statistical abilities of infants are remarkable in language as elsewhere, making it clear that this is a domain-general capacity. (See e.g. Saffran et al 1996).

versa. This also shows that the language faculty is not a monolithic structure but is fractionated into 'sub-modules' – even if not to the extent in GB theory (see above). Neuro-psychological pathologies may likewise doubly dissociate as in the case of prosopagnosia and Capgras' delusion. In prosopagnosia one loses the ability to recognize faces, leading to sufferers exhibiting bizarre behaviour of the kind documented in the title case study of *The Man Who Mistook his Wife for a Hat* (Sacks 1985). In Capgras' delusion the sufferer can recognize faces appropriately but, because of the absence of any associated emotional response, is simultaneously convinced that the person recognized is an impostor.

Despite the simplicity of such examples some caution in appealing to them is necessary. First, it is important to distinguish single from double dissociation. For instance, Smith (1989, ch. 4) documents the case of his toddler son who pronounced *puddle* as 'puggle' ([p^gəl]), presumably because he just couldn't say [p^dəl]. As he demonstrably knew what a puddle was this looked like a simple dissociation between perception and production. But at the same stage of development he pronounced *puzzle* as 'puddle' ([p^dəl]), and was perfectly capable of correctly identifying adult utterances of each. This phenomenon made it clear that his pronunciation [p^gəl] was not just a failure of production but must involve his perception as well; i.e. it reflected a double dissociation not just a single dissociation.

Second, the most striking modular effect occurred in the investigation of the polyglot *savant*, Christopher. (Smith & Tsimpli 1995, Smith et al 2011, Tsimpli & Smith this volume). On a variety of tests, Christopher manifested a striking asymmetry between his general intelligence and his linguistic proficiency in some twenty or so languages. As part of the project Smith and colleagues taught him and some undergraduate controls an invented language (Epun) deliberately designed to have impossible rules. These were, for example, structure-independent rules which necessitated counting the number of words. (On the types of rules allowed by UG, see Adger this volume.) The hypothesis was that Christopher would fail to cope with these examples but that the controls – because of their superior general intelligence – would be able to solve the problem as a logical puzzle. The first half of the hypothesis was confirmed: Christopher failed to learn the rules. But so did the undergraduates! In an environment where language-learning was the focus none of them managed to work out what was going on, although all of them (but not Christopher) could solve comparable counting problems presented as explicit puzzles. The language module disallows counting so in language-learning no such hypothesis was entertained.

On the assumption that Christopher's difficulties were not specific to input or output, but related to language in general, this is a double dissociation within central cognition, and thus evidence for a Chomskyan competence module. One might think that such fractionation of central cognition is problematic for Fodor's view that central cognition is non-modular and unstructured, but it's important to remember that Fodor assumes that Chomsky is right that there are competence systems, in particular I-language. Fodor's modularity and non-modularity theses only concern processing systems.

3.2. Alternatives

Thoroughly non-modular views of cognition, such as connectionism, are still held. But as a theory of linguistic ability, connectionism is too weak and too strong. Connectionist and 'deep learning' machines detect patterns that humans can't. A striking example is provided by the experiment on Christopher and undergraduate controls with impossible languages containing structure-independent rules. Moreover, AIs which have been 'successful' in language-learning have been fed millions of sentences explicitly notated with structure. This is not the experience of the typical two-year-old. If one is interested in gaining insight into the human mind, rather than obtaining particular results to achieve engineering goals, then connectionism seems to be a dead end. (Smith & Allott 2016, 177ff.; Adger 2019, ch.8)

One influential alternative to Chomsky and Fodor's concepts of modularity was Annette Karmiloff-Smith's (1992) proposal that the relevant notion was 'modularisation'. She did not dispute modularity as such but denied that it was innate. Her view was that the infant brain starts out equipotential and a modular structure emerges on the basis of experience. That is, her book was attempting to undermine the innatist conclusions that Chomsky and Fodor drew from their work, not attack the modular ontology they largely shared. (See Smith 1994 for discussion). Similar remarks pertain to Karmiloff-Smith's and others' attempts (e.g. Elman et al 1996) to use the plasticity shown in normal development as an argument for the equipotentiality of the neonate brain and *a fortiori* against modularity. (See Ambridge & Lieven 2011 for discussion). Even on the connectionists' own terms it is not obvious that plasticity raises any kind of problem for either Chomsky or Fodor. As Smith & Allott put it (2016, 181): "the very notion of plasticity presupposes that particular regions are, in the absence of pathological conditions, pre-specified for particular (modular) functions." A corollary of this fact is that the normal course of (language) development is yet another example of the poverty of the stimulus (see Crain & Thornton; Crain, Giblin & Thornton; Gleitman; this volume).

Connectionists typically attempt to eliminate modules and modularity in general. A diametrically opposed position is taken by those who claim that the mind is 'massively modular'[26], i.e. that not only perceptual and motor processing is modular, but that 'central', 'cognitive' processes such as theory of mind, cheater-detection and other kinds of inference are carried out by modules. For such theorists, modules are functionally dissociable units each specialized for a

[26] Key works include Sperber 1994 (which coined the term 'massive modularity'), 2002; Cosmides & Tooby 1992; and Carruthers 2006a, 2006b.

certain kind of task, which may be innately specified. The notion of informational encapsulation is not criterial.

It is not very controversial that there are some such modules – or 'quasi modules' (Tsimpli & Smith 1998's proposed label, to distinguish them from Fodorian modules), but a strong massive modularity thesis (SMMT) is highly controversial: that all mental processing, whether perceptual or 'central', is carried out by dedicated task-specific systems. Whether this is so is outside the scope of this paper, given that SMMT is logically independent of Fodor's and Chomsky's modularity claims.[27] However, Chomsky seems to be sympathetic to the view, saying: "My own personal impression […] is that talk of "general inferential or problem-solving capacities" tends to be rather empty, and that when we investigate actual cases in one or another organism, we find that specific mechanisms are assumed." (Chomsky in Stemmer 1999, 395)

4. Conclusion

Fodor's and Chomsky's distinct conceptions of modularity are both alive and well in current research. Sensory processing and linguistic parsing involve fast, automatic, domain-specific systems which are largely innate. As we have discussed, there is ongoing debate about how much these systems are cognitively penetrated. On current evidence it seems safe to assume that the answer is that their workings are largely impervious to central beliefs and desires. If so, they are Fodorian modules.

Less conspicuously, Chomsky's conception of domain-specific competence modules that are innately specified has been at the heart of several successful research programs in cognitive science. Whether theory of mind and morality are modular in Chomsky's sense is still open to question, but folk biology, folk physics and the number sense are well established competence domains. The language faculty is the most thoroughly explored and best supported module of all.

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[27] For discussion, see Carruthers 2006b; Samuels 2006; Sperber 2002.

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