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Sign language and modularity

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There are two known language modalities used by humans: the oral-aural modality of spoken languages, and the manual-visual modality of signed languages found in the deaf communities of the world. The coexistence of these two systems raises fundamental questions about language and cognition. Sign language is considered here in the context of a particular theory of cognitive organization, the modularity thesis of Fodor (1983). It is argued that that modularity theory, which is based on biological as well as representational/computational considerations, does not stand up in the face of the existence of sign language.

To demonstrate that sign language must be considered to be part of the same cognitive system as spoken language, a formal comparison is drawn at the level of phonology – perhaps the least expected level of linguistic organization because it is the most physiologically bound. It is then argued that despite this similarity, a language module that is stimulus-domain specific and informationally encapsulated could not include sign language.

Sign language is shown to be a challenge for the development of a comprehensive theory of language, which, it is suggested, should aim to predict both similarities and differences between natural languages in the two modalities.

1. Two types of natural language

Despite the apparent complexity of language, the ability to acquire and use it does not seem to rely on any special talent or intelligence: all human communities, and virtually all of their members, have language. This suggests that all humans are biologically endowed with this ability. The brain and the vocal and auditory organs engage in a complex interaction in the service of language.

In most respects, this characterization of language is applicable to the sign

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languages of the deaf. All known deaf communities have sign languages; they are as systematic and complex as spoken languages (for overviews, see Klima and Bellugi 1979, Wilbur 1986); in deaf families, sign languages are acquired without instruction by deaf children from their deaf parents in the same stages and in about the same time as are spoken languages (Newport and Meier 1986). Yet there is an obvious and potentially important difference between the only two types of natural language that humans use: the languages used by the deaf do not involve the vocal and auditory organs, utilizing instead the manual and visual systems.

It has been suggested by some scholars, among them Lindblom et al. (to appear), that humans evolved for spoken language and not for sign language. Consider that if humans had evolved for language in general without respect to modality, then we should expect to find hearing communities that just happen to use sign language instead of spoken language. But we do not.[1] On the view that humans evolved for spoken language, sign language must be seen as an adaptation of existing physical and cognitive systems for the purpose of communication among people for whom the auditory channel is not available.

For students of cognition, two questions present themselves in this context: (1) How similar is the adapted system to spoken language? (2) Do languages in different physical modalities constitute a unified cognitive system? The answers to these questions are not obvious or trivial.

1.1. Language as a module

In his influential 1983 monograph, *The Modularity of Mind* (henceforth, *Modularity*), Jerry Fodor sets out a theory of cognitive organization according to which language is proposed to constitute a unified cognitive module. The criteria for modularity are both representational/computational and biological. That is, modules are identified according to the types of representations/computations they contain and perform, as well as by their neural architecture and their relationship to external stimulus domains. Since sign languages involve representational structures and operations like those of spoken language (as will be demonstrated in detail below), but different physical stimuli and production and perception systems, they provide an interesting test for the proposal that language is a unified module.

[1] While there may well have been evolutionary pressures favoring oral over manual language – such as the ability to communicate while working or hunting as well as to communicate in the dark – it seems likely that these are no longer relevant, and that the spoken modality must have assumed neurological dominance at some earlier stage of human evolution.

Challenges to Fodor's modularity hypothesis generally focus on the relationship between the module and higher level 'central processes'. The discussion presented here will look at the purported language module primarily from the 'other end'. It will describe aspects of the phonetic and phonological levels of structure, and will consider in particular whether the modularity criteria of domain specificity and informational encapsulation are tenable from that perspective. I will argue that they are not, and that the existence of sign languages counterexemplifies the language module hypothesis of Fodor.

The exposition is organized as follows. Section 2 presents evidence for significant structural similarities between spoken language and American Sign Language (ASL) at the phonological level. Section 3 argues that the particular language module proposed in *Modularity* is nevertheless not compatible with the existence of sign language, and that therefore there can be no language module of the kind described there. The discussion focuses primarily on the proposed properties of domain specificity (both biological and computational) and informational encapsulation. Significant structural differences between signed and spoken languages are also described in this section. Other possible types of language modules are considered in section 4: a language module that sign language is not a part of, and a language module that is restricted to structural linguistic properties. Also discussed in that section is a possible top-down leak from central processes to the language module in sign language. Section 5 is a summary and suggestions for future research.

2. Phonological structure of sign language

In order to demonstrate in a rigorous way that signed and spoken language have much in common structurally, I will use an example from what might be the least expected domain: that of the phonology. The term 'phonology' refers to the meaningless but linguistically significant elements of structure in either modality. If similarities here are unexpected, it is because the physiological systems subserving phonology are obviously distinct in the two modalities. Nevertheless, significant similarities do exist.

2.1. The basics

In the following discussion, enough description of the structure of signs will be offered to give the reader an idea of what a sign looks like, and to make possible a comparison of its structure to that of the spoken word. The model of ASL phonology described here is developed in detail in Sandler (1987a, 1989).

The sign in ASL is comprised of three major phonological categories: hand configuration, location, and movement (Stokoe 1960, Klima and Bellugi 1979). Substituting features within any of these categories can result in minimal pairs (Battison 1978). This shows that signs are not holistic gestures, but are made up of smaller, meaningless units that are linguistically significant, like the phonemes in words of spoken language.

Locations refer to the place(s) where the sign is made, either in space near the signer or on some part of the signer's body. Movements are generally the path taken by the hand from one location to another within a sign. Hand configuration, the shape and orientation of the hand, is described in more detail in section 2.2.

So far, the production of signs looks pretty different from that of words. At the phonetic level, this is indeed the case. While spoken sounds involve pushing air through the larynx and manipulating the lips, tongue, larynx, etc., signed languages are articulated by changing the number and position of the fingers, and moving the hands from place to place. In spoken languages, phonological processes, such as assimilation, are closely bound to the physiology of the system (Clements 1985, Sagey 1986). Since sign language is physiologically so different, there is no basis for predicting whether there are such processes at all in sign language, and, if there are, whether they would bear any resemblance to those of spoken languages. Presently it will be shown that such processes do exist, and that they are similar to those of spoken languages.

The three major categories of handshape, location, and movement have a relationship to one another that has both linear and nonlinear properties. Contrary to views which held that sign categories were executed simultaneously (Stokoe 1960, Klima and Bellugi 1979), many researchers have discovered evidence for sequential structure in ASL signs (Supalla and Newport 1978, Newkirk 1981, Padden 1983, Meier 1983, Liddell 1984a, Liddell and Johnson 1989, Sandler 1986, 1989, 1990, 1992a).

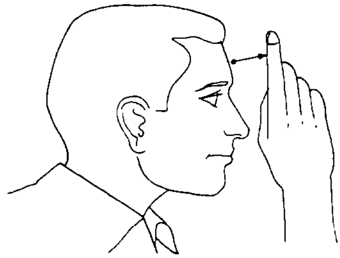
Consider, for example, the sign GIVE. This sign is produced with a handshape consisting of all fingertips touching the thumbtip (in an 'O' shape), palm up. In citation form, the hand moves in an arc path from a location near the trunk of the signer's body to a location a medial distance in front of the body. When the sign is inflected to agree with subject and indirect object, however, each of these locations may change independently. A sign meaning, 's/he gives me', for example, begins at a location to the side of the signer and ends at the location where the citation form begins, i.e., near the signer's trunk. In order for the grammar to include such agreement rules, distinct reference must be made to the first and second locations. Following common linguistic practice, we propose that if an element must be referred to in order to state a rule, then that rule constitutes evidence for the existence of the element in question. Thus, the agreement facts provide strong arguments for sequential structure in the sign. Linear structure is also attested in monomorphemic forms. For example, the signs GOOD and ARRIVE are minimally distinguished by having different *initial* locations. Other signs involve a linear sequence of movements or of handshapes. For full explanation and additional evidence, the reader is referred to the references cited above.

The present model establishes the representation shown in (1), in which the canonical sign consists of two locations separated by a movement. The sign INTELLIGENT is pictured as an example. Ls (locations) and Ms (movements) may be thought of as comparable to consonants and vowels, although no direct analogy is suggested here.[2]

[2] Two points should be noted with respect to the sequential structure and the nature of the segments presented here. (*a*) As is the case in research of spoken language, evidence for phonological primitives often comes from their behavior in morphological processes. For example, McCarthy and Prince (1986) adduce evidence from morphological processes of reduplication for claims about basic prosodic structure at the level of underlying phonological representation. At the same time, there is purely lexical evidence for sequential structure as well, as indicated in the text. (*b*) An anonymous *Lingua* reviewer made the observation that Ms may be redundant in the representations shown here, astutely highlighting a topic of current controversy in sign language phonology. There is evidence that movements must be specified underlyingly in signs (Liddell and Johnson 1989, Sandler 1989) – in order to specify path shape, or contact on the movement segment, for example – and that Ms must be specified in morphologically complex forms (Supalla 1982), and in morphological templates (Sandler 1989, 1990). However, other researchers argue that Ms are generally not underlying in monomorphemic signs (Stack 1988, Van der Hulst 1992). Brentari (1990) proposes that movement features are present underlyingly, but that they assume their sequential status at a level of the phonology that is close to the surface. Since each claim is embedded in a separate theory of sign language structure, an adequate discussion of the issue is not possible here.

I believe it is fair to say that even a conservative appraisal of the literature on these issues leads to the conclusion that there are linguistically significant sequences of locations and movements in ASL, and that at least some movements are more than transitional and require specification.

(1) L M L **INTELLIGENT**



In most simple signs, there is a single hand configuration characterizing the whole sign. This constraint on sign structure suggests an autosegmental representation, in which one hand configuration is associated to all locations and movements.

(2)

```
     HC
  /  |  \
L    M    L
```

Further evidence for this representation comes from temporal asynchrony which is typical of autosegments such as tones (Goldsmith 1976). In some compounds, part of the linear structure internal to the sign falls out, as does the hand configuration of the first member of the compound. In these compounds, on the surface, the hand configuration of the second member characterizes the whole compound that results, as shown schematically in (3).

(3)

```
   HC1            HC2            HC2
  / | \          / | \          / | \
L1  M  L2   +  L3  M  L4   →  L1  M  L4
```

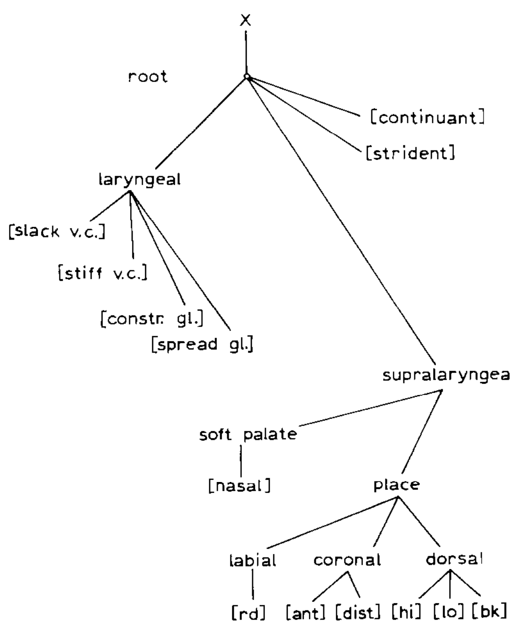
The HC of the second member 'spreads', so that on the surface it characterizes the whole compound, including a location segment that is part of the first member of the compound. This type of temporal asynchrony is evidence of the autosegmental relationship between HC and the LM tier (Sandler 1986, 1989). A more detailed discussion of the behavior of hand configuration in such compounds is presented in section 2.2.

This brief description is intended to make two points. First, spoken and signed languages are very different at the phonetic level. Second, languages in the two modalities have something in common at the phonological level. In particular, signs, like spoken words, consist of linguistically significant meaningless units that combine according to certain structural constraints. Words in both modalities involve sequential structure. Signs have nonlinear structure as well, of a kind attributed to many spoken languages. In the following section, an analysis of the structure of hand configuration and its behavior in assimilation will reveal common phonological properties more explicitly.

2.2.1. Hierarchical organization of phonological features

Many phonologists now believe that phonological features are not listed in unstructured matrices (as in the model established in Chomsky and Halle 1968), but that they have internal organization. Clements (1985) proposes a model of phonological features that represents classes of features hierarchically. Sagey (1986) develops and refines that model; her model is shown in (4).

(4)



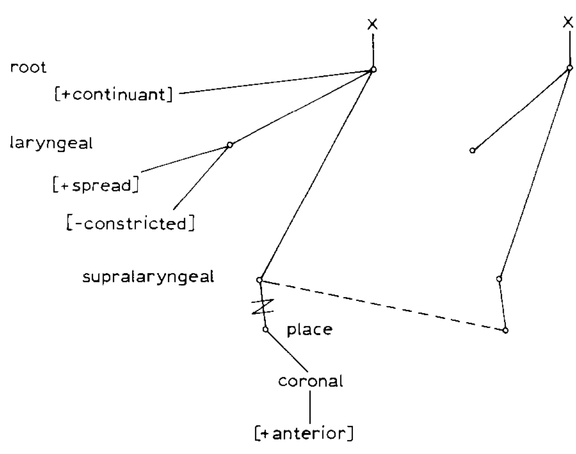
The insight expressed in the model is that groups of features constitute units with respect to forms and rules of languages.[3] Sagey argues that the correspondence between feature groupings and physical articulators adds to the theory's explanatory credibility. The major class nodes, laryngeal and supralaryngeal, correspond to physical divisions within the vocal tract as well as to classes of phonological features.

The literature on feature hierarchies gives motivation for each feature class, represented by a node on the tree. A major form of evidence comes from the types of assimilation rules that are found in the languages of the world. One example (Steriade 1982, cited in Sagey 1986) involves partial assimilation, specifically, assimilation of place of articulation. (5) shows assimilation of /s/ to the place of articulation of the following obstruent in Sanskrit.

(5) tas 'those fem' ṣaṭ 'six' → taṣṣaṭ
divas 'god-GENsg' putras 'son' → divaφ putrah
Nalas kamam 'at will' → Nalax kamam

The assimilation rule is shown in (6).

(6)



[3] Several refinements and alterations of this model have since been proposed, for example, Clements (to appear), McCarthy (1988), Piggott (1990), Steriade (1987), Sandler (1991a). While Clements-Sagey type models are very influential, not all phonologists agree that phonological units are organized this way. Readers are referred to Den Dikken and Van der Hulst (1989) for an overview of some competing theories, and to Goldsmith (1990) for yet another view.

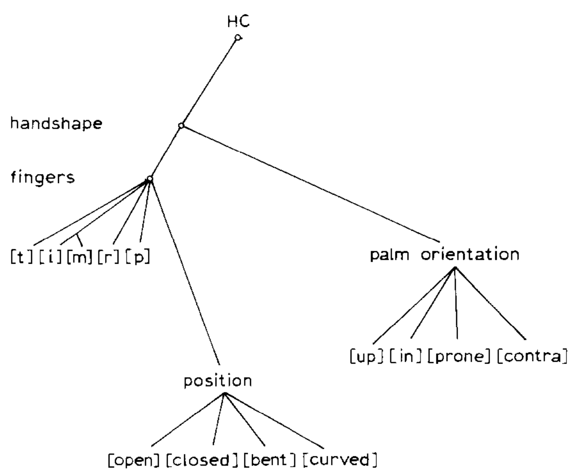
The crucial point is that the place features assimilate, no matter what they are, while other features, such as [continuant], do not assimilate. This is evidence for a place class, including all place features and no others.[4] When a node spreads, in this case the place node, all features below that node spread with it. That is, the hierarchical organization reflects which groups of features may behave in a unified way in rules. The model also makes predictions about assimilations that may not occur. For example, a place assimilation rule, represented as spreading the place node, may not involve assimilation of labial and coronal features only, without assimilating dorsal features. While individual features can assimilate alone, being the terminal nodes in the hierarchy, the model predicts the unlikeliness of encountering rules that spread two features belonging to separate classes. A rule that spreads [hi] and [voice] would be an embarassment for the model.

In addition to the place class, other classes represented in the model have been motivated by similar processes. Total assimilation is represented as spreading of the root node.

2.2.2. Hierarchical organization of HC features

We now turn to American Sign Language. The theory of the phonological structure under discussion includes a model of the structure of hand configuration (HC) shown in (7), adapted from Sandler (1989, 1991a).

(7)



[4] Some researchers have proposed elimination of the place node, and reference to this class of features simply as supralaryngeal (Steriade 1987, Sandler 1991a).

The model of HC is hierarchical in the same way that the model of spoken features shown in (4) is, identifying feature classes on the basis of phonological patterning and physiology. In general, the lowest level components represent refinements of articulations that are produced by the articulators dominating them.[5]

An example of the hierarchical structure revealed by the model is the representation of position features as dominated by the finger node. As with spoken language, phonological patterning coincides with the physical pattern. Just as the tongue dorsum (represented by the dorsal node) articulates the features [hi], [lo], and [back], so do the fingers (finger node) articulate the finger positions [open], [closed], [bent], and [curved]. In signs with hand-internal movement, the position features change independently of the selected finger group, which does not change. This independence is reflected in the representation, in which finger and position features belong to different classes. In the case of signs with changing finger positions, this change is represented as a contour: branching features dominated by the position node. An example appears in the sign DROP, pictured and represented in (9) below.

A constraint on hand configurations requires all selected fingers to be in the same position in a morpheme (Mandel 1981). If there is a change in position, all selected fingers make the same change. This constraint is phonological motivation for representing position features as subordinate to the selected finger node, and not as subordinate to each individual finger (contra Corina and Sagey 1988).

Fingers and palm form a physiological unit distinct from locations and movements, and they generally exhibit temporal unity with respect to the location and movement segments, as explained above and illustrated in (2). These facts motivate representation of both feature classes as part of HC.

However, fingers are physiologically distinct from the palm, in the same way that the larynx is physiologically distinct from the oral cavity. The phonetic result of this independence is that features of each are relatively

[5] Sandler (1991b, in preparation) develops a somewhat different model of low-level components than the one shown here. The more recent model adopts the articulator hierarchy of the Clements-Sagey view, but does not adopt binary distinctive features at the lowest level. Following certain concepts of Dependency Phonology (Anderson and Ewen 1987, Van der Hulst 1989), the revised model proposes unary-valued abstract formational primitives at this level, primitives that combine in specified ways. Corina (1992) offers a hierarchical model of ASL hand configuration in the same spirit as the one presented in (7), but with significant differences as well.

independent of features of the other. One might think of voicing as analogous. Just as almost any stop can be either voiced or voiceless, so any handshape can co-occur with any orientation.

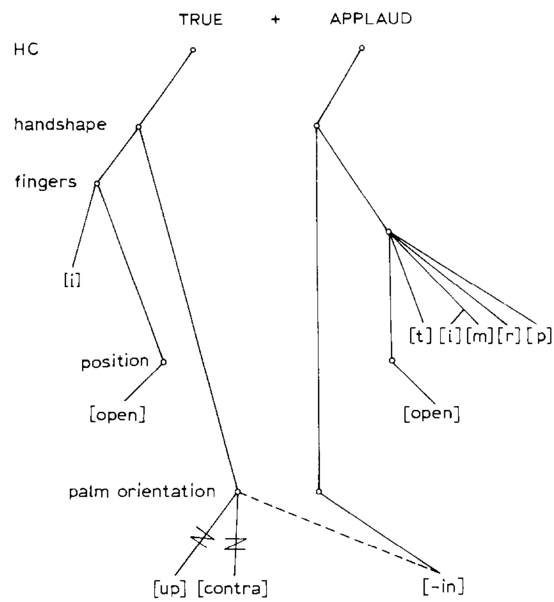
In addition to the physiological and phonetic motivations, there are phonological motivations for distinguishing between fingers and palm as well. If there is a change in HC in an ASL sign, it may be either change of handshape or of orientation, but rarely both.

In the model, palm orientation features are not only distinct from the handshape node, they are subordinate to it. The phonological alternation that supports this particular hierarchical relation is the assimilation of hand configuration in a set of ASL compounds. Just as the morphological process of agreement sheds light on the temporal phonological structure of signs, so does the behavior of phonological elements under the morphological process of compounding lend insight into the nature and organization of those elements.

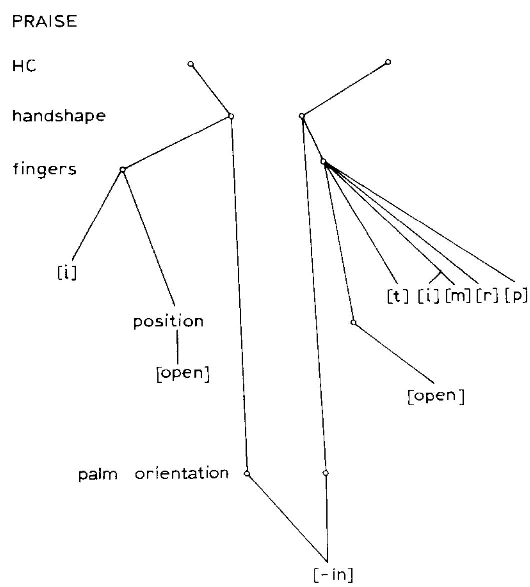
2.3. Compounds and the handshape/orientation hierarchy

First, let us consider the compound PRAISE, from the signs TRUE+APPLAUD. In TRUE, the HC is: index open, palm oriented contralaterally. For APPLAUD, the hands with all fingers open are clapped together, the dominant hand oriented outward from the body. In the compound, the orientation of the first HC becomes that of the second HC, but the handshapes, i.e., the fingers and their positions, remain distinct as in the noncompound form. This is a case of partial regressive assimilation, a process well known in spoken languages (e.g., Sanskrit above), in which only some features of an adjacent segment assimilate. The representations in (8a) and (8b) show the orientation assimilation process occurring on the base signs, and the assimilated compound. The orientation class node spreads leftward to the handshape node of the HC of the preceding sign, and the lower material of the first sign is delinked. Many other compounds show orientation assimilation, regardless of the particular orientation features of the sign. Characterizing the assimilation as class assimilation therefore captures a significant generalization.

(8a)

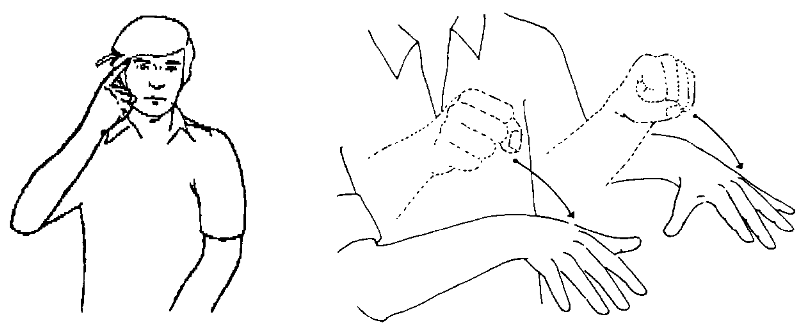

TRUE + APPLAUD
HC
handshape
fingers
[i]
position
[open]
palm orientation
[up] [contra]
[t] [i] [m] [r] [p]
[open]
[-in]

(8b)


PRAISE
HC
handshape
fingers
[i]
position
[open]
palm orientation
[t] [i] [m] [r] [p]
[open]
[-in]

In some compounds, total assimilation occurs. As an example, let us consider the compound FAINT. formed from the simple signs MIND and DROP. In MIND, the HC is, index open, orientation in towards the body, in this case the forehead. In DROP, the hands change their shape from fists to open hands. In the compound sign, only the second HC, the HC of DROP, occurs on the surface for the whole compound. This is represented in (9) as total assimilation.[6] Total assimilation also occurs in many other compounds.

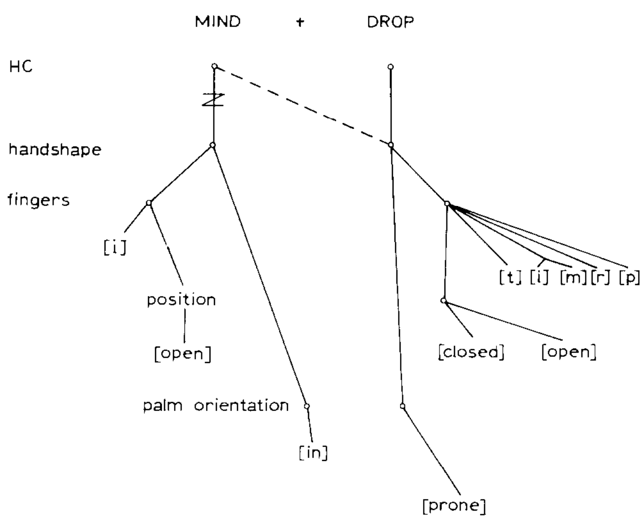
(9) MIND + DROP



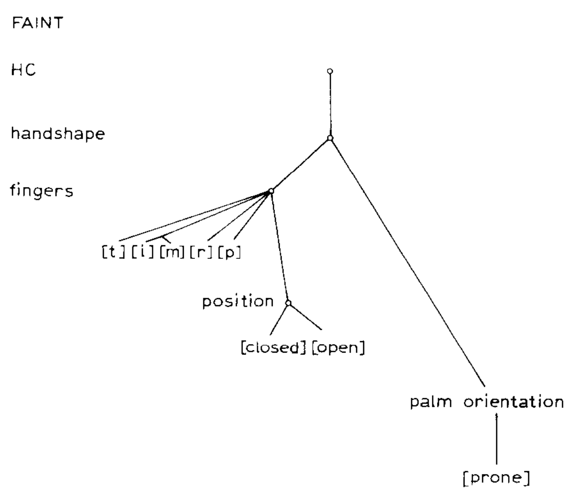
FAINT

[6] For simplicity, the nondominant hand is not dealt with here. Theoretical treatments of the role of the nondominant hand in ASL phonology can be found in Sandler (1989, 1992b), Brentari and Goldsmith (1992), Brentari (1990), and Blevins (1992). The rule for assimilation of HC shown in (9) is an accurate generalization of total HC assimilation. In the particular example of DROP, in which the spreading HC is two-handed, the precise representation includes an additional root node dominated by the HC node, and associating to all the same features as the other root node. That is, each root node represents one hand. The representation in the text is simplified for clarity.

(9a)



(9b)



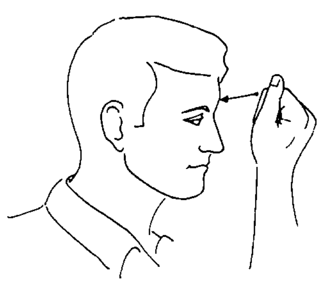
That the process under discussion is indeed total assimilation and not deletion is supported by the following observations. Several compounds in the data I examined, such as THINK + TOUCH = OBSESSED, SLEEP +

SUNRISE = OVERSLEEP, may optionally undergo either total or partial assimilation. If total assimilation were analyzed as a deletion process, the fact that either deletion or partial assimilation of the same element (hand configuration) occurs in the same environment would appear coincidental. In addition, if the first HC were simply deleted, then there would be no way to predict what HC would characterize the first L of the compound in its place. The fact that in all cases the replacing HC is that of the second member of the compound also points to a total assimilation analysis. A hand configuration assimilation analysis, then, offers a unified treatment of the phenomenon.

The particular hierarchy shown in (7) is motivated by the fact that orientation may assimilate without handshape, but if handshape assimilates, orientation, being lower in the hierarchy, must assimilate too.

Handshape does not assimilate alone. It is significant to note that this relationship is strictly phonological and not just physiological or phonotactic. We know this because of the following fact: if handshape-only assimilation were to occur, the articulations that would result are often legitimate and occurring articulations in ASL. Let us take as an example the sign FAINT (MIND + DROP), discussed above. If this compound were to undergo handshape-only assimilation, an articulation that occurs in the sign STUPID would result: closed fist oriented toward and contacting the forehead.

(10) STUPID



If handshape-only assimilation were to occur in the compound OBSESSED (THINK + TOUCH), an articulation occurring in the sign SICK would result (middle finger extended, oriented toward and touching the forehead), and so forth. Yet, handshape-only assimilation is unattested in these signs, and in fact there were no instances of handshape assimilating without orientation in the hundred compounds I examined.[7]

We have now seen some detailed evidence that sign language, even at the physiologically constrained phonological level, is similarly structured to spoken language. In fact, there is a formidable body of literature demonstrating organizational and structural similarities between ASL and spoken language at all levels of analysis (see, for example, the following volumes: Coulter 1992, Fischer and Siple 1990, Klima and Bellugi 1979).

2.4. Neurological similarities

In their book, *What the Hands Reveal about the Brain*, Poizner, Klima, and Bellugi (1987) show that there are similarities in the hemispheric organization of hearing and congenitally deaf people. In particular, they show that sign language aphasia results from left hemisphere damage, but not from right hemisphere damage, despite the likelihood that sign language taps the right-hemisphere function of visuo-spatial manipulation. The three case studies of deaf aphasics also suggest that, as in spoken language, distinct types of language breakdown may be associated with particular focal lesions.

2.5. Summary

We see, then, that there are significant linguistic and biological similarities between spoken and signed languages. Signs are comprised of a discrete set of meaningless, linguistically significant elements. Phonological primitives are organized in classes that behave as units in sign language rules. ASL is characterized by morphological processes, such as compounding, and by phonological processes, such as assimilation. There is also a degree of linear structure in signs. At the biological level, there is evidence that the left hemisphere controls languages in both modalities. The question to be addressed in the rest of this article is, Does it follow that the two classes of natural languages reside in a single cognitive module?

In the following discussion, the only assumption I will make is that sign languages are languages. We are required to assume this much on functional and structural grounds: sign language does everything spoken language does for people, and its structure is too similar to that of spoken language for us to

[7] I am indebted to Ursula Bellugi and the Salk Institute for Biological Studies for their generosity in making videotapes of compounds available to me. Thanks also to Bob Alcorn and Gerry Zimmer, who were ASL consultants for the compounds data.

consider it to be a completely distinct cognitive system. Yet as the concept of modularity becomes more refined, we are confronted with the question of whether these similarities are enough to consider languages in the two modalities to belong to the same module. In the course of the discussion, I will suggest that explaining the similarities as well as the differences between signed and spoken languages is nontrivial and is of theoretical importance.

3. A language module

In his 1983 monograph, *The Modularity of Mind*, Jerry Fodor develops a theory of the organization of cognitive faculties. The theory involves a particular concept of modularity, in which cognitive modules have the following characteristics, among others. Fodorian modules are domain specific, informationally encapsulated, innate/hardwired. In the discussion, I will first summarize the theory of cognition presented in *Modularity* and briefly explain the meaning and significance of the characteristics attributed to modules. I will then argue that a module with these characteristics cannot contain sign language, and that, since sign languages are languages, there can be no language module of this sort.

3.1. Cognitive organization

Cognition, according to *Modularity*, is divided into three levels. First, there is the level of the physical transfer of information from the environment, i.e., of sensory stimuli, to the organism. This is done by transducers. The next level up is the one the theory focuses on. It is the level of input systems which is another name for modules. The role of the modules is to interpret the information made available by the transducers in such a way as to make it accessible to the third level of cognition, called central systems, and including such processes as problem solving and fixation of belief.

The monograph does not provide a detailed description of any of the operations proposed to occur at any level. However, the general character of each level, and particularly of the input system/module level, is presented in such a way as to give the reader an intuitive feel for the kinds of properties that must be involved. In sections 3 and 4, an attempt is made to gain a better understanding of the nature and domains of the transducer and input systems.

3.2. Transducers

Transducer outputs 'specify the distribution of stimulations at the "surfaces" ... of the organism' (p. 42). This sensory level is pictured as involving no interpretation of the signal.

> 'The character of transducer outputs is determined, in some lawful way, by the character of the energy at the transducer surface, and the character of the energy at the transducer surface is itself lawfully determined by the character of the distal layout. Because there are regularities of this latter sort, it is possible to infer properties of the distal layout from corresponding properties of the transducer output. Input analyzers [= modular systems, WS] are devices which perform inferences of this sort.' (p. 45)

3.3. Input systems (modules)

The most definitive characteristics of cognitive modules described in *Modularity* are domain specificity and informational encapsulation. Other important characteristics are innateness and hardwired neural architecture.

3.3.1. Domain specificity

Fodor writes, 'There are distinct psychological mechanisms corresponding to distinct stimulus domains' (p. 48). Considering Fodor's explanation of the interpretation of transduced information, cited above, it is easy to understand why modules must be domain specific. If they were not, they would not be able to infer the properties of the physical signal from transducer output.

The modules proposed by Fodor are the perceptual systems (vision, hearing ...), plus language. This is, as Fodor himself admits, a rather unnatural class, since the spoken language module (Fodor did not consider sign languages) includes another module, namely, audition. The domain of the language module includes (a) sentences that conform to universal syntactic constraints, and (b) the acoustic signal that conforms to phonological universals (p. 51). That is, the module 'recognizes' both the biological and the abstract representational structure of its domain. Fodor leaves little room for doubt that modular domains are domains of physical stimuli, and *cannot* be interpreted *only* as more abstract conceptual or computational domains. In a later comment (Fodor 1985: 4), he writes: '... to cite the classic case – the computational systems that deal with the perception/production of language appear to have not much in common with, for example, the analysis of color or visual form (or for that matter the analysis of nonspeech auditory signals)'. And: '... the visual system ... knows how to derive distal form from proximal displacement, and the language system knows how to infer the speaker's intention from his phonetic productions'. Other indications that the physical stimulus domain for language is explicitly acoustic according to Fodor comes from his discussion of informational encapsulation.

3.3.2. Informational encapsulation

Transducers perceive the signal in the external environment and translate it into a form that is interpretable by the module. The module is informationally encapsulated in that it has access only to this form and to no lower or higher information, nor does it have access to information computed by other modules. Thus we may conceive of Fodor's modules as being encapsulated from all three 'directions': they are encapsulated at the 'bottom', since they only have access to the output of transducers. They are encapsulated at the 'sides', since they do not interact with the data base or computations of other modules. And they are encapsulated at the 'top', in that (a) they have little or no access to central information about the world, and (b) conversely, central processes have no access to the 'lower levels' of input analysis.

Categorical perception of speech sounds is presented as an example of a low level of input analysis to which the central systems have no access. In an extremely influential paper, Liberman et al. (1967) report experiments showing that subjects are better at discriminating between acoustically similar sounds across linguistically contrastive boundaries like /p/ and /b/, than between sounds that are equally similar acoustically, but that are within the same linguistic category (more or less aspirated /p/, or more or less voiced /b/), i.e., that are noncontrastive.

According to Fodor, categorical perception constitutes an example of low-level input analysis. This makes sense theory internally. Transducers do not alter the informational content of their stimuli, but merely present it to the input system in the appropriate 'format'. I interpret this to mean in the case of language that the transducers translate an acoustic signal into a phonetic entity but make no claims about linguistically significant aspects of that entity, such as that it is a distinctive feature or a particular phoneme or a syllable. It follows, although Fodor does not say so explicitly, that assigning speech sounds to categories is one of the phonological processes that takes place in the language module, and that phonological form constitutes one level of the output of the language module. This output is available to higher level linguistic processes, such as lexical access, and/or by central processes (such as decision-making), but the raw phonetic output of the transducers is not.

The Liberman et al. task activates central processes, since it requires conscious decisions about whether sounds are the same or different. And these central processes are shown by the experimental task to have access neither to the purely phonetic information nor to the level of input analysis that throws up phoneme boundaries at particular VOT values (in the case of /p/ vs. /b/). Fodor goes on to point out that the subjects' behavior does show sensitivity to within-category distinctions, since their reaction time is reliably longer when making judgements between within-category sounds they judge to be the same, than when making judgements between two sounds that really are identical.

In my view, Fodor's example and discussion of categorical perception are very important to his argument for the following reason: it is one of the very few clear and specific examples presented in the monograph of a psychological mechanism that is both claimed to be within the language module and is experimentally confirmed to be inaccessible to central processes. While most of Fodor's discussion of informational encapsulation deals with encapsulation of modules with respect to central systems, the categorical perception discussion begins to define a lower boundary for the language module, showing where it is encapsulated with respect to transducer systems.

Fodor's discussion of 'horizontal' encapsulation has much in common with the claims made for domain specificity. The kinds of representations and operations characteristic of one module are likely to be distinct from those of any other module.

3.2.3. Hardwired and innate

Fodor writes that 'modules are associated with specific, localized, and elaborately structured neural systems', and that they are innately specified (not learned) (p. 37). These requirements, and the requirement of specificity of stimulus domain, make the theory an expressly biological one, as has been noted by other authors as well (e.g. Stillings 1987). In my view, the linkage between information processing/cognitive operations and the physiology of the system makes Fodor's theory a particularly compelling and potentially explanatory one. This linkage also makes the theory more testable than modularity theories that are restricted to cognitive operations without reference to the physiology of the system. In the discussion that follows, I will argue that the language module fails a test that is of particular theoretical interest: the sign language test.

4. Sign language and modularity

It is precisely in addressing issues of cognitive organization that consideration of sign language should be most valuable. With this overall goal in mind, we now turn to a systematic examination of the proposed language module.

4.1. Domain specificity

Since the theory includes both biological and computational/representational domains, these will be considered separately.

4.1.1. Physical stimulus domains

Clearly, the physical stimulus domain for sign languages is visual and not acoustic. This either eliminates stimulus domain specificity as a property of a language module, or eliminates sign language from the module. Jackendoff (1987) and Arbib (1987) independently identify this problem for Fodor's hypothesis. I will claim here that it is not only on purely physiological grounds that sign language presents a challenge to the claim about domain specificity, but on computational grounds as well.

Careful reading of the role of transducers, and of that of the language module at that bottom end of it, supports the claim that spoken and signed language cannot be interpreted by the same module at this level. Transducers transmit sensory information, but, according to Fodor, they are very 'dumb', and they 'preserve the informational content of their inputs'. While the meaning of 'informational content' is not spelled out anywhere, a conservative reading of the notion implies minimally that visual information is still visual and that auditory information is still auditory when it reaches the purported language module. It is the job of the module to interpret the transducer output in such a way as to ultimately make it available to the central processes. 'Input systems' computations typically do *not* preserve informational content' (p. 42) (emphasis mine/WS). The language module must then organize this transduced information into linguistically interpretable forms, such as the hierarchically organized classes of phonological components shown in section 2. Since transducers must preserve informational content, the latter process must take place in the purported language module. To my knowledge, no one has speculated about what the precise nature of this process might be. I have presented some evidence that the organization of phonological features is quite similar in spoken and signed languages. However, it seems very clear that the process of organizing transducer output into this form cannot be the same in the two modalities.

Visual primitives, such as edges, textures, relative distances, must presumably be translated into coherent three-dimensional shapes, and, in the case of sign language, into phonological form such as that proposed in (7). Auditory primitives, such as formant structures and voice onset times, must be translated into segments with structures like the one in (4). While (4) and (7) have a lot in common, the input to the computations would have to be qualitatively (and formally) distinct, and therefore the computations themselves must also be distinct. That is to say that at the *computational* level, as well as at the biological level, signed and spoken languages do not belong to the same domains.[8] This argument is extended in the discussion of informational encapsulation below.

Modularity focuses exclusively on language perception. However, if we consider language *production*, then the point that the two language modalities involve separate types of computations is reinforced. In an open peer review of *Modularity*, Mattingly and Liberman (1985: 26) write:

> 'Assuming nature to have been a good communications engineer, we must ... suppose that there is but one module, within which corresponding input and output operations (parsing and sentence planning; speech perception and speech production) rely on the same grammar, are computationally similar and are executed by the same components. Computing logical form, given articulatory movements, and computing articulatory movements, given logical form, must somehow be the same process.'

If this hypothesis is correct, then we may suppose that the process involved in sign production must be as different from the process of speech production as the perceptual processes are in the two modalities. Specifically, the process of translating the hierarchical phonological representation in figure (7) into motor commands for the hands must be intrinsically different from the process of translating the formally similar representation in (4) into motor commands to the vocal tract.

8 An anonymous *Lingua* reviewer suggested that the appropriate question is whether or not the transduced information with its domain-specific vocabulary is inside or outside the language module. This implies, contrary to what is being claimed here, that assuming the vocabulary to be different may not be a challenge to the Fodorian language module. The position taken here is the following: allowing for a language module that can interpret information that is encoded in the vocabulary of different stimulus domains grants far more flexibility to the module than Fodor seems to intend (see quotation from *Modularity* in section 3.2 of this paper). In any case, this discussion underscores *Modularity's* lack of clarity in defining the various levels of representation and their interaction, pointing to an important direction for future research.

Fodor's brief discussion of 'cross-modal linkages' is relevant to this point. In particular, he considers the McGurk effect (McGurk and MacDonald 1976). In the experiment, subjects were required to make category judgements about segment categories in syllables that are presented auditorily and visually at the same time. The mouth movements viewed on a television screen influenced judgements. This visual influence was discerned when mouth movements that conflicted with simultaneous auditorily perceived syllables resulted in erroneous judgements in favor of the visual stimuli. Fodor writes that such cross-modal effects do not bear on domain specificity, since they are explained by the theory that speech perception involves a mental representation of speech production. This view is compatible with that of Mattingly and Liberman quoted above.

Crucially, however, the same argument cannot be made for the visual input of sign language, which is not a case of cross-modal linkage, but rather is a distinct language system in a distinct physical modality. Associating a visual image of closed lips parting with /p/ or /b/ involves interpreting a visual image that *reflects* an aural/oral linguistic event. The sounds can of course be easily identified in the absence of any visual signal. In sign language, on the other hand, the visual image *is* the linguistic event.

4.1.2. Differences in computational/representational domains

Together with the striking formal similarities between spoken and signed languages, some of which are described in section 2, there are also significant differences. For example, linear structure in sign languages is very limited compared to that of spoken languages. Eliminating redundant sequential structure that results from reduplication (Sandler 1989), it seems that ASL signs, even morphologically complex signs, typically consist of no more linear structure than LML, comparable to CVC in spoken language. My investigation of Israeli Sign Language (ISL) has so far indicated that ISL signs are typically LML as well, and dictionaries of other unrelated sign languages reveal the same structure for signs (apart from compounds). Though ASL is rich in morphology, the morphological processes are primarily nonlinear, and therefore usually do not result in added sequential structure.

Linear affixation in ASL is limited to about four suffixes: an agentive suffix, a comparative suffix, a superlative suffix which is arguably derived from the comparative, and a multiple agreement suffix. The semantic function and linear position of the first three of these may have been borrowed from English, since they perform the same functions as their English counterparts *-er* (agent), *-er* (comparative), and *-est* (superlative), though they have been incorporated into the grammar of ASL and pattern somewhat differently than the corresponding English forms.

One inflectional process involves prefixal material (Liddell 1984b), and one small class of derived signs involves suffixal material (Woodward 1974, Sandler 1989). But in both of these cases, other linear structure gets deleted, so that the derived surface forms are again one location, one movement, and another location, LML (Sandler 1989). The only truly productive linear morphological process is compounding. As in the schematic example shown in (3), even some lexicalized compounds reduce to the canonical linear limit of LML (Sandler 1989). In any case, compounding generally retains the integrity of each lexical item, and cannot be considered to be affixation. Israeli Sign Language has no linear affixes that I have been able to find (although compounding is very productive in this language as well).

By contrast, the primary type of morphological process in spoken language, it appears, is linear affixation, i.e., prefixation and suffixation. Even languages that have nonlinear templatic morphology, such as Semitic languages, are characterized by linear affixation as well. There is, to be sure, a typological continuum in spoken language, from, say Chinese to Yupik Eskimo. But it is fair to say that prototypical spoken language morphology involves linear affixation.

Another difference between the two systems involves the way in which nonlinear information is carved up. I have argued elsewhere (Sandler 1986, 1989) that hand configuration (HC) has autosegmental properties vis-à-vis locations and movements, reminiscent of the relationship between tones and the rest of the segmental structure in tone languages (Goldsmith 1976). HC, like tones, is characterized by long-distance spreading, for example in the assimilating compounds described in section 2. If we look at the nature of HC, however, we see that it is extremely complex, actually carrying a large part of the phonological and even of the lexical information of signs.[9] This is in contrast with the long-distance autosegments that have been described in spoken languages, such as tones or nasality, which are generally characterized by a single feature. The implication is that within a lexical item, more information is transmitted nonlinearly, or simultaneously, in signs than is the case in spoken words. This conclusion is supported by the fact that under

[9] See Supalla (1982), Kegl (1985), and Sandler (1989) for discussions of hand configuration as an independent morpheme.

morphological processes, while locations and movements may be altered, hand configuration is generally constant.

Though not outside the confines of forms and processes predicted by phonological theory,[10] sign languages appear to be universally distinguished from spoken languages in the ways described. This indicates that, in addition to differences in physical stimulus domains, there are also systematic differences in the formal representational domains of the two systems.

In this section, I have argued that signed and spoken languages belong to distinct domains, both in terms of cognitive processes, and in terms of the physiology involved in each. By cognitive processes, I have been referring both to the kinds of computations that translate raw phonetic input into phonological form, and to linguistic representations and rules. In this view, a domain-specific language module is ruled out by the existence of a class of languages with different physical and computational/representational domains.

4.2. *Informational encapsulation*

There are three 'sides' to encapsulation. Modules are argued to be encapsulated with respect to lower-level sensory information, higher-level central processes, and to other modules. In this section, I will argue that sign language has systematic 'leaks' in all three directions, and therefore presents a problem for the language module under discussion.

4.2.1. *Perception and the language module: Vertical-downwards encapsulation*

I pointed out earlier that categorical perception is the clearest and most detailed example given by Fodor for domain specificity. It is at the same time an argument for informational encapsulation, as should be clear from the exposition in the previous section: (1) input to the transducers and the operations by which they in turn provide input to the language module are assumed to be inaccessible to the module (e.g., *Modularity*, p. 56); and (2) both the input that reaches the module, as well as the process of interpreting it into phonological form, which takes place within the module, are experimentally demonstrated to be inaccessible to central systems.

[10] The fact that sign language phonology falls within phonological theory does not make the differences trivial. It is possible, in fact, to interpret these facts in the following way: perhaps certain aspects of phonological theory are too powerful and can predict other types of human behavior apart from language. Stephen Anderson (1989, 1992) has made a similar observation. Be that as it may, since these differences are systematic across sign languages, they demand an explanation.

If this encapsulation were particular to language, and if a language in another modality were also characterized by categorical perception, then categorical perception would provide important support for the type of language module proposed in *Modularity*. However, there is evidence that neither of these conditions are met.

It is by no means conclusively proven that categorical perception is peculiar to language. In fact, categorical perception may be restricted neither to speech nor to animals that have language. For example, humans perceive certain nonspeech signals categorically (Newport 1982 and references cited there). Perhaps more alarmingly, chinchillas apparently perceive certain speech signals categorically (Kuhl and Miller 1975). While this does not mean that categorical perception does not characterize language as well, such findings weaken categorical perception, and the informational encapsulation it exemplifies, as definitive properties of a language module.

A more damaging blow is dealt to categorical perception as evidence for informational encapsulation of a language module by experiments in perception of sign language. Newport (1982) presents experimental results showing that sign language phonemes are *not* perceived categorically. Rather, signers perform as well on discrimination tasks within handshape and location categories as they do on discrimination tasks between categories. This means that noncontrastive (nonlinguistic) distinctions are accessed by the module and by the central processes. These results suggest a difference in informational encapsulation of language input in the two modalities.

4.2.2. Horizontal encapsulation

The second problem for the notion of informational encapsulation of a language module is the fact that sign language takes information from another purported module, namely, vision, thereby violating 'horizontal encapsulation'. In some yet to be explained way, Fodor allows that some part of the auditory module is subsumed by the language module. However, if the language module had equal access to all sensory modules, this would be a violation of horizontal encapsulation. It must be underscored that this observation does not necessarily argue against modularity in general, but *does* stand opposed to the particular type of module proposed by Fodor, as the following quotations from the monograph indicate:

'If ... we say that the flow of information in language comprehension runs directly from the determination of the phonetic structure of an utterance to the determination of its lexical content, then we are saying that only phonetic information is available to whatever mechanism decides the level of confirmation of perceptual hypotheses about lexical structure ... Such mechanisms are encapsulated with respect to nonphonetic information ...' (p. 69)

That Fodor intends for 'phonetic information' to be interpreted as *acoustically* transduced information is quite clear, both from his categorical perception arguments, and from the explicit distinction he makes between the language module, which for him is acoustically based, and the visual module:

'... to cite the classic case – the computational systems that deal with the perception/production of language appear to have not much in common with, for example, the analysis of color or visual form (or for that matter the analysis of nonspeech auditory signals).' (p. 4)

'The visual system ... knows how to derive distal form from proximal displacement, and the language system knows how to infer the speaker's communicative intentions from his phonetic productions.' (p. 4)

The present discussion highlights a certain incoherence in the view of cognitive organization proposed in *Modularity*. The set of input systems is claimed to contain the perceptual systems, and language. As mentioned earlier, Fodor himself acknowledges that there is a certain asymmetry here, an asymmetry that has been criticized by other writers (e.g., Arbib 1987). However, the asymmetry is implied to be mainly in the 'size' of the language module vis-à-vis that of the perceptual systems, i.e., the language module is 'bigger' in terms of the amount and variety of information it processes.

As the previous section suggests, however, the problem appears to extend beyond asymmetry. The language module, as it is described in *Modularity*, just happens to encompass one of the perceptual systems (or part of it), namely, audition. In the absence of any discussion about the particular relationship holding between the auditory module and the language module, the overall cognitive picture is rendered incoherent. The theory offers no principled way to predict which input system may encompass which other input systems (or parts thereof). Can vision encompass audition? Can audition include language, instead of the other way around? Consideration of sign language is helpful in placing this theoretical problem in high relief.

4.2.3. Horizontal/vertical-upwards/vertical-downwards interaction

Examination of certain aspects of the grammatical structure of ASL suggests that there is a type of ongoing interaction between the language system and the visual system, and between the visual system and central systems, that appears to violate informational encapsulation.

Although, as we have seen, ASL has very little linear affixation, the language does have a wealth of morphological processes (see for example Fischer and Gough 1978, Newport and Supalla 1978, Klima and Bellugi 1979, Padden 1983, Padden and Perlmutter 1987, Sandler 1989). These are for the most part nonlinear, and are often described as 'spatial'. The verb agreement described in section 2 for the sign GIVE is one of many possible examples of how space is used in the grammatical processes of the language: verb argument referents are established in the signing space, and the hands move toward or away from these spatial points to express verb agreement.

In many cases, what is referred to as spatial grammar in sign language exemplifies a type of interaction with both visual and central processes that is arguably unencapsulated in a way that is unique to sign languages. If referents for agreeing verbs such as GIVE are present in the vicinity of the discourse, then agreement markers are directed toward their real-world locations. Similarly, if referents for locative verbs (Padden 1983), such as PUT, are present, then agreement markers are located at (or toward) their referents' real-world locations. However, it can happen that these real-world referents are not stationary. If, for example, the second person referent of an agreeing verb (the addressee in the conversation) were moving around the room during the conversation, say, painting the walls, the agreement marker for second person could have many different formal instantiations, even in the same sentence.

Note also that these markers are not predictable by the grammar, but can only be determined by on-line processing of unpredictable, non-linguistic, visually perceived information. The type of visual information involved is itself arguably at a high level of processing: it requires volitional tracking of a particular figure with an established identity as it moves.[11] That this tracking is volitional, on-line, and motivated by a search for the real-world referent of a participant in the discourse indicates a constant flow of information between the visual module and central processes. While the degree to which this visual tracking process is in fact volitional has yet to be satisfactorily demonstrated, it seems fair to suggest at this point that it is not automatic and mandatory in the same sense as, say, categorical perception of speech sounds is. If this reasoning is correct, then such agreement processes are not easily dismissed as low-level cross-modal linkages.

Such processes as verb agreement also involve constant on-line communication between the visual module and the language module, as the latter must

[11] Thanks to Ruth Kimchi for useful discussion of visual perception. The conclusions I have drawn from this discussion are my responsibility alone.

adapt its agreement marking accordingly. Therefore, it appears that the language module leaks with respect to a separate module, vision, and that at the same time and in order to subserve the same linguistic function, vision must have access to central processes.

This apparently universal property of sign languages has no counterpart in spoken languages. It constitutes a type of interaction both with the visual system and with the central systems which, I suggest, violates the principal of informational encapsulation, horizontally, and vertically (upwards).

4.3. Innateness and hardwiring

Modules are claimed to be innate and hardwired. Research in sign language and deafness is revealing for these proposed properties as well. Helen Neville and her associates have made some interesting discoveries about brain activity in hearing and deaf people which make it more difficult to assert these claims unequivocally. By measuring ERPs, Neville and Lawson (1987) show that hearing and congenitally deaf subjects have different patterns of brain activity when perceiving visual stimuli projected to the periphery of the visual field. In particular, deaf subjects show far more activity in the left temporal and parietal cortex than do hearing subjects for peripheral, but not foveal, visual stimuli. What is remarkable about this finding is that these cortical areas subserve *auditory* functions in hearing people.

The researchers' interpretation of these findings is two-pronged. First, they suggest that the areas of cortex under discussion are responsive to both visual and auditory stimuli in neonates, and become more specialized for auditory processing with auditory experience. In the absence of such stimuli, in congenitally deaf people, there is 'an increased visual responsiveness in these areas due to lack of competition from auditory input' (p. 280).

Second, they suggest that the particular experience that accounts for this behavior with peripheral stimuli, and not with stimuli presented to the center of the visual field, is perception of sign language. When perceiving sign language, signers focus their gaze on the face (Siple 1978). This places most of the linguistic information, that which is actually signed, in the visual periphery. In the absence of auditory input, the authors argue, auditory cortical areas are marshalled for processing the rapid, temporally structured, visual information of sign language.

Under Neville and Lawson's interpretation, their results are evidence in favor of a role for language *experience* in fixing at least part of the neural architecture. To extend this claim in the same spirit, one might hypothesize that in hearing people, it is exposure to spoken language in particular that claims the same cortical areas for auditory input. On this interpretation, the findings challenge absolute and unqualified claims about hardwiring and innateness of modular systems. In particular, it appears that neither the visual nor the auditory module can be seen as hardwired and innate in the light of Neville and Lawson's findings. If it can be shown that the same neural structures are active in processing sign language, as the authors' interpretation suggests, then these findings would present more problems for the modularity hypothesis. That is, if the same neural structure were shown to control low-level nonlinguistic as well as linguistic visual stimuli, then the requirements of fixed neural architecture, informational encapsulation, and domain specificity would all be challenged.

4.4. Summary

In this section, I have argued that the existence of sign languages makes the *Modularity* language module untenable. Sign language violates domain specificity, since it involves different physical domains and, in certain cases, different computational/representational domains than does spoken language. It violates informational encapsulation vertically, with respect to transducers. Sign language also violates informational encapsulation horizontally, by interacting with the visual module. It is also suggested that the visual module violates informational encapsulation vertically upwards, by tapping central processes, and that this 'communication' interacts in turn with explicitly linguistic encoding. Finally, research with congenitally deaf signers indicates that linguistic input may influence neurological function with respect to nonlinguistic stimuli, and that this connection between function and neurological structure is neither innate nor hardwired in an absolute sense.

5. Conclusions and strategies for future research

These arguments strongly suggest that Fodor's language module hypothesis is not compatible with the existence of sign language. Yet it has also been demonstrated that there are very significant formal similarities between spoken and signed languages at the physiologically linked level of phonology. Therefore, it seems ill-advised to suggest that spoken and signed languages represent two distinct cognitive systems. But, having said all this, we must ask, what sort of research strategy holds the most promise?

One possibility is to assert that there is a Fodorian language module, but sign language is outside it. This would be a very unenlightening position to take, since there are significant structural, functional and even neurological arguments for considering spoken and signed language to belong in some yet-to-be-defined way to the same cognitive system. Worse, the coincidental existence of a full, natural language system with formal similarity to spoken language, outside the language module, would weaken the concept of a language module to the point of vacuousness.

On the other hand, if sign language is included in Fodor's language module, this would necessarily be at the expense of other crucial properties claimed to characterize modules, as we have seen. The inclusion of sign language, then, would have the effect of making the definition of a language module tautological and therefore meaningless: 'The language module is anything that includes language'.

Another possible way of upholding the existence of a language module should be considered. This view is agnostic with respect to physical perception and of translation of physical signals into linguistic form. Therefore, it would have no problem with physical stimulus domains. The principal requirement of the language module, in this view, is that grammatical forms, constraints, and rules – what I have been calling representations and operations or computations – be unique to the module. This is essentially the view put forward by Chomsky (1980), who writes, '... there is good reason to suppose that the functioning of the language faculty is guided by special principles specific to the domain' (p. 44). A significant body of these principles is believed by Chomsky to be innate, but he makes no specific claims about their relation to the physiology of the organism.

It is important to notice first of all that this is not the same kind of module as that proposed by Fodor. The language module under the alternative thesis, call it the Grammatical Form Module (GFM), has less potential explanatory power than the Fodorian module, precisely because it makes no claims about the relation between computational/representational and physiological properties of the language module. Any modularity thesis claiming hardwiring and innateness ought to be concerned with those characteristics that could perspicuously reflect such properties, such as stimulus domain specificity and informational encapsulation. Chomsky recognizes the potential value of discovering the relationship between the computational and the physical domains, and asks:

'To what extent does the organization of sound properly belong to the system of language

> rather than to other systems? Here there are real and significant empirical questions concerning perceptual categorization and its possible special relation to language. Studying the interaction between the perceptual system and the system of language, with particular attention to possible specialization for language, we can hope to refine our understanding of the representation of form provided by the grammar, and thus of the rules that enter into determining this representation.' (1980: 61)

However, while the GFM approach does not rule out investigation of perceptual systems, and Chomsky even encourages it, leading research paradigms in linguistics (and in perception for that matter) are in general proceeding quite independently. For example, the GFM approach to linguistic investigation, in contrast with Fodor's theory, has little to say about informational encapsulation vis-à-vis other cognitive systems, either vertical or horizontal. The only evidence so far adduced for a language module in the GFM approach comes from GF itself, and no serious attempt has been made to incorporate lower level processes or to compare the GFM to other cognitive systems. The fact that our advanced linguistic science has uncovered complex and interesting properties in the structure of language in no way precludes the existence of directly analogous structures in other cognitive domains, not matter how unlikely linguists may believe this to be.

This in no way diminishes the importance of a GFM strategy for conducting research on language. It is doubtful that linguists could have made the remarkable progress that they have over the past few decades had they not isolated language from the rest of human cognition in order to study it. Indeed, it is to the credit of formal phonological theory that it is capable of revealing the similarities and differences between signed and spoken language, that we have seen here, in a relatively rigorous way. However, as I have argued, and will further support presently, a GF-only paradigm is not sufficient for fully predicting language universals and for distinguishing them from those of other cognitive systems.

Considering sign language is once again instructive here. Assuming that humans are specialized by evolution for use of spoken language, sign languages represent an adapted system. What, then, might be the principles according to which the mind organizes movement of the hands and movements of the vocal apparatus, each perceived by distinct systems, into *similar* phonological form? And of equal interest to language theorists is the question, What principles of physical or cognitive organization predict the formal *differences* between the two systems at this level? Does the brain 'know' that it is processing language and organize itself accordingly? Or are there some particular properties that characterize language, and, perhaps, other cognitive systems as well, that are responsible for this type of neurological organization? In other words, *how* does the organism adapt itself?

Answers to these questions are not at hand. Yet, a comprehensive theory of language should be able to predict the similarities and the differences between signed and spoken languages. So it is important to determine what sort of research paradigm should be adopted that will facilitate the asking and answering of the right questions. I have argued that the language module paradigm of *Modularity* is ruled out, counterexemplified by sign language. A GF module approach, on the other hand, requires only universal principles of language structure as evidence for a language module, without making any predictions about its relation to biological systems or other cognitive systems. We have seen that there are systematic typological differences between spoken languages and sign language, though none of them fall outside the possible structures and rules available to linguistic theory. With the GF approach, then, important and potentially revealing questions go unasked.

A number of approaches suggest themselves. First, the principal of integrating computational/representational (essentially GF-type) research with explicitly biological investigation, suggested by Fodor's approach, is likely to yield the most convincing results. Consider, for example, the evidence of Neville and Lawson that the same area of cortex is used for processing peripheral visual stimuli in deaf people, and auditory stimuli in hearing people. The authors' explanation is essentially that linguistic input influences neurological specialization, *regardless of modality*. The authors suggest in passing that it is the rapidity and temporally sequential structure of language that is responsible for such specialization. The result of this specialization is not language-modularized, however, since both linguistic and nonlinguistic stimuli are apparently handled by the same cortical area. While such suggestions are speculative and not developed, they raise potentially illuminating research questions.

Second, as this article has attempted to demonstrate, sign language research offers a unique natural laboratory for testing theories of linguistic universals and of cognitive organization. It is of particular interest that we have succeeded here in isolating ways in which sign languages (apparently universally) differ from spoken languages, yet without deviating from the predictions of linguistic theory. This result in itself illustrates that restricting investigation of language to GF and to spoken language is an inadequate research strategy. In addition, it appears that at a given level, there may be more than one type of linguistic operation available, depending on the modality (see discussion in section 3.2). To the extent that organization of phonetic signals (here, I use *phonetic* in a generic, modality-independent sense) into phonological form is a linguistic operation, it is reasonable to assume that sign language uses different, though still linguistic, operations at this level of computation. If this is true, then it presents a challenge to both Fodor's theory and to the GFM view.

In sum, this article has attempted to make three points. (*i*) Fodor's (1983) language module is counterexemplified by the existence of sign languages. (*ii*) Formal, representational linguistic investigation fails to predict systematic differences between natural languages in different modalities, and therefore it alone does not suffice as a comprehensive theory of language. (*iii*) By incorporating in cognitive investigations of language both sign language research and perceptual investigation, we are likely to reach a more comprehensive and adequate theory of language.

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