July 10th, 2010

The following text is a piece of my forthcoming book (**updated** with respect to the first version that was posted on the EGG site)

> Scheer, Tobias forth. How morpho-syntax talks to phonology. A survey of extra-phonological information in phonology since Trubetzkoy's Grenzsignale. Berlin: Mouton de Gruyter.

The text is "wild" in the sense that cross-references to other pieces of the book are not repaired and appear with an error message; also, there is no guarantee that the reference section contains all items quoted in the text.

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## Contents

# 1 Modularity

## Chapter 1
## 2 Introduction: the relative absence of modularity in interface thinking

On various occasions of the historical survey in Part I, modularity was referred to, and a number of arguments were made in its name. A striking fact is that the interface literature itself does not seem to take modularity into account: it is hard to find any explicit reference, and even harder to find modularity-based reasonings.[1] This is unexpected, to put it mildly, since modularity is part and parcel of the generative approach to language: it is never missing in introductory classes and introductions to the general architecture of grammar in textbooks. Quite opposite of its supposed overarching importance, however, is its influence on theory design. In comparison to straight theories of syntax, phonology and other subdisciplines, this of course is a much more pressing issue for interface theories.

The absence of modularity from interface thinking and interface design is certainly one reason for the current situation in OT: modularity is supposed to be in place (OT is a generative theory), but it is systematically violated without this arousing much discussion (§§**Erreur ! Source du renvoi introuvable.**,**Erreur ! Source du renvoi introuvable.**). We have seen that OT is not the only modularity offender (SPE and Distributed Morphology are other cases in point), though. A summary as well as further discussion and classification of generative modularity offenders is provided in §**Erreur ! Source du renvoi introuvable.** below.

A telling example of the absence of modularity in interface thinking was reported in §**Erreur ! Source du renvoi introuvable.**: the head stone of Prosodic Phonology, the principle of Indirect Reference, is a direct expression of modularity – but it was introduced without any reference to

[1] There are number of noticeable (and rather recent) exceptions, including namely the work by Charles Reiss and Eric Raimy: Reiss (2000), Hale & Reiss (2008:105ff), Isac & Reiss (2008), Reiss (2008), Cairns & Reiss (2009), Reiss forth, Raimy (2003), Idsardi & Raimy (forth). Unfortunately this work has quite little visibility in current interface thinking of mainstream theories.

this concept. Rather, non-isomorphism was invoked – an empirical argument that turns out to be immaterial when carriers of morpho-syntactic information are local, rather than domain-based (§**Erreur ! Source du renvoi introuvable.**). In sum, what happened is that Prosodic Phonology did exactly the right thing – Indirect Reference – for the wrong reason (non-isomorphism). Although modularity was contemporary (Fodor's foundational book appeared in 1983), the simple argument that direct reference to untranslated morpho-syntactic objects is ruled out by the modular architecture was never made as far as I can see.

An introduction to modularity as such that exposes the modular view of how the cognitive system works is therefore not superfluous. Linguists, especially phonologists, may or may not be familiar with the cognitive foundations of modularity, what it requires, and what it rules out. Also, modularity has already done critical labour, and will do still more in this book, where it is used as a referee (§**Erreur ! Source du renvoi introuvable.**).

It goes without saying that the pages below do not aim at a fully-fledged introduction to modularity: the specialised Cognitive Science and psychological literature that is mentioned throughout does a much better job. The same goes for connectionism, the competing theory of cognitive organisation. This Interlude is only meant as a short armamentarium in modularity for phonologists (and more generally linguists).

Isac & Reiss' (2008) and Boeckx's (2010) recent (text)books on language and cognition cover a number of issues that are discussed below: they provide a broad introduction to language and linguistics from the Chomskian (and, in the case of the latter, specifically biolinguistic) point of view, and argue on the backdrop of Cognitive Science (without however engaging into discussion with connectionism: modularity is taken for granted).

# Chapter 2
# 3 Modularity and connectionism, mind and brain

## 4 1. Monism vs. dualism, symbolic vs. non-symbolic representations

### 5 1.1. Levels of representation in the standard cognitive model

Under the header of what today is called the cognitive revolution (e.g. Gardner 1985), the modular approach to cognition was put on the agenda in the 50s and 60s as an alternative to (psychological) behaviourism and parts of (linguistic) structuralism. Rather than describing the stimuli and the responses of an organism, focus was put on the actual cognitive processes that take place when speech is produced and processed (a black box in behaviourism). Rather than describing a linguistic system without location in space and time, the cognitive operations that it supposes became the centre of interest. This call for cognitive realism is essentially what Chomsky's (1959) critique of Skinner's book is about. Generative linguistics were leading in the introduction of the new cognitive conception then, and today language remains a central issue.

Critical for modularity and generative linguistics is the difference between mind and brain, which is akin to the distinction between competence and performance. Although the mind of course has a neural implementation, it may be studied independently of the neuro-biological reality. In fact, trying to get hold of language by looking at its neuronal reality alone is quite unlikely to produce significant insight. On the other hand, models of the mind are constrained by the limitations of what is neurally possible and plausible. The best understanding of language may therefore be expected from a dialectic exchange between the study of mind and the study of brain, bottom-up as much as top-down.[2]

The debate between the classical cognitive model on the one hand and connectionism on the other is about 25 years old; the following discussion only ambitions to provide a brief summary of some basic aspects. More detail is available for example in Dinsmore (1992). Laks (1996) and Pylyshyn & Lepore (eds.) (1999) offer informed overviews; more specialised literature includes Newell (1980), Fodor & Pylyshyn (1988), Smolensky (1988a, 1991), Fodor & McLaughlin (1990), Harnad

[2] Simon & Kaplan (1989:7f) and Pylyshyn (1989a:60ff) elaborate on the standard notion of levels of representation in Cognitive Science.

(1990), and other references that are mentioned as we go along. Finally, Fodor (1985) provides a helpful overview of the different schools of thought in Cognitive Science.

## 6 1.2. A language of thought: symbolic vs. anti-symbolic views of cognition

Theories of the mind necessarily use representations and symbols (such as trees, DPs, nuclei etc.), which are supposed to get as close as possible to the units that are manipulated by the mind. This is the "language of thought", a notion that was introduced by Fodor (1975) and has been debated since then.

(1) "There has always been opposition to the view that we have symbol structures in our heads. The idea that the brain thinks by writing symbols and reading them sounds absurd to many. It suggests to some people that we have been influenced too much by the way current electronic computers work. The basic source of uneasiness seems to come from the fact that we do not have the subjective experience that we are manipulating symbols. But subjective experience has been a notoriously misleading source of evidence for what goes on in the mind. Research in human information processing reveals countless processes that clearly must be occurring (for example, parsing, inference) of which we have little or no subjective awareness." Pylyshyn (1989a:61)

The rejection of symbolic representations has condensed into the theory of connectionism in the 80s (Rumelhart *et al.* 1986). Connectionism challenges the standard cognitive model on the grounds of the mind-brain distinction, which is denied (typically, though not by all representatives of connectionism, as we will see): only the brain is relevant since only the neural level is decision-making. Therefore anything that goes beyond the study of the brain and its modelling (in terms of artificial neural networks) is misleading and unhelpful. That is, computation should be brain-style (rather than a machine-style), as Rumelhart (1989:134f) puts it: the basic calculating units must be (eventually artificial) neurons, and the items processed are numbers, rather than symbolic representations.

Connectionism (or at least some versions thereof) is thus reductionist in kind: it does not accept the mind-brain dichotomy. Symbolic and representational systems describe things that have no neural basis and hence are pure speculation (e.g. Churchland 1993, Chomsky 1995b exposes the rationalist refutation of reductionism).

Philosophically speaking, connectionism is monistic (the cognitive system is made of the brain and of nothing else), while the classical cognitive model is dualistic (the mind and the brain exist and are both relevant). Also, connectionism is a typical incarnation of empiricism which relegates any reasoning that is not data-based into the realm of unwarranted speculation. By contrast, the dualistic mind-brain approach falls into the tradition of rationalism/mentalism.

Interestingly, the charge against the classical cognitive model is thus led in the name of cognitive realism, just as was the introduction of the cognitive model in the 50s-60s: cognitive realism then, neural realism now. The linguistic implementation of the empiricist-connectionist approach is called "Cognitive" Grammar (see §11 for references and further discussion). The name of this framework is a good illustration of the issue at hand: it is deliberately chosen in order to warrant a copyright on the word "cognitive". Defenders of this model try to establish that their theory is the only cognitive theory about language – pure propaganda.[3] But they are deadly serious about stamping generative linguistics as non-cognitive. The following quote is form a textbook that introduces to "Cognitive" Grammar.

(2) "While most linguists, nowadays, would no doubt agree that linguistics is a cognitive discipline […], there have been important approaches within linguistics which have denied, or simply ignored, the discipline's cognitive dimension. Among these we can identify the formalist and the behaviourist approaches. (A cynic might say that quite a lot of modern linguistics is actually to be located within the formalist approach, with appeals to cognitive aspects being little more than lip-service to a modern fashion.) […] Work by Chomsky and his sympathizers, as well as various offshoots of Chomsky's theories, […] are very much formalist in orientation." Taylor (2002:6f)

In this vein, Taylor (2002:6) talks about Chomskian linguistics as "cognitive linguistics", i.e. in quotation marks. Saying that one of the founders of modern Cognitive Science denies or ignores cognitive issues in language is coming on a little strong. This kind of statement illustrates the empiricist-connectionist line of attack, though (which is sometimes expressed with more subtlety).

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3 Which is the reason why I refer to the framework as *"Cognitive"* Grammar in this book.

### 7 1.3. What would adult science look like without symbols?

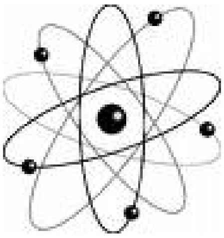
Looking at what appears to be one of the central debates of Cognitive Science from the outside, the question arises whether any other science, especially any adult science, could afford such a discussion.

What is physics, what is chemistry, what is biology about? Understanding how things work, or trying to produce a photograph of the natural object under study? Scientific discoveries have always been made in symbolic terms (I am not sure whether there is any exception at all): objects are thought, described and drawn before instruments provide evidence for their existence (think of molecules, atoms, the double helix, electrons, protons or whatever is your favourite). And scientists write down mathematical formulae in order to describe processes.

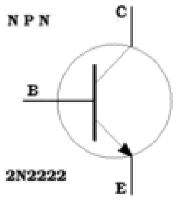
The point is that in all adult sciences, the only scientific reality is a representation of the real-world reality, in terms of a drawing and/or in terms of a formula. The relationship between both is often non-trivial, and it typically takes a lot of effort in order to be able to go from one to another: this is what engineering is about. Engineers construct machines on the grounds of a scientific insight. The engineering effort is typically undertaken long after the death of the scientist on whose discovery it is based. Engineers are the negotiators between the scientific reality and the real-world reality.

Take the atom: the well-known representation under (3)a is the only scientific reality that counts. No doubt the picture under (3)a is idealised and only remotely resembles a real atom that would be visualised by some image-giving system (microscopes today can see individual atoms, but they cannot yet look into them). Or consider what it takes to understand how a computer works, i.e. its basic building block, the transistor: do we need to know about (3)b, or do we need to inspect the makeup of the kind of physical item under (3)c?

(3) physical and scientific reality
a. an atom: scientific reality



b. a transistor: symbolic




c. a transistor: physical

Science is about gaining insight, not about engineering. No physicist would ever challenge the physical reality of (3)a; optical confirmation or any other instrumental evidence is of course welcome – but this is secondary with respect to the reality of (3)a that owes its legitimacy to its explanatory virtue. In particle physics, highly sophisticated machines, particle accelerators, are busy providing experimental evidence (though indirect: nobody has ever seen a quark on a photograph) for all the particles that are predicted by theoreticians whose only equipment is a sheet of paper and a pencil. And the particles predicted were found one by one.

Of course representations such as (3)a may turn out to be imprecise, incomplete or, according to the degree of incompleteness, simply wrong. But they have been established as the scientific reality, the only reality that counts in science, on grounds that have got nothing to do with any attempt to mimic its real-world properties: electrons turn around protons and neutrons because there is evidence to this end – remote effects whose inspection has led to (3)a as the best hypothesis. And it was by the same mechanism – observation of remote effects that make only sense if a certain structure is assumed – that it was discovered that protons are made of still smaller units, quarks. Will anybody argue against thirteen-dimensional string theory because strings are only a symbolic metaphor for some real "reality"?

Another point of interest is that in the history of (adult) science, progress has always been made when something was understood – not when it could be implemented. Einstein did not do any real-world experiment in order to build relativity theory – it was enough for him to think. Like it is often the case in adult science, the core of his discovery is a symbolic mathematical formula, $E = mc^2$. Long after Einstein died, relativity (among other things) eventually allowed humans to walk on the moon, and to engineer machines that allow a precise location on the planet (GPS). It was mentioned earlier that perhaps with a few exceptions, objects of the real world have always been thought and drawn on a piece of paper before they were eventually visualised by advanced instrumentation: cells, molecules, the double helix, quarks, strings, $H_2O$ and so forth.[4]

It is therefore difficult to understand why regular scientific standards seem to be questioned just when the object of study happens to be the mind/brain. Prohibiting to draw pictures and to talk about things in terms of symbols because the real world does not have any of those would not cross any physicist's mind. On the other hand, it is obvious and undisputed (in physics, chemistry and Cognitive Science) that whatever symbolic hypothesis is made, it must be compatible with what we know about the real world. That is, a biological theory that dismisses the cell can be rejected out of hand as much as a cognitive theory that supposes infinite storage capacity.

The relationship between symbolic scientific reality and real-world objects – their "implementation" – is intricate and dialectic, but in any case non-arbitrary: hypotheses must be implementable, but it takes a lot in order to show that a symbolic system could not possibly be the correct representation of a natural object. The history of science offers countless examples where some hypothesis was judged outright impossible, sometimes for centuries, before being found to be real (think of the history

4 In phonology, Morris Halle has used this line of argumentation a long time ago in order to justify the reality of the phoneme: "Helmholtz postulated that electric current is a flow of discrete particles without having isolated or even having much hope of isolating one of these particles. The status of the phoneme in linguistics is, therefore, analogous to that of electrons in physics, and since we do not regard the latter as fictional, there is little reason for applying this term to phonemes. They are every bit as real as any other theoretical entity in science" Halle (1964:325).

of astronomy). Scientific hypotheses are abandoned because they are shown to be wrong, not because they are made of symbols or non-symbols.

It is hard to see why symbolic representations in cognitive matters – a syntactic tree for example – should have any different heuristic, epistemological or scientific value than (3)a. In both cases, the negotiation with the real world is dialectic and complicated, and the distance with the symbolic representation may be more or less important. Since the relationship between representation and "reality" is dialectic, experimentation in both cases will provide valuable evidence for the eventual amendment of the representation, just as much as the experiments are designed on the grounds of hypotheses whose basis is the representation.

In particle physics, particle accelerators provide experimental evidence, while in Cognitive Science neurobiology (image-giving systems) plays this role. In both cases, representational and experimental activity must of course work hand in hand. And again, there is no question about that in adult science: it would be utterly absurd to doubt that this collaboration is necessary. Non-adult science is not only non-adult because it is younger and not (yet) confirmed by massive experimental evidence and engineering success – it is also childish because it does not behave like adults: reducing activity to either representational or neurobiological endeavour seriously reduces the chances of a serious scientific prospect.

The dialectic relationship between the functions of the mind and their (specialised and localisable) neural existence is further discussed in §29.

## 8 2. Connectionism and its representatives in linguistics

### 9 2.1. The symbolic front line and its roots in Cognitive Science

The symbolic front line introduced above is worked out in a special issue of Cognition on Connectionism and Symbol Systems in 1988 (number 28, edited by Steven Pinker and Jacques Mehler, also published as Pinker & Mehler (eds.) 1988). As the editors explain in the introduction, this issue is more or less the answer of standard Cognitive Science to the connectionist challenge was raised by Rumelhart *et al.* (1986). Especially the article by Fodor & Pylyshyn (1988) works out the symbolic vs. anti-symbolic line of division. While Dinsmore (1992) provides a book-length contrastive overview of the two approaches, Newell (1989) is a non-comparative introduction to symbolic models of cognition (and their parallels with computers). The issue is also discussed from a wholesale perspective by Pylyshyn (1999).

But of course connectionism does not reduce to the symbolic issue. The quote of Fodor & Pylyshyn below locates the connectionist research programme in the context of traditional Cognitive Science.

(4) "Connectionism really does represent an approach that is quite different from that of the Classical cognitive science that it seeks to replace. Classical models of the mind were derived from the structure of Turing and Von Neumann machines. They are not, of course, committed to the details of these machines as exemplified in Turing's original formulation or in typical commercial computers; only to the basic idea that the kind of computing that is relevant to understanding cognition involves operations on symbols. […] In contrast, Connectionists propose to design systems that can exhibit intelligent behaviour without storing, retrieving, or otherwise operating on structured symbolic expressions." Fodor & Pylyshyn (1988:4f)

Below some basic information on how the connectionist model works is provided.

10 2.2. How neural networks work

The connectionist approach to the cognitive system is based on the assumption that there are only two significant items, neurons and synapses. The former are computational units, which are fed by the latter: synapses transport information among neurons and decide how much of it gets through the pipe: this is the *weight* of a neuronal connection, which decides on the activation value of the target neuron. The quote below provides a summary of how a neural network works.

(5) "Connectionist systems are networks consisting of very large numbers of simple but highly interconnected 'units'. Certain assumptions are generally made both about the units and the connections: Each unit is assumed to receive real-valued activity (either excitatory or inhibitory or both) along its input lines. Typically the units do little more than sum this activity and change their state as a function (usually a threshold function) of its sum. Each connection is allowed to modulate the activity it transmits as a function of an intrinsic (but modifiable) property called 'weight'. Hence the activity on an input line is typically some non-linear function of the state of activity of its sources. The behavior of the network as a whole is a function of the initial state of activation of the units and of the weights on its connections, which serve as its only form of memory." Fodor & Pylyshyn (1988:5)

There are many surveys and introductions to how connectionist systems work, e.g. Rumelhart (1989), Stillings *et al.* (1995:63ff), Thagard (2005:111ff); Smolensky (2003) and Smolensky & Legendre (2006) provide a linguistically oriented overview. The following section takes a closer look at one particular aspect of the connectionist approach, the non-status of stored information and the outgrowths of this idea in linguistics.

11 2.3. No distinction between storage and computation (the rule/list fallacy)

Beyond the symbolic issue, the references are clear from the quote under (5): regular Cognitive Science follows the Turing/von Neumann idea that computation is done by short-term/working memory in a procedural way (step by step) on the grounds of a storage device – long-term memory. The dissociation of actual action and independently stored instructions that govern this action is the essence of the Universal Turing Machine where a "head" performs action on the grounds of instructions that are found on a "tape".

This simple architecture was improved by John von Neumann, who introduced a distinction between two kinds of storage systems: the one that contains the actual instructions for action (Relative Access Memory, which today would be called the programme/software), and another one that is just a data-storage device where things can be stored that are not needed for current action, and from which they can be retrieved when necessary. To date this is the basic architecture of computers, and also of Artificial Intelligence (AI) (e.g. Haugeland 1989:133ff, see also §18).

On the cognitive side, the memory that stores instructions for action (the programme/software) is the essence of the relevant module, the data-storing device is long-term memory and the computational space where actual action is performed is short-term memory. There is neuropsycholgical evidence that declarative (long-term memory) and procedural (instructions for action) knowledge are distinct: they can be dissociated by brain damage (Stillings *et al.* 1995:62, 312ff, Squire 1987).

In sum, computation and storage are crucially independent: the former builds on the latter. That is, a process transforms a pre-existing object. Connectionism denies the distinction between computation and storage: the only "storage" that it provides for is the online value of activation levels. In practice, the "experience" of a neural network – the equivalent notion of memory – is acquired when the patterns of connectivity change: neurons may develop new connections (synapses), may lose old connections, or modify the strength (weight) of existing connections (the two former are often viewed as a special case of the latter). The computational units themselves have no variable behaviour that contributes to the properties of the whole, which are exclusively determined by the connective network (see Stillings *et al.* 1995:114ff on connectionist models of memory).

All linguistic theories since Antiquity of course rely on the assumption that there is a lexicon which exists independently of grammatical activity. Grammar transforms lexically stored objects into actual speech. The linguistic mirror of the connectionist non-separation of storage and computation is so-called "Cognitive" Grammar, which was founded by Ronald Langacker (1987) (see Taylor 2002). Langacker (1987 Vol.1:42) talks about the "rule/list fallacy". The phonological off-spring of this line of thought is represented by exemplar- and usage-based approaches in general, and by Joan Bybee in particular. The following quote is explicit on that.

(6) "Perhaps the most fundamental difference between the model to be explored here and structuralist or generativist models is the rejection of the notion that material contained in rules does not also appear in the lexicon and vice versa. […] Linguistic regularities are not expressed as cognitive entities or operations that are independent of the forms to which they apply, but rather as schemas or organisational patterns that emerge from the way that forms are associated with one another in a vast complex network of phonological, semantic, and sequential relations." Bybee (2001:20f).

We are thus light-years away from anything that could be reconciled with generative thinking, actually with any linguistic thinking at all at least since the 19th century.

12 ## 2.4. All-purpose parallel vs. specialised step-by-step computation

Another important connectionist headline is Parallel Distributed Processing, which contrasts with the classical Turing/von Neumann assumption that computation is serial: the output of one computation is the input to another. On the connectionist count, several computations take place simultaneously, like in the brain. Rumelhart (1989) explains why computation cannot be step-by-step when it is carried out by real brains: this would require too much time.

(7) "The operations in our models then can best be characterized as 'neurally inspired.' How does the replacement of the computer metaphor with the brain metaphor as model of mind affect our thinking? This change in orientation leads us to a number of considerations that further inform and constrain our model-building efforts. Perhaps the most crucial of these is time. Neurons are remarkably slow relative to components in modem computers. Neurons operate in the time scale of milliseconds, whereas computer components operate in the time scale of nanoseconds – a factor of $10^6$ faster. This means that human processes that take on the order of a second or less can involve only a hundred or so time steps. Because most of the processes we have studied – perception, memory retrieval, speech processing, sentence comprehension, and the like – take about a second or so, it makes sense to impose what Feldman (1985) calls the '100-step program' constraint. That is, we seek explanations for these mental phenomena that do not require more than about a hundred elementary sequential operations. Given that the processes we seek to characterize are often quite complex and may involve consideration of large numbers of simultaneous constraints, our algorithms *must* involve considerable parallelism. Thus although a serial computer could be created out of the kinds of components represented by our units, such an implementation would surely violate the 100-step program constraint for any but the simplest processes." Rumelhart (1989:135, emphasis in original)

Another aspect of connectionist computation is that the units which carry out computation – neurons, or clusters thereof – are not specialised for a particular computational task, or for a particular input material. Rather, neurons are an all-purpose computational unit that is able to perform any computation on the grounds of any type of information submitted. This is why connectionist computation is called distributed.

A corollary of distributed computation is the claim that computation is opportunistic and does not need any specialisation of its support units, the neurons: computation is colourless.

We will see below that the modular approach works with the exact reverse assumption: there are stable, genetically endowed, content-sensitive computational units that are devised for a very narrow and specific function, which can only work with a particular type of input vocabulary, and can do nothing else than what they are designed for.

In a historical perspective, Marshall (2001:510) comes up with a quote by Charlton Bastian from the late 19th century that is surprisingly modern in anticipating the debate between modularity and connectionism.

(8) "The fundamental question of the existence, or not, of real 'localizations' of function (after some fashion) in the brain must be kept altogether apart from another secondary question, which though usually not so much attended to, is no less real and worthy of our separate attention. It is this: Whether, in the event of 'localization' being a reality, the several mental operations or faculties are dependent (a) upon separate areas of brain-substance, or (b) whether the 'localization' is one characterized by mere distinctness of cells and fibres which, however, so far as position is concerned, may be interblended with others having different functions. Have we, in fact, to do with topographically separate areas of brain-tissue or merely with distinct cell and fibre mechanisms existing in a more or less diffuse and mutually interblended manner?" Bastian (1880, emphasis in original)

Significantly, Bastian's book is entitled "The brain as an organ of mind" (more on this relationship in §42).

13 2.5. Where it all comes down to: connectionist computation is content-free

The properties of the connectionist architecture mentioned conspire to the assertion that the mind does not know what it is doing when computation takes place: computation is only general-purpose, that is non-specialised for any task or function; it works without reference to any symbolic code, which would make the operations specific to a particular domain or content since symbols are symbols of something, and may be opposed to symbols of a different kind. General-purpose parallel computation cannot rely on memory either because memory, again, would be the memory of something, that is specific to a particular content.

We will see below (§19) that modularity takes the opposite position on every issue mentioned, and that this follows from the conception that computation is computation of something: it is specific to a domain and to a function, that is content-sensitive and content-imparting (Cosmides & Tooby 1992a focus on these notions as a key difference between the modular and the connectionist approaches).

14 3. Conclusion: peaceful coexistence at first, but not for long

In sum, there are two competing conceptions of how the mind/brain works: the cognitive system is either made of interconnected all-purpose units (neurons), or a network of specialised and unexchangeable units (modules).

The connectionist line of attack is to challenge the standard cognitive model because of its unwarranted analogy with microelectronic computers (that carry out specialised and serial computation and work with short- and long-term memory): nothing entitles to conclude that the mind/brain should work like the most sophisticated man-created machine that is currently available. This is challenging the symbolic model on the very grounds on which it emerged during the cognitive revolution of the 50s-60s: psychological realism. Still more real than symbolic units are neurons, and in their self-understanding, connectionist models are neurally inspired and develop a brain-style (rather than a machine-style) computation (Rumelhart 1989:134).

Interestingly, the connectionist and the standard cognitive approaches were not understood as irreconcilable competitors at first: in the early literature when connectionism individuated from the symbolic cognitive mainstream, it was viewed as an interesting complement which offers a biologically and neurally grounded implementation of the higher level symbolic system. Smolensky (1987) for example is explicit on this.

(9) "In this paper I present a view of the connectionist approach that implies that the level of analysis at which uniform formal principles of cognition can be found is the subsymbolic level, intermediate between the neural and symbolic levels. Notions such as logical inference, sequential firing of production rules, spreading activation between conceptual units, mental categories, and frames or schemata turn out to provide approximate descriptions of the coarse-grained behaviour of connectionist systems. The implication is that symbol-level structures provide only approximate accounts of cognition, useful for description but not necessarily for constructing detailed formal models." Smolensky (1987:95)

Connectionism was thus a question of levels: following the work by Marr (1982) on vision, the symbolic level could stand unchallenged as long as connectionist neural networks were understood as an intermediate level between the (neural) biology of the brain and the functional view of the symbolic level. Dinsmore (1992) and Macdonald & Macdonald (1995) have edited books that revolve entirely around the possibility of understanding the classical theory of the mind and connectionist mimicking of neurons and synapses as two ways of looking at the same object which are equally legitimate: rather than constructing competing views of the mind/brain, they are complementary and both necessary for the understanding of the mind/brain, just as zoology and biology are for the understanding of living species.[5] The book about modularity and language edited by Garfield (ed.) (1987) also falls in this early period where a synthesis was still an option.

Fodor & Pylyshyn (1988), from the camp opposite to Smolensky's, also arrive at this conclusion.

(10) "Treat Connectionism as an implementation theory. We have no principled objection to this view (though there are, as Connectionists are discovering, technical reasons why networks are often an awkward way to implement Classical machines). This option would entail rewriting quite a lot of the polemical material in the Connectionist literature, as well as redescribing what the networks are doing as operating on symbol structures, rather than spreading activation among semantically interpreted nodes.
Moreover, this revision of policy is sure to lose the movement a lot of fans. As we have pointed out, many people have been attracted to the Connectionist approach cause of its promise to (a) do away with the symbol level of analysis, and (b) elevate neuroscience to the position of providing evidence that bears directly on issues of cognition. If Connectionism is considered simply as a theory of how cognition is neurally implemented, it may constrain cognitive models no more than theories in biophysics, biochemistry, or, for that matter, quantum mechanics do. Al1 of these theories are also concerned with processes that *implement* cognition, and all of them are likely to postulate structures that are quite different from cognitive architecture. The point is that 'implements' is transitive, and it goes all the way down." Fodor & Pylyshyn (1988:67f, emphasis in original)

One senses, though, that the peaceful coexistence will not last long on either side: the battle is engaged for pocketing the biggest possible piece

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5 One track followed in the "bridging" literature, i.e. which tries to make classical Cognitive Science and connectionism peacefully cohabitate, is to take artificial neural networks that are designed according to connectionist principles, and to add content-labels to the neurons, which are also arranged graphically in order to mimic the image provided by the classical theory. In linguistics, for example, Stevenson (1999) draws regular syntactic trees whose nodes are interpreted as neurons with the relevant linguistic labels, and whose branches are synapses. This of course is violating all principles on all sides: connectionist neural networks cannot have any content, and branches of syntactic trees represent domination relationships: they have got nothing to do with activation levels. In the same spirit, Plaut (2003) relates sub-components of grammar by a neural network: phonology is characterised as a neural entity that entertains relationships (in terms of activation levels) with other neural entities representing semantics, acoustics and articulation.

of the cake: how much of cognitive activity is symbolic, and how much is connectionist? Where exactly are decisions made? Smolensky's (1987) conclusion also goes this way.

(11) "The heterogeneous assortment of high-level mental structures that have been embraced in this paper suggests that the symbolic level lacks formal unity. This is just what one expects of approximate higher-level descriptions, which, capturing different aspects of global properties, can have quite different characters. The unity which underlies cognition is to be found not at the symbolic level, but rather at the subsymbolic level, where a few principles in a single formal framework lead to a rich variety of global behaviours." Smolensky (1987:108)

The front lines have grown more rigid since the 80s, and as far as I can see there is not much left of a peaceful level-specific coexistence of symbolic and connectionist models. They are globally competing theories of cognitive activity, even if this or that connectionist model may not completely exclude the existence of a symbolic residue. It was already mentioned in §**Erreur ! Source du renvoi introuvable.** that Smolensky & Legendre's (2006) version of OT, Harmonic Grammar, pursues the peaceful coexistence programme in linguistics: parallel distributed computation (constraint ranking) operates over traditional symbolic items (typically segments).

The main connectionist import into linguistics is parallel computation, which is the headstone of (all versions of) OT. The question whether this import into a rationalist theory of language (generative grammar) can succeed without serving as a Trojan Horse for other empiricist properties of connectionist thinking is discussed in Scheer (2010a:205ff). Namely the D of PDP (Parallel Distributed Processing) is modularity-offending, or gears OT towards the dissolution of modular contours, since it promotes a scrambling trope where all types of computation (phonetic, phonological, morphological and even syntactic for some) are carried out in one single constraint chamber (see §**Erreur ! Source du renvoi introuvable.**).

On the other hand, the modern version of the classical symbolic model is Jerry Fodor's modularity, which is introduced on the following pages.

# Chapter 3
15 The modular architecture of the mind: where it comes from

## 16 1. The brain as a set of functional units: F-J Gall's early 19th century phrenology

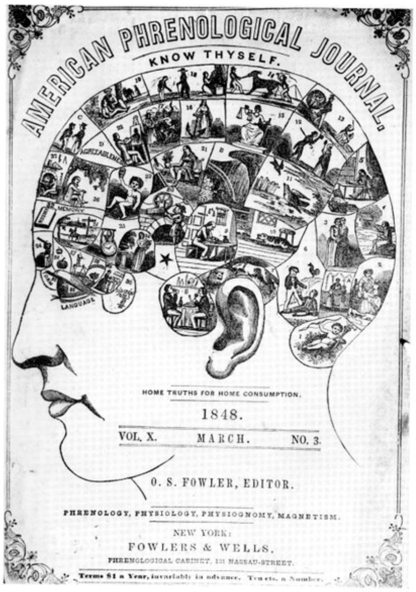
The idea that certain brain areas have localised and specific functions goes back to the inventor of phrenology, Austrian physician Franz-Joseph Gall (1758-1828), who also first proposed that the brain is the (only) organ of the mind (e.g. emotions are not located in the heart, but in the brain).

(12)

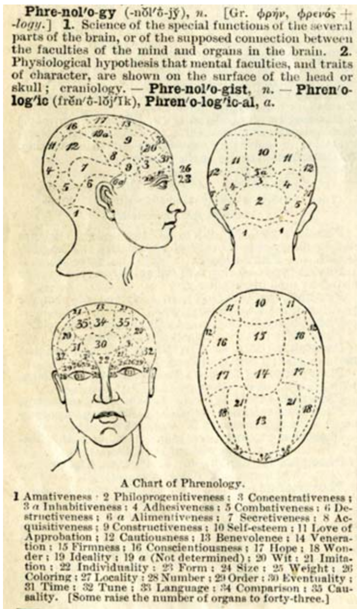

Franz-Joseph Gall (1758-1828)

Phrenology holds that the mind decomposes into a number of individual mental faculties which are localised in a specific area of the brain and correlate with precise areas of the overlying skull bone. Hence in the 19th century when phrenology was popular especially in the Anglo-Saxon world, phrenologists divided the human skull into areas that represent faculties such as combativeness, wit, hope, willpower, cheerfulness or number (mathematics): maps were drawn which identified certain areas of the skull with specific faculties. Table (13) below reproduces two relevant figures.

(13)




American Phrenological Journal, 1848




Webster's Academic dictionary, 1895

Phrenology and its history are described in greater detail for example by Sabbatini (1997) and van Wyhe (2004). Marshall (2001) situates the idea that cognitive functions are independent (in mind and brain) in the history of philosophy, namely in Ancient Greek thinking. Boeckx (2010:154ff) and Nicolas (2007) discusses phrenology in the context of modern functional anatomy (the localisation and cartography of cognitive functions in the brain, see §29).

17 2. Independent faculties, their correlation with size and the skull bone

The basic observation that led to the decomposition of the mind/brain into a set of basic faculties was that certain individuals are good at doing some mental activity (e.g. counting) but bad at some other (e.g. memorising), and that the distribution of acuity concerning various faculties over humans cannot be predicted. Given this inter-individual independence of faculties, then, the conclusion is that they must be independent units – mentally and in the brain.

Based on this observation, Gall promoted the idea that there is a correlation between the acuity of a given faculty and its physiological size

– and that in addition the latter corresponds to a predictable zone on the skull bone. That is, the greater the acuity for a given faculty, the bigger the corresponding area of the brain, whose size is directly proportional to a corresponding zone of the skull ("the skull fits the brain like a glove fits the hand"). Hence somebody with a large number area will be good at mathematics, but somebody with a small moral area will be of little morality etc.

Predictably enough, this alleged skull-to-mental-faculty relation was misused for racist purposes and the apology of this or that ideology or belief. This kind of instrumentalisation included the superiority of the white race in colonial 19th century, but also "domestic" issues: on the grounds of phrenology, the Irish were argued to be close to the Cro-Magnon man and thus to have links with the "Africinoid" races (van Wyhe no year). This was the more tempting as the mental faculties that phrenologists focused on concerned higher cognitive functions such as personality and character, rather than lower functions such as perceptual systems etc.

For these reasons, phrenology has been largely discredited in the 20th century. Gall and 19th century phrenologists of course were wrong in asserting that the size of the area of the brain that accommodates a mental faculty correlates with the performance of this faculty in any way. And it is also not true, of course, that mental faculties correlate in any way with areas of the skull bone.

Gall's central tenet, however, has received massive empirical support in modern times: today it is an established cognitive and neurobiological fact that all areas of the brain do not perform all tasks: some are specialised in doing this, others in doing that – mental and neural structure has a functional architecture. The modern incarnation of this idea was formulated in terms of faculty psychology by Jerry Fodor (1983 et passim) before neuro-imaging systems that reveal gross functional areas in the brain were available.

18 

## 3. Faculty psychology married with computation theory (von Neumann - Turing)

In Fodor's work, the idea that the human cognitive system is composed of several functionally and computationally autonomous sub-systems is married with the model of computation that was developed in the 40s, and which is the basis of Artificial Intelligence, Chomskian linguistics, the standard model of Cognitive Science and various strands of mathematics, logic and the Humanities (see Gardner 1985 for a overview).

Also, the technology of modern micro-computers is based on this work (hardware and software alike: structured modular programming), whose most prominent figures are the British mathematician Alan Turing (1912-1954) and the Hungarian-American mathematician John von Neumann (1903-1957). Overview literature of what is commonly called the von Neumann-Turing model and its application to Cognitive Science includes Herken (1995), Clapin (2002), Pylyshyn (1984, 1989a,b), Haugeland 1989:133ff); an introduction from the linguistic perspective is provided by Boeckx (2010:33ff). An early argument in favour of a computationally based modular conception was made by the founder of Computational Neuroscience, David Marr, on the grounds of vision (Marr 1982).

Central to this theory of computation are the following claims: computation is based on distinct short-term (working) and long-term memory (this is the essence of the Universal Turing/von Neumann Machine, see §11), it is serial (i.e. step-by-step, rather than parallel), its is based on a symbolic, pre-determined and machine-specific language, and it is organised in functional units that are devised to solve a specific problem – the modules. The symbolic issue was already discussed in §4.

Fodor's modular organisation of the mind/brain that he proposes thus unites the two strands, computation theory and faculty psychology (which roots in phrenology and related traditions in psychology, see Posner 1981).

# Chapter 4
# 19 The modular architecture of the mind: how it works

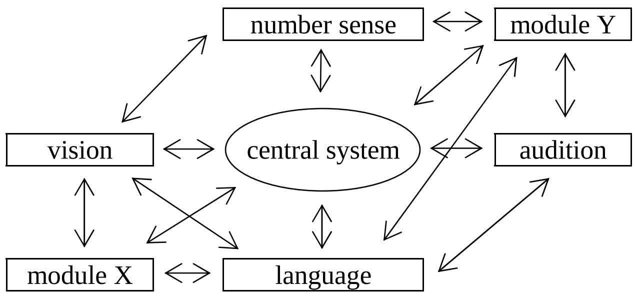
## 20 1. Higher and lower cognitive functions, modules and the central system

Given Gall's idea that the mind is a set of functional sub-systems, the question arises what exactly counts as a module: how many different faculties are there, how coarse-grained and of what type are they, what kind of evidence can be brought to bear in order to identify them and how can they be delineated?

Regarding the problem of functional taxonomy, Gall himself already argued against very broad abilities (whose operations may apply to different domains) such as intellect, acuity, volition, attention, judgement or memory (Fodor 1983 calls these horizontal faculties). Just like instinct (of birds to sing etc.), these abilities do not have a specific neurological localisation in Fodor's model. Rather, they emerge from the conjugation of more fine-grained abilities (which Fodor 1983 calls vertical faculties) such as vision, audition or number processing. A range of this kind of problem-solving entities (which are known as lower cognitive functions in psychology) are thus the construction workers of higher cognitive abilities such as moral and social judgement, which Fodor (1983) calls the central system.

Table (14) below depicts the relationship between Fodor's central system and modules (how modules communicate with other modules, and with the central system, is a central issue that is discussed in §65 and also in Vol.2).

(14) Fodor (1983): modules and the central system that they inform




The central system is (or rather: the central systems are) informed by the work that is done by modules, but it is not a module itself. Namely, higher cognitive abilities that are the result of the central system lack the two main characteristics that define modules: they are not domain specific, and they are not (informationally) encapsulated (more on these notions shortly). Also, they try "to make sense" of the information that is submitted to them and hence may be goal oriented.

Unlike central systems, modules are "dummy" and non-teleological: they have do decisional latitude, do not make or evaluate hypotheses and hence do not try to achieve any goal: they are simple computational systems which calculate a predictable output on the grounds of a given input ("input systems" which are stimulus-driven). They provide evidence that the central system needs in order to manage hypotheses, but are entirely insensitive to whatever the central system may "ask" them to do. Modules do their job fast, well, they are very reliable, and they are mandatory: humans cannot decide to switch them off. For example, visual stimulus always ends up as a three dimensional picture, language is always processed as such and not as noise, and subjects cannot help identifying what kind of surface their fingers are running over.

Prime examples of lower cognitive functions that qualify as modules have already been mentioned: audition, vision, number sense. At least the two former are no doubt genetically endowed. Being innate is thus another property of modules. Fodor (1983:44) grants modular status to "the perceptual faculties plus language" – an interesting definition.

Following the Fodorian track, general introductions of the modular approach to the mind include Stillings *et al.* (1995:16ff), Segal (1996), Cattell (2006) and Samuels *et al.*(1999:85ff). Following Marr (1982), vision is certainly the best studied cognitive faculty which indeed provides pervasive evidence for a modular architecture of the mind/brain (e.g. the papers on vision in Garfield (ed.) 1987:325ff, Stillings *et al.* 1995:461ff).

## 21 2. How much of the mind is modular?

### 22 2.1. Peripheral vs. massive modularity: is there a non-modular core?

Fodor (1983) is pessimistic about our ability to understand how central systems work: he assumes that they are resistant to scientific theorising and ultimately to human understanding because they cannot be appraised through the modular prism: "the more global […] a cognitive process is, the less anybody understands it" (Fodor 1983:107).

A different line of thought expands the modular architecture to central systems as well. Pinker (1997) and Plotkin (1998) are the most prominent figures of this direction: according to them, all mental processes are computations. Smith (2002, 2003) also questions the strict separation between modules and non-modular central systems, and Smith & Tsimpli (1995:164ff, 1999) are optimistic regarding our chances to understand how central systems work: they craft the notion of quasi-modules, which they believe higher cognitive functions are produced by. The volume edited by Hirschfeld & Gelman (eds.) (1994) also contains a number of papers that argue for the domain specificity of higher cognitive functions such as social categories, cultural representations and emotions (domain specificity is a central property of modules, see §26 below).

Following the same track, Higginbotham (1987:129f) argues that language is a central system *and* modular. Sperber (1994, 2001) also promotes the modular character of central systems: according to his *massive modularity*, the brain is modular through and through.

Fodor (1987:27) calls this the "modularity thesis gone mad": he has always held the view that not all cognitive functions are modular in nature. Fodor (1987) for example is a defence of this position. The article opens like this: "There are, it seems to me, two interesting ideas about modularity. The first is the idea that some of our cognitive faculties are modular. The second is the idea that some of our cognitive faculties are not."

More recently, Fodor (2000) is a book entirely devoted to the question whether all or only part of the cognitive system is based on a modular architecture. The book is an exegesis and a refutation of Pinker's and Plotkin's "New Synthesis Psychology" (which Fodor calls rationalist psychology, see also Fodor 1998). Gerrans (2002) provides an informed overview of the debate regarding the articulation of modules with central systems.

23 2.2. Is the central system impenetrable for human intelligence?

What really is behind this debate is (against a possible prima facie impression) a categorical, rather than a gradual distinction – one that has deep philosophical roots and far-reaching consequences. That is, the modular paradigm falls into two opposing camps, one holding up Descartes' position that the mind, or at least some of it (the central system in Fodor's terms), is beyond what can be understood by human intelligence and will always remain an impenetrable mystery (the soul is of course lurking behind the mind of Descarte's mind-body dichotomy); by contrast, the other camp makes no difference between lower and higher cognitive functions, which are both the result of modular activity.

We have seen that the former view is defended by Fodor (1998, 2000), but also by Chomsky in linguistics (e.g. Chomsky 1984:6f, 23f, Chomsky 1995b:2f, chapter 4 of Chomsky 1975 is called "Problems and mysteries in the study of human language"). Fodor's and Chomsky's position blocks any inquiry into how the mind really works (all of the mind for Descartes, just a subset of it, the central system, for Fodor/Chomsky) before it has even started: don't try to find out how it works, you will fail anyway. This has direct consequences for the dialogue with the implementational level (see §29): only a subset of the mind may be mapped onto neuro-biology – the central system is not based on any neuro-biological activity, or at least will humans never be able to understand what the relationship is.

24 2.3. Is the mind (are modules) the result of Darwinian adaptation?

The latter position, i.e. where all cognitive functions are in principle accessible to human intelligence and must ultimately be able to be mapped onto neurobiology, is what Fodor calls rationalist psychology. In other quarters, it is called evolutionary psychology in recognition of the fact that it is intimately interwoven with the Darwinian perspective. Pinker (1997) and Plotkin (1998) hold that the mind, like the brain and all other properties of living beings, is the result of an adaptive evolution which was marshalled by selectional pressure over millions of years.

Obviously, if all is the result of environment-driven adaptation, no part of the mind can stand aside. Which means, viewed from the other camp, that Fodor and Chomsky must deny the idea that all of the mind is the result of Darwinian selection. This is precisely what they do in the biolinguistic programme: the controversy between Hauser *et al.* (2002)

(also Fitch *et al.* 2005) and Pinker & Jackendoff (2005a,b) is about this issue.

Hauser *et al.* (2002) argue that the FLN (Faculty of Language in the Narrow sense), i.e. what really makes language distinct and unique (with respect to other cognitive functions), boils down to recursion (of morpho-syntax) and the ability to talk to interpretational systems (phonology and semantics), that is to Merge and Phase. They also hold that the FLN is the only property of language that could not possibly be the result of an (adaptive) evolution based on an animal ancestor: the FLN is given (more on this debate in §48). This claim lies at the heart of the biolinguistic programme (where phonology and semantics for example are not specifically human, see §54) and is further developed with specific attention for phonology by Samuels (2009a,b).

On the other hand, the general viewpoint of evolutionary psychology on the mind is exposed by Cosmides & Tooby (1992a, 1994), Barkow *et al.* (1992). Samuels *et al.* (1999) offer a valuable digest of the debate between peripheral (Fodor/Chomsky) and massive (evolutionary psychology) modularity on the backdrop of the opposition between what they call Chomskian and Darwinian modules. Even though based on a non-evolutionary perspective, Sperber (1994, 2001), Smith (2002, 2003) and Smith & Tsimpli (1995:164ff, 1999) go along with the Darwinian party.

## 25 3. Core modular properties

### 26 3.1. Domain specificity

Modules are computational units that are devised for just one highly specific task. Therefore the symbolic vocabulary that they work with is as specific as their task: the input, its transformation by computation and the output are written in a specific vocabulary.

A module can only understand its own vocabulary: whatever information is submitted that is not written in the specific symbol code of the module is uninterpretable: it is treated as noise and simply ignored. For example, the visual module can only take visual stimulus as an input. It will ignore any auditive or other alien information.

Arguments for domain specificity come from various fields, including neuropsychology, computational theory and cognitive evolution (Gerrans 2002:261 provides an overview, see in particular Cosmides & Tooby 1992a). Hirschfeld & Gelman (eds.) (1994) provide an overview of domain specificity and the kind of domains that can be isolated (which include higher cognitive functions such as social categories, culture-specific representations and emotions); Fodor (2000:58ff) discusses the various ways in which domain specificity has been used.

Domain specificity will be put to use in §55 in order to identify the grammar-internal modular architecture.

27 3.2. Informational encapsulation

Modules are also (informationally) encapsulated, which means that during the computation performed, they do not need and cannot take into account anything that was not present in the input. That is, once the input is defined and computation has begun, nothing can alter the course of events, and the output is produced in complete disregard of any module-external information such as high-level expectations, beliefs (coming from the central system), memory, inference and attention or results of other modules.[6] Conversely, modules are unable to communicate any intermediate result of their work: transmission to other modules or to the central system is only possible once the computation is completed. In sum, modules are autistic (Fodor 2000:62ff, Gerrans 2002 and Smith & Tsimpli 1995:30f provide a concise introduction to encapsulation).

The effect (and hence existence) of encapsulation is typically shown on the grounds of optical illusions. Under (15) below appear a number of well-known cases, which all demonstrate that humans are "fooled" by their visual system even if they know beforehand that what they "see" is not true: there is no way to willingly marshal vision according to prior knowledge of the central system, to some desire or presupposition. Vision does whatever it does without asking any other cognitive system, and even against the will of the subject: no other cognitive system, modular or central, can "break into" vision in order to change its course once computation has begun.[7]

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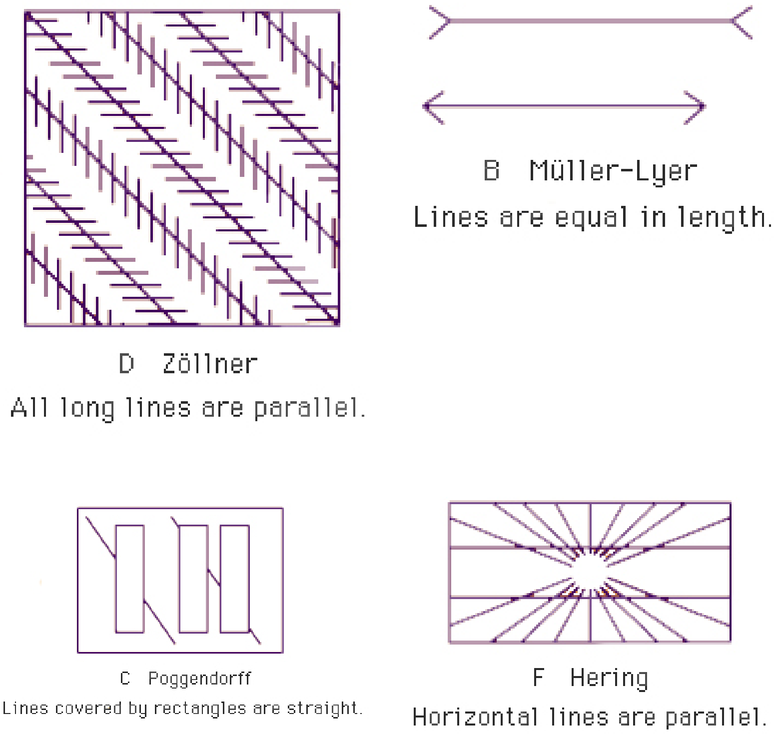
[6] This of course does not withstand the existence of networks of modules or of "loops" whereby the result achieved by a given module serves as the input of several other modules and eventually, enriched with additional information, is pulled several times through the same module.

[7] The reason and genesis of the illusions are secondary for the argument. Also note that the effect is the same for all humans (who are subject to the illusion: some are not), i.e. perfectly independent of culture, language, age, social parameters and so forth.

(15)




Encapsulation has been challenged on the grounds of the possibly non-encapsulated communication between the central system and modules whereby the former affects ongoing modular computation. Arguments to this end have been made on the connectionist side (e.g. Elman 1994), but also in the quarters of developmental psychology (Karmiloff-Smith 1998). Ongoing debate is reviewed by Gerrans (2002), who argues in favour of encapsulation.

The syntactic application of encapsulation is Chomsky's (1995a:228) inclusiveness, on which more in §63. Encapsulation will also play a role in §36 when the modular status of grammar and its subsystems is discussed.

**28** 3.3. Summary: how to identify a module

A module is thus a hard-wired and genetically determined computational unit that builds on a fixed and localisable neural structure; it is domain specific (i.e. content-based), autonomous, automatic, mandatory, stimulus-driven and insensitive to central cognitive goals. Segal (1996:145) provides an informed and concise overview of the modular idea in its various incarnations. His list of core properties contains nine items, which are shown under (16) below.

(16) core properties of cognitive (Fodorian) modules according to Segal (1996:145)
a. domain specificity
b. informational encapsulation
c. obligatory filtering
d. fast speed
e. shallow outputs
f. limited inaccessibility
g. characteristic ontogeny
h. dedicated neural architecture
i. characteristic patterns of breakdown

Crucially for linguistics (as we will see below), a module is designed for a special purpose and can only work with the specific vocabulary associated – all the rest is noise: modules "solve a very restricted class of problems, and the information it can use to solve them with is proprietary" (Fodor 1998).

Now recall Chomsky & Halle's (1968) description of the phonological rule system that was already quoted in §**Erreur ! Source du renvoi introuvable.**: it is quite surprising an anticipation of what Fodorian modules will look like 15 years later.

(17) "The rules of the grammar operate in a mechanical fashion; one may think of them as instructions that might be given to a mindless robot, incapable of exercising any judgment or imagination in their application. Any ambiguity or inexplicitness in the statement of rules must in principle be eliminated, since the receiver of the instructions is assumed to be incapable of using intelligence to fill in gaps or to correct errors." Chomsky & Halle (1968:60)

Given these core modular properties, a question is how modules are practically delineated within the host of cognitive functions. The typical answer is domain specificity: a computation that builds on heterogeneous primitive units cannot be done in one and the same module. As we will see below (§37), there is serious debate in linguistics regarding which entities (sub-disciplines) exactly are identical or distinct computational systems (ongoing controversy namely concerns morphology and syntax, see §**Erreur ! Source du renvoi introuvable.**). In this situation, the guiding light will be to look at which kind of vocabulary is processed on each side, and whether it is the same. In case it is not, the two entities cannot be incarnations of the same module.

§33 introduces yet another way of detecting modules, (double) dissociation, which may be called external in comparison to the internal handle that is offered by domain specificity. While the latter requires only the inspection of linguistic properties (the vocabulary used), (double) dissociation requires the examination of speakers that experience significant cognitive and/or brain damage.

Overview literature regarding the general properties of modules includes Segal (1996), Pinker (1997), Plotkin (1998), Sperber (2001), Gerrans (2002), Jackendoff (2002:218ff), Smith (2002, 2003) and Fodor (2000). Cosmides & Tooby (1992b:93ff) provide a historical overview of the modular idea from the psychologist's perspective.

## 29 4. Specialised neurons and neural localisation of cognitive functions

### 30 4.1. Mind-brain relationship

The modular approach to the mind/brain has a number of implications in philosophy, neurobiology, psychology, linguistics and other areas of knowledge. Chomsky (2002:45ff) provides a historically oriented overview, arguing that Cognitive Science, where the mind-brain dichotomy is still puzzling, may learn a lot from the history of adult sciences like physics and chemistry, which had to face similar problems a while ago.

Below two testing grounds that have been prominently explored in the literature are given closer attention: on the one hand, the prediction that functional specialisation of the mind implies the existence of specialised and localisable suites of neurons in the brain. On the other hand, the prediction that if there are functionally specialised modules and neurons, cognitive and/or brain damage must be able to "plug them out" without this affecting other faculties (§33).

Let us first take a closer look at the former. It was mentioned in §7 that the relationship between symbolic representations and real-world objects, in physics, chemistry and biology as much as in Cognitive Science, is intricate and dialectic, but in any case non-arbitrary. It is an established neurobiological fact that all neurons do not do everything: suites of neurons may be specialised (although not necessarily to do one single thing).

For example, that the Broca and Wernicke areas of the brain are specifically related to the processing of language is known since the 19$^{th}$ century (Broca 1861, see e.g. Loevenbruck *et al.* 2005 for a modern investigation) and has even found its way into popular science. Posner (2001) and Nicolas (2007) offer a historical survey of the efforts that are made in order to localise cognitive functions in the brain (see also Boeckx 2010:149ff regarding language). The quote from Bastian's (1880) book "The brain as an organ of mind" that is reported in §12 is quite instructive in this respect.

31 4.2. Functional anatomy: the existence of specialised and localisable (suites of) neurons is undisputed

Gerrans (2002:259) points out that the symbolic issue which was discussed in §4 is entirely independent of the functional specialisation that is predicted by modularity: whether or not computation relies on symbols and hence is content-sensitive is orthogonal to the question whether the mind/brain is made of functional units. Neurobiologically speaking, the existence of functionally specialised suites of neurons provides evidence for modularity no matter what it actually is that the neurons in question process.

The modern study of vision for example has produced undisputed evidence that specialised neurons exist and are localisable in the brain.

(18) "Functional specialisation occurs within the neural systems on which vision depends. The visual cortex contains individual and suites of neurons specialised for detecting orientation, disparity, wavelength, velocity, direction and size. (Marr, 1982). This neuroanatomical organisation reflects the functional organisation of the visual module for good reason. Rather than involve the same region in more than one task, 'Regional specialisation, on the contrary means that columns of cells can he connected with neighbours that have related functions.' (Shallice, 1988, p. 19)." Gerrans (2002:263)

Gerrans (2002:263) goes on to point out that "clearly however, there is no one-to-one mapping from cognitive function to unique neural location" – it was mentioned earlier that a complicated and dialectic relationship is certainly what is expected.

In our past and present understanding where symbolic representations and functional anatomy are still light-years away from being able to be matched, the classical strategy is to approach the problem by thinking of it in terms of levels. Since linguistic representations are much too coarse grained, and neuobiological functioning way too fine grained, intermediate levels may help to do justice to both and make our understanding of the overall situation progress.

This is what connectionism set out to do in the late 80s when it was considered to be an implementational level of symbolic representations, but still ranging above neurobiology: recall from §14 that this is Smolensky's (1987) position, which he carried over into his version of OT (Smolensky & Legendre 2006). The work by David Poeppel, often in collaboration with linguists, also follows this track: here the relevant level of abstraction is the *circuit*, a brain structure that computes simple operations. A circuit is simple enough not to exceed what can be measured neurobiologically, but at the same time complex enough to allow for the representation of a simple linguistic process. This research programme is laid out in Poeppel & Hickok (2004), Embick & Poeppel (2005) and Poeppel & Embick (2005); relevant work includes Hickok (2004, 2007), Poeppel (2008). Boeckx (2010:158ff) echoes this line of thought and inserts it into a broader (also historical) perspective.

The plasticity of the brain is another factor: suites of neurons that support a given cognitive function may "migrate" within the brain due to damage, hemispherectomy, growth of a tumour and the like. Locations of cognitive functions in the brain are thus approximative anyway (no two brains are identical), and only valid for subjects with normal development. Finally, nothing requires a cognitive function to be supported by a suite of neurons where all neurons involved are adjacent: a function may be spread over several locations in the brain.

### 32 4.3. Some literature

The section of Brain and Biology of Dupoux (ed.) (2001) offers a number of overview articles that report on how functional brain-imaging techniques (PET, fMRI, ERPs)[8] interact with classical psychology and Cognitive Science, eventually achieving the localisation of a number of cognitive functions in the brain. Posner (2001) is about language and attention; Newport *et al.* (2001) show how neuroscience can enlighten questions of language acquisition and the notion of critical periods (and vice-versa); Peretz (2001) uses brain imaging in order to approach auditory and emotional processing in relation with music. The section on the

[8] PET = Positron Emission Tomography, fMRI = functional Magnetic Resonance Imaging, ERPs = Event-Related Potentials.

neurological basis of language in Banich & Mack (eds.) (2003) offers similar perspectives.

In the area of phonology, the book edited by Durand & Laks (eds.) (2002) contains three articles that discuss the relationship between cognitive functions and their neural implementation in the brain, namely from the modern neuro-imaging point of view. Démonet *et al.* (2002) hunt down anatomical and temporal indexes of the neural activities that underlie language perception (especially phonological and lexical-semantic processes); they also discuss the evolution from aphasia-based to neuro-imaging-based techniques that are and were used in the study of the physiology of cognition.

Schwartz *et al.* (2002) discuss the relationship of perception, action control and phonology. They argue that empiricist approaches based on self-organising statistical and exemplar-based models are unsuited since they lack constraints on regulation and control, which according to the authors can only come from a perception-action link at the intersection of phonetics and phonology.

Abry *et al.* (2002) draw arguments from aphasia, especially from a babbling-like type (which *tan-tan* [tãtã], the bequeathed production of Broca's patient, could illustrate), in order to localise the control of CV-recurring utterances in the non-lateral left hemisphere.

These bibliographical indications are not systematic: the literature on the topic is booming, and I am not a specialist of the field. The purpose is just to show that there is something like Cognitive Neuroscience, a new discipline that has emerged in the recent past, which tries to achieve "the synthesis of mind and brain", as Posner (2001) puts it.

## 33 5. Modules can be plugged out without affecting other faculties

### 34 5.1. Double dissociation

Let us now consider the other interesting prediction made by modular theory: so-called double dissociation is based on the functional character of modules; it opens a fairly precise empirical testing ground on the basis of cognitive and/or brain damage.

If different functions are managed by different modules with no overlap (i.e. a given function is computed by one and only one module), then any module should be able to be plugged out, causing the loss of the function that it is responsible for, but leaving the rest of the system without damage. If on the other hand there are no modules and all functions are intertwined (this is the connectionist take), the damage of a particular area should impact a variety of other areas and functions.

Hence showing that two cognitive functions are entirely independent is providing support for the modular architecture. The demonstration of functional independence requires so-called double dissociation (e.g. Smith 2003): given two abilities, different subjects may lose one while retaining the other and vice versa. A trivial case is blindness and deafness: some people are blind but not deaf, others are deaf but not blind. Hence it is reasonable to assume that vision and audition do neither use the same hardware (brain) nor the same software (mind).

### **35** 5.2. Documented cases: face recognition, number sense

Examples of (double) dissociation are frequently reported in the pathological literature (e.g. Karmiloff-Smith *et al.* 1995). One case in point is discussed by Smith (1998:9): "prosopagnosia is the sad condition which afflicted Oliver Sacks' eponymous subject. 'The man who mistook his wife for a hat'. As a result of a cerebral lesion involving the visual system he became unable to recognise faces, even though he could still identify people from their voice or smell or touch, and his conceptual abilities were unaffected." This is evidence to the end that vision is not just one undifferentiated cognitive function. Rather, it falls into several computational systems, one of which is specialised in face recognition (also, shape and colour appear to be determined independently). On the other hand, Moscovitch *et al.* (1997) document the symmetric dissociation: they study a case where object vision is impaired, but face recognition is normal.

Another case in point is the number sense, which appears to actually involve two separate modules: one that computes small numbers up to four or five with high precision and very rapidly (paucal); the same module also roughly guesses bigger numbers (8 items are less than 20, 20 items are about 20, not 60) (approximate). A different module manages so-called verbal counting: it operates over natural numbers and performs mathematical calculus (the four basic operations). Based on evidence from subjects with various cerebral lesions, Dehaene (1997) reports that the paucal and the approximative abilities are always associated: if a subject is impeded in one area, the other will also be affected. However, verbal counting and paucal/approximate counting are doubly dissociated: subjects who cannot cope with one may have undamaged abilities regarding the other.

Dissociation is also documented for implicit and explicit knowledge by Reber & Squire (1998).

Besides pathological evidence that relies on damage of the mind and/or brain, the (double) dissociation of cognitive functions may also be demonstrated on the grounds of data from development: Hermer & Spelke (1996) for example study spatial reorientation in this perspective.

### 36 5.3. Double dissociation of language

Regarding language, Neil Smith and Ianthi-Maria Tsimpli have documented the case of Christopher over a relatively long period (Smith & Tsimpli 1991, 1995, 1999, also Smith 1998, 2002, 2003). Christopher has severe cognitive deficits (he cannot look after himself, has trouble to find his way around, poor hand-to-eye coordination etc.), but an extraordinary talent for the acquisition and use of language. That is, Christopher is fluent in some 15 or 20 languages, in which he can construct morphologically and syntactically well-formed sentences after minimal exposure. His enhanced talent for language and languages falls into the same category as other cases of the so-called savant syndrome: brain-damaged savants that are otherwise mentally handicapped and typically autistic are documented with unbelievable skills for calendrical calculation (ability to tell instantly on which day of the week any date in past, present or future centuries falls) or various artistic talents (e.g. musicians who can play complex passages after a single hearing).

Smith & Tsimpli (1995) explain the relevance of Christopher's case (and other similar cases) for establishing language as a module.

(19) "Although no one else has been reported as displaying the multi-lingual prowess that Christopher does, these cases illustrate the same dissociation between linguistic and general cognitive abilities as is exhibited by such individuals as Laura […], by Williams Syndrome children […], by 'chatterbox' children […], and by hyperlexics […], all of whom have great linguistic ability in the presence of severe cognitive deficits. Examples in the opposite direction – cases of people with impaired language in the presence of normal intellectual ability – are provided by some deaf people, some aphasics, and by those suffering from SLI (Specific Language Impairment), where brain damage (in some cases genetically caused) occasions a language deficit independently of the rest of the cognitive profile […].
The existence of these varied conditions provides a classical example of *double dissociation*: language can be impaired in someone of otherwise normal intelligence, and – more surprisingly – someone with intelligence impaired by brain damage may none the less have normal, or even enhanced, linguistic ability." Smith & Tsimpli (1995:3, emphasis in original)

The basic argument for the (double) dissociation of language is thus the fact that in the case of Christopher the language faculty may work well (actually better than normal) in absence of control by "general intelligence": Smith & Tsimpli (1991:325) write that "it is clear that his talent exists in the absence of the normal 'general intelligence' one might expect to find associated with multi-lingualism." They also draw on encapsulation of Christopher's language performance, which – as predicted by Fodorian modularity – is independent from general purpose considerations or global goals: the general goal to produce non-nonsensical translations is not able to "break into" Christopher's language performance while translating.

(20) "In the present context informational encapsulation would mean that Christopher's linguistic ability was independent of his general cognition and could operate in the absence of 'central' control. His method of translating makes this extremely plausible. When asked to translate, he starts instantly and proceeds word by word rather like an automaton. If he is asked to slow down and mull over the meaning of the whole passage in an attempt to improve his performance, he shows visible signs of distress and professes himself incapable of doing any such thing. Moreover his equanimity at producing nonsensical translations indicates either that he is incapable of discerning such nonsense, or that his linguistic (morpho-syntactic) system operates in divorce from any semantic or pragmatic control."
Smith & Tsimpli (1991:325)

This is evidence to the end that language as such is a module: it appears to be doubly dissociated. That is, it may be "plugged in or out" without affecting the (non-)deficient rest of cognitive abilities.

Williams Syndrome also provides strong evidence to this end (see Tager-Flusberg & Sullivan 2000). Williams Syndrome "is a rare genetic disorder resulting in certain characteristic facial features and physical problems as well as a unique and particularly striking cognitive profile. Subjects are retarded, with an average IQ of around 50. They are also particularly impaired with respect to arithmetical and visual-spatial abilities. However they exhibit an unusually high level of linguistic ability, with a particular penchant for sophisticated and unusual vocabulary items" (Segal 1996:154, who offers a concise general introduction to Williams Syndrome).

This kind of evidence that is typically used for the (double) dissociation of language form other cognitive functions has also been given other interpretations: Bates (1994) argues for the innateness and the localization of language in the brain, but against its domain specificity. The argument is based on the fact that the dissociations observed are never one hundred percent waterproof: linguistic deficits are accompanied by minor non-linguistic impairment as well, and non-linguistic developmental disorders such as Williams Syndrome have also some impact on language.

In any event, modularity and Chomsky's conception of a language organ (§42, e.g. Chomsky 1995b, Chomsky 2000b:106ff) predict that language as such is a plug-in unit in the concert of cognitive functions. The question, then, is whether it may be decomposed into yet smaller units. The modular structure of language itself is hinted at by the quote under (20), where morpho-syntax appears to be estranged from semantic and pragmatic control. This is what the following pages are about.

# Chapter 5
# 37 Modularity of and in language, related systems

## 38 1. Modularity in the early days of generative grammar: 50s-60s
### 39 1.1. A spearhead of the cognitive revolution of the 50s in language

Language has always played a prominent role in the development of Cognitive Science: it was a prime candidate for the implementation of the von Neumann-Turing programme (see §18, Gardner 1985:182ff) that really started to penetrate modern science in the 50s (e.g. Gardner 1985:28ff).

Noam Chomsky and generative linguistics were the spearhead of the computational conception in the realm of language (e.g. Cosmides & Tooby 1992b:93ff, Chomsky 1993b). In 1972, computer scientists Allen Newell and Herbert Simon recall the 50s and the inception of Cognitive Science.

(21) "Within the last dozen years a general change in scientific outlook has occurred, consonant with the point of view represented here. One can date the change roughly from 1956: in psychology, by the appearance of Bruner, Goodnow, and Austin's *Study of Thinking* and George Miller's 'The magical number seven'; in linguistics, by Noam Chomsky's 'Three models of language'; and in computer science, by our own paper on the Logic Theory Machine." (Newell & Simon 1972:4, emphasis in original)

Also, Chomsky has always considered that the study of language is undissociable from the study of mind: cognitive realism is a founding statement of the generative enterprise – since Chomsky (1959) it constitutes the fraction line with (certain types of) structuralism (in linguistics) and behaviourism (in psychology and learning theory).

In this context, modularity is a necessary ingredient of the generative enterprise, both regarding language in the concert of other cognitive functions and its internal organisation. The former area may be illustrated by the following quote from Chomsky (1975) (among a host of others, e.g. Chomsky 1972, 1980, 1984, 1988, 1993b etc., Higginbotham 1987 and Hirschfeld & Gelman 1994:5ff provide historical discussion).

(22) "[T]he position we are now considering postulates that this faculty [the language faculty] does exist, with a physical realization yet to be discovered, and places it within the system of mental faculties in a fixed way. Some may regard this picture as overly complex, but the idea that the system of cognitive structures must be far more simple than the little finger does not have very much to recommend it.
The place of the language faculty within cognitive capacity is a matter for discovery, not stipulation. The same is true for the place of grammar within the system of acquired cognitive structures. My own, quite tentative, belief is that there is an autonomous system of formal grammar, determined in principle by the language faculty and its component UG. This formal grammar generates abstract structures that are associated with "logical forms" (in a sense of this term to which I will return) by further principles of grammar. But beyond this, it may well be impossible to distinguish sharply between linguistic and nonlinguistic components of knowledge and belief. Thus an actual language may result only from the interaction of several mental faculties, one being the faculty of language. There may be no concrete specimens of which we can say, these are solely the product of the language faculty; and no specific acts that result solely from the exercise of linguistic functions." Chomsky (1975:43)

Another point of interest is that language has always been considered a prime candidate for modularity – more than other cognitive systems – in the debate regarding which faculties exactly are modular, and which ones are not, i.e. result from the activity of Fodorian central systems (see the question "how much of the mind is modular?" in §21). Smith & Tsimpli (1995:30) for example distinguish between perceptual and cognitive systems, where the former identify as "the sensorium plus language", while the latter are Fodor's central systems (fixation of belief, thought, storing knowledge). On this view, language is on a par with vision, audition, taste, smell and the sense of touch.

The intimate relationship of language and modular theory is also reflected by the fact that Fodor's (1983) seminal book has emerged from a class on cognitive theory that Fodor co-taught with Chomsky in fall 1980.

## 40 1.2. LSLT: language is made of modules (levels), a concatenation algebra and interfaces

The internal organisation of language in terms of distinct computational and functional systems that are specialised in morpho-syntax, phonology and semantics is made explicit in one of the earliest generative documents: Chomsky's Logical Structure of Linguistic Theory, published only in 1975, is based on a 1955-56 manuscript (one chapter of which was eventually outsourced to make Chomsky's Ph.D thesis). In the structuralist environment of the time, Chomsky holds that the basic units that language is made of are levels (see §**Erreur ! Source du renvoi introuvable.** on structuralist Level Independence).

(23) "[T]he theory of linguistic structure [is], essentially, the abstract study of 'levels of representation'.
[…]
A linguistic level is a system L in which we construct unidimensional representations of utterances. Thus a level has a certain fixed and finite 'alphabet' of elements, which we will call its 'primes.' Given two primes of L we can form a new element of L by an operation called 'concatenation,' symbolized by the arch ^. Thus if a and b are (not necessarily distinct) primes of L, we can form a^b and b^a as new elements of L. Concatenation is essentially the process of spelling, where primes are taken as letters. Given the element a^b and the prime c, we can form a new element (a^b)^c." Chomsky (1955-56:105)

Levels are thus computational systems, which operate each on a specific vocabulary and produce suites of vocabulary items associated with a hierarchical structure that reflects their concatenative history. This is precisely the description of a Fodorian module: a domain specific computational unit that works only on its own proprietary vocabulary (§26). And the quote also describes what is known today as the basic minimalist engine, Merge. Viewed from this perspective, phrase structure rules were an ephemeral interlude (see also Lasnik & Lohndal 2009:46 on the 50s-roots on Merge).

LSLT is at variance in an interesting way with the inverted T model that emerges in the 60s and represents the generative architecture of grammar up to the present day (§**Erreur ! Source du renvoi introuvable.**). Indeed, LSLT does not make any difference between concatenative and interpretative systems: all levels carry out concatenation. In phonology, Chomsky holds that phonemes are concatenated.

(24) "[T]he level of phonemes for English has among its primes the symbols *p*, *i*, *n*, which can be concatenated to form the string p^i^n, which is the Pm-marker of 'pin'." Chomsky (1955-56:66)

The number and nature of the levels that Chomsky assumes also witnesses the structuralist environment.

(25) "We will find it necessary to distinguish at least the following levels for linguistic description: phonemes (Pm), morphemes (M), words (W), syntactic categories (C), phrase structure (P), and transformations (T). The grammar must indicate the structure of each utterance on each of these levels." Chomsky (1955-56:66)

Finally, the existence of distinct computational systems that produce hierarchised suites of distinct vocabulary items requires interface mechanisms for inter-level communication. This need for translation, also a perfectly modern and modular concern, is made explicit by Chomsky.

(26) "A linguistic level is not determined completely by the statement that it is a concatenation algebra. We must also specify its relations to other levels (i.e., the conditions of compatibility between levels)." Chomsky (1955-56:106)

In sum, all basic ingredients of Fodorian modularity are already present in one of the earliest generative documents: LSLT defines a number of modules that language is made of (many more than what the inverted T will recognise, though); these modules are input-output systems and have a "concatenation algebra", which in modern terms means that they are domain specific and carry out Merge (all modules, not just morpho-syntax, though have the concatenative privilege); finally, LSLT modules have the ability to talk to other modules, Phase in modern vocabulary.

## 41 1.3. Modularity on its way: from LSLT to Aspects and SPE

Newmeyer (1986:172f, 198f) provides some elements of how the modular conception that was laid out in LSLT was progressively introduced and worked out in generative grammar. He mentions Chomsky & Miller (1963) as an early source for the explicit statement that syntax and phonology are distinct computational (input-output) systems.

(27) "We regard grammar as having two fundamental components, a *syntactic component* of the kind we have already described and a *phonological component* to which we now briefly turn our attention. […] The phonological component embodies those processes that determine the phonetic shape of an utterance, given the morphemic content and general syntactic structure of this utterance. […] As distinct from the syntactic component, it plays no part in the formulation of of new utterances but merely assigns to them a phonetic shape." Chomsky & Miller (1963:306f, emphasis in original)

"The phonological component can be thought of as an input-output device that accepts a terminal string with a labelled bracketing and codes it as a phonetic representation." Chomsky & Miller (1963:308)

The inverted T model was formally introduced in Aspects (Chomsky 1965:15ff) (see §§**Erreur ! Source du renvoi introuvable.**,**Erreur ! Source du renvoi introuvable.**); it fixes the existence of (at least) three independent computational systems (morpho-syntax, phonology, semantics) and to date represents the bottom line of the generative architecture of grammar. The quote from SPE under (17) (§28) also shows that the generative conception of the internal structure of grammar was already modular in the 60s, even though of course this particular vocabulary item was not used. Since 1965, Chomsky has been constantly explicit on the modular character of language (e.g. Chomsky (1972, 1975, 1984).

An early source is also Chomsky (1965 [2006]), a chapter included in later editions of Chomsky (1972), but which Chomsky explains in the preface to the second edition was actually written in 1965. In this text, the units of the inverted T model are referred to as components (syntactic, phonological, semantic).

The further development of modularity within the inverted T model in the 80s is discussed in §43 below.

42 2. Modularity implies biology and innateness: the language organ

A consequence of the view that language is a module is its genetic determinacy: recall that modules, among other things, have the property of being genetically endowed (§28).

This is where Chomsky's biological conception of language – known under the header of the language organ and more recently the biolinguistic programme (§§24,54) – comes from. On this view, the neural existence of the language module and the genetic endowment for its inception in the growth of young humans gives rise to an organ just like the liver, the heart or other parts of the human body that are specialised in some particular task: cleaning or pumping of blood etc. The only peculiarity of the language organ, then, is to be localised in the brain, rather than elsewhere in the body.[9]

In this perspective, linguistics is "that part of psychology that focuses its attention on one specific cognitive domain and one faculty of mind, the language faculty" (Chomsky 1980:4). Therefore, "we may regard the language capacity virtually as we would a physical organ of the body and can investigate the principles of its organization, functioning, and development in the individual and in the species" (Chomsky 1980:185) (also e.g. Chomsky 1975:11: "the idea of regarding the growth of language as analogous to the development of a bodily organ is thus quite natural and plausible. It is fair to ask why the empiricist belief to the contrary has had such appeal to the modern temper"). The modern offspring of this genuinely generative tradition is Chomsky's biolinguistic program (e.g. Hauser *et al.* 2002, Chomsky 2005, on which more in §54; see Jenkins 2000 for an overview).

Together with UG, the language organ is probably the best-known property of generative grammar outside of its own quarters. It has become a buzz-word in popular scientific texts and neighbouring disciplines, foremost philosophy and psychology where its validity is challenged and provokes much discussion. This debate goes far beyond the scope of the present book. Relevant literature from both sides includes Stich (1972), Katz (1984), Devitt & Sterelny (1989), Kasher (1991), Fodor (1981), Chomsky (2002); Wauquier (2005:175ff) provides an informed overview.

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9 In psycholinguistic quarters that were a priori Chomsky-friendly, the biological conception of language was anything but popular in the 80s: people refused even to think about an eventual neural correlate of cognitive functions. Dehaene *et al.* (2001) report on this pre-brain imaging period with the following quote from Jacques Mehler, which sums up Mehler *et al.* (1984): "For all I know, language perception might be going on in the brain. but my research would not be affected if it was found to be occurring in the left pinky." Dehaene *et al.* (2001) and the section on Brain and Biology of Dupoux (ed.) (2001) that they introduce then show how things have changed today.

## 43 3. Grammar itself is made of modules: GB-subtheories and their (questionable) status as cognitive modules

### 44 3.1. The inverted T is the baseline since the 60s

If language is one piece of the modular architecture of mind, the question arises whether there is only one single computational unit that carries out all grammatical calculation, or whether there are several linguistic modules. In turn, if language is made of distinct computational systems, the question is how many linguistic modules there are, and how exactly they are delineated.

The early generative literature on language-internal modularity was already discussed in §38: the bottom line that is condensed in Aspects (Chomsky 1965:15ff) grants modular status in terms of a an independent and domain specific computational system to the three components of the inverted T model: morpho-syntax, phonology and semantics. These represent the core of "internal" linguistic activity and are related to non-linguistic cognitive activity by at least a conceptual device (which matches real-world objects and concepts with linguistics items) and pragmatics. Or, in other words, the interplay of the three "internal" components is called grammar, while their exchange with grammar-external cognitive activity produces language (see Newmeyer 1986:172ff for a historical description and the state of the art in early GB).

### 45 3.2. GB-subtheories are presented as modules, but insulated from the cognitive context

Modularity was embodied in the inverted T, but as such not much of an issue until the 80s when the principles and parameters framework was introduced. In his Pisa lectures, Chomsky (1981) divides syntax into six autonomous subsystems (bounding theory, government theory, theta theory, binding theory, case theory, control theory), which he refers to as modules. The modular structure of GB is the major innovation of the new theory.

Surprisingly enough, though, Chomsky studies language-internal (or rather: syntax-internal) modularity in absence of any reference to the broader claim that the entire human cognitive system is modular in kind. This is to be appraised in the context of Fodor (1983), the major reference of the modular theory of mind that was in the making when Chomsky wrote, and also of the fact that Fodor's book grew out of lecture notes of a class on contemporary cognitive theory that Jerry Fodor co-taught with Noam Chomsky in fall 1980 (see the acknowledgements in Fodor 1983).

While language plays an important role in Fodor (1983), the idea that the language faculty and/or its sub-components are just specific cases of cognitive modules that are embedded in a broader modular architecture is absent from Chomsky (1981). Chomsky does not mention the fact that modules, whether they compute grammatical or other functions, have a number of properties (domain specificity, encapsulation, dissociation) which allow us to delineate their contours.

The result is not really in line with the history of generative grammar and Chomsky's personal contribution to Cognitive Science: when generative linguists think of grammar-internal modularity, what they typically have in mind is an exclusively linguistic horizon (more on that in §51).

One may be inclined to believe that this is a good deal of the reason why (real cognitive) modularity has played virtually no role within generative grammar, even when it would have been decisive (while it has always been an argument for the definition of grammar as opposed to other cognitive functions). I have come across two obvious cases where the absence of the modular argument is really surprising, looked at from the outside: interactionism and direct syntax (see §§**Erreur ! Source du renvoi introuvable.**,**Erreur ! Source du renvoi introuvable.** and the summary in §**Erreur ! Source du renvoi introuvable.**).

46 3.3. Chomsky (1981): subcomponents (inverted T) vs. subsystems (theta theory etc.)

In the first chapter of the Pisa lectures entitled "Outline of the theory of core grammar", Chomsky (1981) first exposes the classical position according to which the three extremities of the inverted T are modules.

(28) "The theory of UG must therefore specify the properties of (at least) three systems of representation - S-structure, PF, LF - and of three systems of rules: the rules of the syntactic component generating S-structures, the rules of the PF-component mapping S-structures to PF, and the rules of the LF-component mapping S-structure to LF. Each expression of the language determined by the grammar is assigned representations at these three levels, among others." Chomsky (1981:4)

He then introduces the distinction between *subcomponents* of the rule system of grammar, and *subsystems* of principles. The former are the members of the inverted T, i.e. the default candidates for modular status, while the latter are the subtheories of GB, which the book sets out to introduce (Chomsky 1982:4ff is analogous, the only noteworthy difference is the fact X-bar theory is added to the six subsystems that are introduced in the quote below).

(29) "UG consists of interacting subsystems, which can be considered from various points of view. From one point of view, these are the various sub-components of the rule system of grammar. From another point of view, which has become increasingly important in recent years, we can isolate subsystems of principles. I will assume that the subcomponents of the rule system are the following:

(1) (i) lexicon
(ii) syntax
(a) categorial component
(b) transformational component
(iii) PF-component
(iv) LF-component

[…]
The subsystems of principles include the following:

(2) (i) bounding theory
(ii) government theory
(iii) θ-theory
(iv) binding theory
(v) Case theory
(vi) control theory"
Chomsky (1981:5)

The characterisation of morpho-syntax (and semantics) as a network of interacting sub-devices is the central innovation of GB, and this is why the focus of Chomsky (1981) of course is on these subsystems. They are the new perspective, and this is what the book is all about. Also, they exist within the old architecture of grammar, the inverted T, which remains untouched by the new perspective.

47 3.4. Are GB-subsystems cognitive modules?

In the quotes above, Chomsky does not use the word "module" in order to refer to GB-subtheories, which he calls subsystems. These are opposed to subcomponents, i.e. the three computational systems of the inverted T. The question is whether these GB-subtheories ought to be regarded as modules in the Fodorian cognitive sense. Implicit in the quote under (29) is that they are not granted this status: subcomponents are distinct rule systems, while subsystems are only distinct sets of principles. A module, however, is defined as a computational system. Whether GB-subtheories are input-output systems that carry out a computation is certainly debatable, but I was unable to find any relevant discussion in the literature, both contemporary of the 80s and more recent overview-oriented (e.g. Lasnik & Lohndal 2009, Freidin & Lasnik forth, Newmeyer 1986:198ff), precisely (one senses) because linguistics were (and still are to a certain extent) insulated from the cognitive macrostructure in linguistic quarters.

The question to be asked is thus whether GB-subtheories act as mere filters that define well-formedness, or whether they carry out actual computation, i.e. modify an input. It seems to me that well-formedness filters and computational systems are not the same thing, but the question certainly deserves to be debated.[10]

Applying the other diagnostics for cognitive modules that are available appear to be inconclusive, at least from my point of view: GB-subtheories could perhaps be argued to be informationally encapsulated, but again the fact that they referee well-formedness would seems to require that they intervene at different stages of the syntactic construction.

Domain specificity is also debatable: at first sight it looks like syntax as a whole uses the same vocabulary: person, gender, number etc. But these are the lexical ingredients, i.e. the input to the syntactic module as defined by the inverted T. GB-subtheories apply during the syntactic derivation, and their input, if any, will not be made of lexical material. Hence it could be argued that the case theory module works only with a specific vocabulary that is dedicated to case, the government module only calculates locality and so forth. This view is taken by Hornstein (2009:7, note 13) and is also entertained by a modern heir of the GB architecture, Edwin Williams' (2003) Representation Theory. Williams explains that

[10] See Scheer (forth) on the computational question and how computation is conceived of in phonology and syntax.

(30) "several different aspects of clausal structure are characterized as separate 'sublanguages' (to anticipate: Theta Structure (TS), Case Structure (CS), Surface Structure (SS), Quantification Structure (QS), Focus Structure (FS). Then the syntax of a sentence will be a collection of structures, one […] from each of these sub-languages and a set of shape-conserving mappings among them." Williams (2003:2)

This perspective may be argued to face a problem because of its nested modular structure (see also the quote in §51): it supposes that there is a "big" syntactic derivation (the syntactic module of the inverted T) which somehow accommodates "small" sub-modules (the GB-subtheories) that concur to the overall result. It appears that this can only work in violation of informational encapsulation of the "big" syntactic module: its computation should be complete before any result can be sent to other (sub)modules. The same objection may be levelled against derivation by phase, though: morpho-syntactic computation sends partial results to PF and LF before it has reached its end, i.e. the matrix CP. This may be solved by considering that the "big" syntactic derivation is not performed by a module in one single go, but that the same module treats pieces of a sentence in several computations. Again I am not aware of any discussion in the (linguistic) literature on the compatibility of multiple spell-out with encapsulation, but Williams will be able to hook on the argument that will be made by defenders of derivation by phase, whatever that will be: the situations are parallel.

Finally, the diagnostic based on double dissociation is probably not workable for GB-subtheories since it will be difficult to come by relevant pathologies (the evidence available is discussed in §57 below).

48 3.5. Biolinguistics: an evolutionary argument against language-internal modularity (Hornstein 2009)

Biolinguistics looks at language from the biological and evolutionary perspective and thereby continues the earlier strand of Chomsky's language organ (§§24,42,48). Based on Hauser, Chomsky & Fitch (2002), the idea is that the appearance of language in the evolution of the species sets a restrictive frame that imposes certain properties upon grammar. Contrary to earlier generative thinking where much of what was found to be universal was put into UG, i.e. held to be genetically endowed and specific to language, UG is by and large emptied.

Chomsky (2005) identifies three factors in language design: 1) UG (i.e. genetically endowed properties that are specific to language), 2) experience and 3) more general cognitive capacities that are not specific to language or even to the species. The shift, then, is from UG to the third factor: language relies on mechanisms that are much less specific to language than what was believed in earlier generative theories. Hauser *et al.* (2002) suggest that UG could actually reduce to recursion (Merge) and the ability to communicate with the interfaces (Phase): this is the Faculty of Language in the Narrow sense (FLN) (Pinker & Jackendoff 2005a,b oppose this view, see §24).

On this backdrop, Hornstein (2009:4ff) levels an objection against language-internal modularity that is based on evolutionary timelines. As was mentioned, Hornstein (2009:7, note 13) believes that GB-subtheories do qualify for modular status. The Language Faculty as such, however, he argues, must not be cut into further subsystems because modular complexity implies genetic endowment and a relatively slow adaptational evolution along the Darwinian lines of environment-driven selection. The appearance of language, however, was much too rapid in order to fit into an adaptive scenario.

(31) "A common assumption is that language arose in humans in roughly the last 50,000 - 100,000 years. This is very rapid in evolutionary terms. It suggests the following picture: FL [Faculty of Language] is the product of (at most) one (or two) evolutionary innovations which, when combined with the cognitive resources available before the changes that led to language, delivers FL. This picture, in turn, prompts the following research program: to describe the pre-linguistic cognitive structures that yield UG's distinctive properties when combined with the one (or two) specifically linguistic features of FL. The next three chapters try to outline a version of this general conception.
The approach, I believe, commits hostages to a specific conception of FL. It does *not* have a high degree of internal modularity. The reason for this is that modular theories of UG suppose that FL is intricately structured. It has many distinct components that interact in complex ways. On the assumption that complexity requires natural selection and that natural selection requires time to work its magic (and lots of it: say on the order of (at least) millions of years), the rapid rise of language in humans does not allow for this kind of complexity to develop. This suggests that the highly modular structure of GB style theories should be reconsidered." Hornstein (2009:4f, emphasis in original)

Hence we are back to the debate exposed in §21 between the two camps within the modular approach: following Descartes, Chomsky and Fodor hold that some properties of the cognitive system (Fodor's central systems) lie beyond what can be understood by human intelligence and will always remain an impenetrable mystery; by contrast, evolutionary psychology (Pinker, Plotkin, also Sperber and Smith) believe that all of the mind is modular and accessible to human understanding. A correlate of these contrasting positions is the Darwinian issue: in Fodor's and Chomsky's perspective, central systems are not the result of adaptive evolution along the laws of natural selection, while Pinker & Co hold that all properties of the mind/brain are modular and hence the result of adaptive evolution.

Hornstein's argument thus supports the Fodorian/Chomskian view, and it is interesting to observe that Hornstein (2009:5, note 9) calls on literature from evolutionary psychology (Pinker 1997, Cosmides & Tooby 1992a) in order to back his critical assumption that complexity requires natural selection. His alternative, i.e. the emergence of the Language Faculty as a (by-)product of one or two evolutionary innovations based on pre-human cognitive capacities, is the basic idea of Hauser *et al.* (2002) and the biolinguistic programme.

In this view, the FLN is not a product of selective adaptation, while the FLB (the Faculty of Language in the Broad sense) is shared with animals and results from natural selection.

Finally, it should be added that the entire discussion is only about (morpho-)syntax: in the biolinguistic perspective, phonology and semantics belong to the animal-based FLB and hence do not really belong to grammar, i.e. to what is language-specific in the human cognitive system. PF and LF are thus supposed to have been present before the one or two innovations that produced Merge and Phase, and therefore to be available to and mastered (or masterable) by (certain) present-day animals (more on this in §54).

This also explains why Hornstein in his discussion of what exactly counts as a module does not even mention the classical inverted T: his biolinguistically shaped horizon ends before PF and LF are in sight. The conclusion that one draws is that the inverted T still exists and that the three endpoints are still Fodorian modules – only are PF and LF not located in grammar anymore.

## 49 4. GB modules and their perception in non-linguistic quarters

### 50 4.1. Chomsky (1981) calls GB-subtheories modules without comment

It was mentioned in §46 that at the outset of the Pisa lectures Chomsky (1981) distinguishes between subcomponents (the endpoints of the inverted

T) and subsystems (GB-subtheories). Later in the book, however, he gives up on this distinction and systematically talks about modules when referring to the six GB-subtheories (also Chomsky 1982:29).

(32) "The full range of properties of some construction may often result from interaction of several components, its apparent complexity reducible to simple principles of separate subsystems. This modular character of grammar will be repeatedly illustrated as we proceed." Chomsky (1981:7)

"Note that the distribution of the empty categories, the differences among them and their similarities to and differences from overt elements are determined through the interaction of quite simple principles that belong to several different subtheories, in accordance with the modular approach to grammar that we are pursuing throughout." Chomsky (1981:72)

"This dissociation of properties is what we would expect on our modular assumptions - that is, on the assumption that such processes as 'passive' are composed of more fundamental abstract features, such as the elements of Case theory, θ-theory, etc." Chomsky (1981:126)

"Note that the full range of properties of PRO and trace discussed in §2.4, as well as the partially similar properties of overt anaphors, are determined by the interaction of four theories: the theory of bounding (for trace), the theory of control (for PRO), the theory of Case (for elements with phonetic content, including overt anaphors), and the theory of binding (for all NPs). The latter two theories are developed within the theory of government. Again, we see the highly modular character of the theory of grammar, with the basic subsystems of principles discussed in chapter 1 serving as quite simple and fundamental abstract components that interact to yield a complex range of properties." Chomsky (1981:192)

After having introduced each individual GB-subtheory in chapter 2 (which is called "Subsystems of core grammar"), the conclusion of this chapter confirms the modular character of GB-subtheories.

(33) "The system that is emerging is highly modular, in the sense that the full complexity of observed phenomena is traced to the interaction of partially independent subtheories" Chomsky (1981:135)

Finally, the modular interpretation of GB-subtheories is also repeated on the last page of the book: "[t]he system that has been developed is highly modular" (Chomsky 1981:344).

All this is done without mention or discussion of the Cognitive Science background, and without indicating whether the GB modules are considered to be cognitive modules. As we will see below, the discussion of the previous section has never been led, and everybody – in generative quarters and elsewhere – takes for granted that GB modules are cognitive modules in the Fodorian sense because Chomsky has used this word.

## 51 4.2. Perception of GB-modules in non-linguistic quarters: puzzlement

While in generative quarters the word *module* was continued to be used without any particular reference to the broader organization of the cognitive system, observers from other fields, and especially from Cognitive Science of course, took for granted that the modules of the linguists are cognitive modules in the Fodorian sense. This led to some puzzlement and confusion.

In the introduction to the volume on domain specificity of cognitive functions ("toward a topography of mind"), that they edit, Hirschfeld & Gelman (1994) talk about the situation in GB from the position of the external observer.

(34) "Chomsky and other maintain that these findings provide compelling evidence for the claim that the mind is modular, comprising a number of distinct (though interacting) systems (the language faculty, the visual system, a module for face recognition), each of which is characterized by its own structural principles. […]

Chomsky, however, has also suggested that the mind is modular in a somewhat different way. […] This, in other more technical writings, Chomsky has described 'modules of grammar' (e.g., the lexicon, syntax, bounding theory, government theory, case theory, etc.) (1988:135). Here the notion of modularity appears to be tied to specific subcomponents or subsystems of the language faculty rather than to the modular uniqueness of the language faculty itself. The grammar, in the traditional sense, is located at the intersection of these distinct modules.

It is not clear whether these two notions of modularity are to be distinguished, and if so how to interpret the relationship between them. One possibility is that modules are nested, that is, the language faculty is a separate module that in turn consists of distinct component operations or modules. Another interpretation – supported indirectly by the fact that Chomsky speaks of the language faculty *as* a module to nonlinguists but speaks of the language faculty *as consisting of* modules to linguists – is that the mind is, strictly speaking, modular with respect only to these second-level component modules. The language faculty itself would accordingly be a more vaguely defined construct resulting from the operation of these modules, but one that in itself is not modular in the sense of being defined in terms of a distinct set of principles." Hirschfeld & Gelman (1994:8, emphasis iin original)

Looked at from the inside, Hermon (1985) is a typical representative of the approach to modularity that was (and is) widespread in generative quarters. Hermon's goal is to demonstrate that the interplay of the subtheories of the newly established GB theory are well suited to account for parametric variation, and this is the only reason why the book is called *Syntactic Modularity*. There is no reference to any extra-linguistic work regarding modularity (Fodor 1983 is absent from the reference section), and the reader does not learn anything about cognitive modules, how they work, how they are defined, detected etc. Similar cases are Farmer (1984) and Nespor & Vogel (1986) (see §**Erreur ! Source du renvoi introuvable.**).

## 52 5. Minimalism and biolinguistics do away with GB modules

### 53 5.1. Minimalism: GB-subtheories have to go

In their textbook on minimalism, Hornstein *et al.* (2005:11ff) evaluate the validity of GB-subtheories in the light of minimalist requirements and, following the GB-tradition, refer to them as modules. The items of the inverted T, i.e. morpho-syntax, phonology and semantics, are called levels (Hornstein *et al.* 2005:9 and elsewhere). The word "modularity", however, only appears when language as a whole is considered in the concert of other cognitive functions (Hornstein *et al.* 2005:3, note 2).

A core goal of the minimalist programme is to reduce the GB-subtheory zoo to what is strictly required for conceptual reasons and by interface conditions. Grammar is perfect unless deviated from perfection by interface requirements: minimalist design produces "a theory of language that takes a linguistic expression to be nothing other than a formal object that satisfies the interface conditions in the optimal way" (Chomsky 1995a:171). In this minimalist frame, Hornstein's (2009) argument against GB-modules that is based on the third-factor perspective of biolinguistics was already discussed in §48.

This does not mean, however, that the insight of GB is wrong: Hornstein (2009:6) believes that the generalisations made by GB are "roughly empirically correct". However, they are in need of further interpretation: minimalist work in general and his book in particular is about how to have the labour of GB-subtheories done by different, non-modular means, and to derive the empirical generalisations of GB by more general principles; these are ideally of the third factor kind, i.e. unspecific to language.

### 54 5.2. Grammar reduces to morpho-syntax: PF and LF are neither language- nor species-specific

It was already mentioned in §48 that interestingly enough, PF and LF are not even mentioned when Hornstein (2009) and others talk about the faculty of language in a biolinguistic perspective. This is because according to Hauser *et al.* (2002), PF and LF do not belong to the FLN (Faculty of Language in the Narrow sense). Rather, they are a piece of the FLB (Faculty of Language in the Broad sense), which humans share with (certain) animals. Unlike the FLN which did not have enough time to emerge by Darwinian means, the FLB came into being through adaptive evolution that occurred under selective pressure during the common evolution of certain animals and the ancestors of homo sapiens long before the critical hardware-modification occurred that made emerge FLN.

Filling in this scenario on the phonological side, Samuels (2009a,b) tries to show that phonology is entirely a third factor mechanism, i.e. that there is nothing language- or species-specific to human phonology: (certain) animals are perfectly equipped to do human phonology.

In sum, language reduces to morpho-syntax, which is made of one single Fodorian module, i.e. morpho-syntax. This perspective reassesses the delineation of grammar (phonology and semantics stand aside), and hence makes the inverted T appear in a different light. The new limits of grammar, however, do not change anything in the relationship between the three actors of the inverted T: PF and LF may not be specifically linguistic modules anymore, but they are still modules. Therefore whatever the relationship of morpho-syntax with them, it must follow the general rules of intermodular communication: the way morpho-syntax talks to PF and LF is not any different from the way it talks to other cognitive modules such as audition or vision.

## 55 6. Identifying linguistic modules

### 56 6.1. How to identify grammar-internal modules

Given the GB-interlude and the minimalist and eventually biolinguistic perspective, one may say that generative grammar is back to where it started in the 60s: we are left with the inverted T. That is, there are three relevant modules, morpho-syntax, PF and LF, of which the latter two lie outside of grammar if one wants to follow biolinguistics. At least two more systems are relevant and interact with these: pragmatics and a conceptual device.

Below evidence is gathered that allows us to evaluate this working hypothesis. Methods for identifying cognitive modules are as before, one internal (domain specificity, §§25f), the other external (double dissociation, §33). As far as I can see, there is only little evidence available from the latter source, which will be reviewed in the following section. The literature that builds on domain specificity in order to tease apart the number and nature of language-relevant modules is not substantial either.

## 57 6.2. Dissociation: Pragmatics, Lexicon vs. morpho-syntax

Dissociation arguments come either from stable synchronic states where cognitive functions are selectively impaired (i.e. from subjects with cognitive and/or brain damage), or from acquisition, where different cognitive functions are dissociated in their development (see §35). When zooming into grammar (understood as including phonology and semantics) from the larger perspective of cognitive functions, the most coarse-grained differentiation is between the two standardly assumed peripheral systems that relate grammar to other functions, and grammar itself. The two systems in question are pragmatics and a conceptual device.

Evidence for the independence of the pragmatic and the grammatical systems was already discussed in §36: Christopher, the savant studied by Smith & Tsimpli (1991 et passim), appears to be unable to make pragmatic pressure (to produce a sound translation) influence his linguistic performance. Also, Chien & Wexler (1990) provide evidence from acquisition for the dissociation of binding (a grammatical principle) and pragmatics.

In an early study on the dissociation of language-related cognitive functions based on pathological data, Curtiss (1981) concludes that while morpho-syntax is insulated from other cognitive functions, the development of lexical and relational semantic knowledge hinges on broader conceptual abilities.

(35) "[D]ata from case studies of children show […] clear dissociations between language and nonlanguage cognitive abilities. The implications of such data are discussed. The major implications appear to be that lexical and relational semantic abilities are deeply linked to broader conceptual development but morphological and syntactic abilities are not. The development of a normal linguistic system, however, one in which grammar is systematically related to meaning, requires concurrent and concomitant linguistic and nonlinguistic cognitive development." Curtiss (1981:15)

Finally, Newmeyer (2006:241f) proposes a kind of double dissociation argument without recurring to cognitive and/or brain damage. In order to show that syntax and semantics are independent computational systems, he demonstrates that a particular syntactic structure does not select for semantic values, and conversely that a particular semantic or discourse-based construct may map onto various syntactic structures.

Newmeyer (2006) thus defends a strict modular segregation of syntax and semantics. He shows that the seeds of blurred modular contours between these two items of the inverted T were sown by Chomsky (1981), who introduced the idea that thematic roles are directly relevant for the statement of syntactic generalisations. Since then and especially in the minimalist environment, the bonds between syntactic position and semantic interpretation have been strengthened. On this backdrop, Newmeyer (2006) proposes evidence from an analysis of English negation that militates against a conflation of syntactic and semantic features.

Higginbotham (1987) also argues for the autonomy of syntax and semantics in a modular perspective, which is tightly correlated to the reading of Fodor (1983). He reviews the classical linguistics-internal arguments that Chomsky has made since the 50s in order to establish the mutual independence of syntax and semantics.

The following section discusses the reverse attitude, i.e. which validates the convergence of syntax and semantics on the grounds of domain specificity.

### 58 6.3. Domain specificity (Starke): morpho-syntax-semantics vs. phonology

In unpublished work,[11] Michal Starke argues that morphology, syntax and semantics are just one module because they use the same vocabulary: number, person, animacy, quantification, aspect and so forth are categories that are used, understood and processed by syntax as much as by morphology and semantics.[12] Much unlike phonology, where number, person and the like are unknown: phonology does not use or process these categories. Conversely, morphology, syntax or semantics neither process or are sensitive to genuinely phonological concepts such as labiality, stopness and the like.

On Starke's count, then, phonology (as much as pragmatics and the conceptual device) works with specific vocabulary and is thus a module distinct from morpho-syntax-semantics. Discussing the detail of the evidence that Starke relies on would lead too far afield here (a published version will hopefully be available at some point). Let us merely note the structure of his argument, which is along the lines of domain specificity.

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[11] Starke's work has been presented at various conferences and at the Central European Summer School in Generative Grammar (EGG) in 2002 (Novi Sad) and 2006 (Olomouc).

[12] Of course semantics is to be understood as "grammatical" semantics, i.e. the system that assigns an interpretation to morpho-syntactic structure. The meaning of lexical items and the relation with the conceptual world are entirely different issues.

The result is a broad distinction of two macro-modules, phonology and morpho-syntax-semantics, which are supplemented by (at least) two modules that mediate between grammar and other cognitive functions (pragmatics and the conceptual device).

### 59 6.4. Domain specificity (Jackendoff, Chomsky): phonology is distinct

Jackendoff's (1987, 1992, 1997) modular theory, Representational Modularity (which Jakendoff 2002:218ff prefers to call Structure-Constrained Modularity today), also points out the obvious ontological gap between phonology and other linguistic devices, which is greater than the distance between any other two linguistic candidate disciplines.

(36) "The overall idea is that the mind/brain encodes information in some finite number of distinct representational formats or 'languages of the mind.' Each of these 'languages' is a formal system with its own proprietary set of primitives and principles of combination, so that it defines an infinite set of expressions along familiar generative lines. For each of these formats, there is a module of mind/brain responsible for it. For example, phonological structure and syntactic structure are distinct representational formats, with distinct and only partly commensurate primitives and principles of combination. Representational Modularity therefore posits that the architecture of the mind/brain devotes separate modules to these two encodings. Each of these modules is domain specific.
[…] The generative grammar for each 'language of the mind,' then, is a formal description of the repertoire of structures available to the corresponding representational module." Jackendoff (1997:41)

Chomsky (2000a) makes the same point.

(37) "The phonological component is generally assumed to be isolated in even stronger respects: there are *true* phonological features that are visible only to the phonological component and form a separate subsystem of FL [the Faculty of Language], with its own special properties." Chomsky (2000a:118, emphasis in original)

Domain specificity within grammar thus identifies what appears to be the deepest fraction line, which separates phonology on the one hand and all other classical disciplines (syntax, morphology and semantics) on the other.

Jackendoff ends up with three modules that are involved in the management of grammar: phonology, syntax and the conceptual device. He calls modules processors and distinguishes between integrative and interface processors (see Vol.2). The latter translate the output of the former into vocabulary items that can be understood by other "true" modules, i.e. phonology, syntax and the conceptual device in our case. Intermodular communication is discussed in §64 below (and at greater length in Vol.2).

60 6.5. Phonology-free syntax

That phonology is ontologically distinct also shines through more familiar linguistic work that does not think in modular categories or look at domain specificity: the distinctness of phonology is the core message of phonology-free syntax, which was discussed in §**Erreur ! Source du renvoi introuvable.** (also §**Erreur ! Source du renvoi introuvable.**).

In Zwicky & Pullum's (1986a,b) strong original version, phonology-free syntax holds that syntax and morphology are deaf for any phonological information: there is no morpho-syntactic process that has a phonological conditioning. For example, there is no syntactic movement on record that is triggered only if, say, the candidate begins with a labial.

A weaker version (see §**Erreur ! Source du renvoi introuvable.**) distinguishes between melody (i.e. phonological objects located below the skeleton) on the one hand and syllabic as well as prosodic properties on the other (e.g. supra-skeletal structure). The inability of melody to bear on morpho-syntax appears to be a correct generalisation, while syllabic and prosodic properties such as intonation, minimal word constraints and other counting operations are found to condition morphological and syntactic processes.

The fact that the weaker version is probably correct is actually more interesting from the modular perspective: it means that the basic phonological vocabulary is unintelligible for morpho-syntax, but that projections thereof may be perceived. Which thus nicely confirms that domain specificity is about vocabulary, rather than about the output of a computation that is based on this vocabulary (§66 elaborates on this).

61 6.6. Late Insertion is the segregation of phonological and other vocabulary

The ontological separation between phonology and morpho-syntax is also central in Distributed Morphology: while up to GB morpho-syntactic computation was done on the basis of complete lexical information that included syntactic, morphological and semantic features as much as phonological material (sealed suitcases), Late Insertion is the idea that phonological material is absent from morpho-syntactic computation (see §**Erreur ! Source du renvoi introuvable.**). Only morpho-syntactic information is available at the beginning of a derivation; phonological material (vocabulary items) is only inserted after the completion of the morpho-syntactic derivation.

62 6.7. Phonology vs. phonetics

Although this book does not consider the relationship of phonology with phonetics, i.e. the (eventual) lower limit of phonology, it is worth pointing out that domain specificity is also used in the large body of literature that debates this issue in order to insulate both areas: this is what Hale & Reiss (2008:118) do. Kingston (2007) provides a good overview of the positions that are taken, and especially of the debate whether phonology and phonetics are distinct modules or instances of the same computational system.

63 7. Encapsulation is called inclusiveness in syntax

Informational encapsulation is a core property of modules (§25): modules produce an output on the grounds of a domain specific input, and there can be no communication with anything beyond the module (i.e. possible sources of additional information) during the computation.

It is worthwhile to be mention that Chomsky's (1995a:228) inclusiveness is the syntactic formulation of encapsulation: syntactic structure must be exclusively based on information that is present in the input; no element may be added in the course of a syntactic derivation.

# Chapter 6
# 64 How modules communicate

## 65 1. Intermodular communication requires translation

Let us now turn to intermodular communication. A direct consequence of the fact that different modules speak different languages (of the mind) is their inability to understand each other. Modules can only parse objects that belong to their own language, i.e. which are part of the domain specific vocabulary that they are designed to process. This is what Jackendoff explains in the quote below.

(38) "'Mixed' representation[s] should be impossible. Rather, phonological, syntactic and conceptual representations should be strictly segregated, but coordinated through correspondence rules that constitute the interfaces." Jackendoff (1997:87ff)

Applied to the phonological module, this means that phonology could not react on any untranslated input from the morpho-syntactic module. This is precisely the principle of Indirect Reference that was introduced by Prosodic Phonology (see §**Erreur ! Source du renvoi introuvable.**): phonology can only take into account morpho-syntactic information that was previously translated into phonological vocabulary. The whole architecture of Prosodic Phonology is shaped according to Indirect Reference: a Translator's Office mediates between morpho-syntax and phonology. That is, the morpho-syntactic output is mapped onto prosodic constituency, which is the input to phonology.

The basic idea of intermodular communication that materialises in the architecture of Prosodic Phonology is thus the following: in order for two modules to talk to each other, there must be a mediating instance which understands the vocabulary of both the input and the output module and translates information from one into the other. Untranslated information is noise and will be ignored by the receiving module.

The idea that morpho-syntactic information must be translated before phonology can use it has always been present in phonological theory since the 19th century. A summary of how translation was practised since structuralist times is provided in §**Erreur ! Source du renvoi introuvable.** below.

66 2. Translation of what?

67 2.1. Modular computation: vocabulary (input) vs. structure (output)

When talking about modules, an important distinction is between vocabulary (content) and structure. The structure of a module is the result of its computation: based on an input that is made of domain specific vocabulary, computation builds structure. In syntax for instance, the morpho-syntactic tree is the projection of morpho-syntactic features; in phonology, syllable structure is the projection of segmental properties.

While vocabulary is necessarily domain specific, structure does not have to be. That is, different modules may produce the same type of structure, i.e. which has identical properties (one important aspect of which is hierarchical organisation). This means that structure is predestined for being shipped to other modules at the end of a computation: in case both vocabulary items (terminals) and structure are shipped off, the receiving module will be unable to make sense of the former, but may be able to interpret the latter, which is domain-unspecific.

This is a somewhat tentative hypothesis that depends a lot on how intermodular translation actually works. Closer inspection of this issue is only provided in Vol.2. In anticipation of the discussion, the regular view is that translation is done by a specialised translation module, i.e. by some computation (the Translator's Office in Prosodic Phonology, Jackendoff's interface processors). An alternative is translation through a lexical access: like in a dictionary, each item of the input vocabulary is matched with an item of the output vocabulary. That is, translation does not involve any computation (this is what Michal Starke argues for).

68 2.2. Is structure, but not vocabulary, translated?

In principle, translation could translate vocabulary items and structure alike. There is some indication, though, that modules may be sensitive to structure, but not to vocabulary. This empirical generalisation was already mentioned in §**Erreur ! Source du renvoi introuvable.**: there is at least a strong trend for phonology to be sensitive to morpho-syntactic structure, i.e. geometric properties of the tree, while node labels are by and large ignored.

The same is true in the opposite direction: phonology-free syntax (see §60, originally discussed in §**Erreur ! Source du renvoi introuvable.**) is in fact melody-free syntax: the basic vocabulary items of phonology are the objects that occur below the skeleton, i.e. melodic primes such as labiality, stopness and so on. On the other hand, syllable structure and other properties of supra-skeletal phonological representations are the result of phonological computation that is based on this basic vocabulary.

If it is true that structure may be translated, while vocabulary remains untranslated, melody is predicted to be unable to bear on morpho-syntax – and this is indeed what we observe. By contrast, supra-skeletal phonological structure may be read by other modules. This is indeed the result produced by the literature that set out to challenge phonology-free syntax: all cases where phonology influences morpho-syntax appear to concern phonological properties that are located above the skeleton (§**Erreur ! Source du renvoi introuvable.**, see also §**Erreur ! Source du renvoi introuvable.**).

While the empirical situation is unambiguous in the direction from phonology to syntax (cases where morpho-syntax reacts on labiality or the like are not on record), it is not exactly clear-cut in the opposite direction: cases such as the well-known stress-determining difference between nouns and verbs in English (*récord* vs. *recórd* etc.) stand in the way. Category-sensitive phonology is further discussed in §**Erreur ! Source du renvoi introuvable.**.

Finally, vocabulary may not only be excluded as an input to translation – maybe it does not qualify as its output either. This is suggested by the discussion in §**Erreur ! Source du renvoi introuvable.** below: melody (i.e. phonological vocabulary) is not only invisible for morpho-syntax – it is also unheard of as a carrier of morpho-syntactic information in phonology. In sum, then, vocabulary would be excluded from translation altogether: only structure qualifies as its input and output.

## 69 3. Translation is selective, and the choice of translated pieces is arbitrary

Another pervasive property of intermodular communication appears to be the fact that translation is never complete. That is, only a subset of the structure of the sending module is made available to the receiving module through translation. Also, it appears that the pieces which are chosen for transmission cannot be predicted.

Ray Jackendoff's work regularly draws attention to the underfeeding of the receiving module.

(39) "Correspondence rules perform complex negotiations between two partly incompatible spaces of distinctions, in which only certain parts of each are 'visible' to the other." Jackendoff (1997:221)

"The overall architecture of grammar consists of a collection of generative components $G_1$, …, $G_n$ that create/ license structures $S_1$, …, $S_n$, plus a set of interfaces $I_{jk}$ that constrain the relation between structures of type $S_j$ and structures of type $S_k$. […] Typically, an interface $I_{jk}$ does not 'see' all of either $S_j$ or $S_k$; it attends only to certain aspects of them." Jackendoff (2002:123)

The fractional character of translation in intermodular communication is further discussed in Vol.2, where illustration from various cognitive functions is provided.

How exactly the respective translating mechanisms work has received little or no attention at first: the distribution of juncture phonemes was stated in prose (if anything), and SPE had a universal algorithm that distributed hashmarks according to hierarchical morpho-syntactic structure (§**Erreur ! Source du renvoi introuvable.**). Prosodic Phonology paid much more attention to the labour that translation requires, which was done by a special kind of rules, i.e. mapping rules (§**Erreur ! Source du renvoi introuvable.**). In OT, mapping is constraint-based (instead of rule-based, §**Erreur ! Source du renvoi introuvable.**), and in Jackendoff's (1997 et passim) general landscape, modules communicate by means of so-called correspondence rules, which in his more recent work appear as Interface Processors (see Vol.2).

Of course, translation only concerns the representational aspect of the interface: cyclic chunk-submission runs independently. The genuine contribution of Vol.2 to the interface discussion lies on the representational side. Two issues are examined in detail. On the one hand, the question is asked whether it is reasonable (or even workable) to have two distinct means of piecing together phonological material (representational objects) that serves as the input to the phonological module: vocabulary (lexical) insertion on the one hand (which concerns morphemic information, origin: the lexicon), and "added" non-morphemic information that comes in through translation (juncture phonemes, boundaries, prosodic constituency, origin: output of the Translator's Office). It will be argued that the answer is no: this is not reasonable. All phonological material that phonological computation uses originates in the lexicon (One Channel Translation, an idea of Michal Starke).

On the other hand, the diacritic issue is examined. In the history of post-war phonology, the output of translation have always been the units of the current theory: juncture phonemes in structuralist times, ([-segment]) segments in SPE, prosodic constituency in the autosegmental 80s. The trouble is that all of these are diacritics: a juncture phoneme is obviously not a phoneme, a boundary is evidently not a segment, and prosodic constituency, unlike all other tree structure (in phonology as much as in morpho-syntax) is a projection of nothing, i.e. not a bottom-up construction (more on this in §**Erreur ! Source du renvoi introuvable.**). Direct Interface (Scheer 2008a, 2009a,c, to be introduced at greater length in Vol.2) holds that the output of translation must be genuinely phonological objects, that is items which belong to the vocabulary that the phonological module works with, and which exists independently of any interface issue (i.e. of extra-phonological factors).

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