Iconicity, isomorphism, and non-arbitrary coding in syntax

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Thomas / Givón
University of Oregon

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ISOMORPHISM IN THE GRAMMATICAL CODE: COGNITIVE AND BIOLOGICAL CONSIDERATIONS

T. Givón
Linguistics Department
University of Oregon

1. **Isomorphic vs. arbitrary coding**

The notion that language somehow mirrors thought, and thought, in turn, some external reality, goes back to at least Aristotle. Thus, in *De Interpretatione* one finds:

> "...Now spoken sounds [= words; TG] are symbols of affections of the soul [= thoughts; TG], and written marks are symbols of spoken sounds. And just as written marks are not the same for all men [= are language specific; TG], neither are spoken sounds. But what these are in the first place signs of -- affections of the soul -- are the same for all [= are universal; TG]; and what are these affections are likenesses of -- actual things -- are also the same..."
> Aristotle, *De Interpretatione* (tr. & ed. by J.L. Ackrill, 1963)

Still, we have no evidence that Aristotle's semiotic relation -- either between words and concepts or between concepts and objects -- was meant to be iconic in any but the most trivial sense.**[FN 1]**

The more current notion that the syntax of human language is not arbitrary, but rather is somehow **isomorphic** to its mental designatum, is due to C.S. Peirce, who observed:

> "...In the syntax of every language there are logical icons of the kind that are aided by conventional rules..." C.S. Peirce (1940, p. 106)

As Peirce had already anticipated, the iconicity of syntax is not absolute, but rather <u>tempered</u>. The reference to 'conventional rules' is indeed meant to draw our attention to the interaction between more iconic and more *symbolic* -- i.e. more arbitrary -- principles of syntactic coding.

The suggestion that syntactic structure is substantially iconic and non-arbitrary has been vigorously attacked by structuralists, beginning with Saussure (1915), continuing with Bloomfield (1933) and culminating with Chomsky (1957, 1968). The latter in particular sees language as a human-specific innate faculty, modular and rigidly split from both cognition and pre-human communication. To linguists of this general persuasion, structural **arbitrariness** is the hallmark of human language, in this regard contrasting it with the more iconic nature of animal communication. This is how Chomsky (1968) puts it:

> "...every animal communication system that is known... either consists of a fixed, finite number of signals, each associated with a specific range of behavior... or it makes use of a fixed, finite number of linguistic dimensions, each of which is associated with a particular non-linguistic dimension in such a way that selection of a point along the linguistic dimension determines and signals a point along the associated non-linguistic dimension... When I make an arbitrary statement in human language... I am not selecting a point along some linguistic dimension that signals a corresponding point along an associated non-linguistic dimension..."
>
> N. Chomsky *Language and Mind* (1968, pp. 69-70)

In the last 20 years, a resurgence of interest in the iconicity -- non-arbitrariness -- of syntax has taken place, with studies such as Chafe (1970), Bolinger (1977), Haiman (1980, 1983, 1985a, 1985b ed.), Hopper and Thompson (1980, 1984), Slobin (1985b), Givón (1979a, 1989) and many others. This resurgence has been firmly grounded in the emergent functionalism in linguistics of the past twenty years, after five solid decades of the structuralism. If structure is not arbitrarily wired in, but is there to perform a function, then the structure must in some way reflect -- or be constrained by -- the function it performs. As Jespersen -- an early functionalist throwback -- noted:

> "...The essence of language is human activity -- activity on the part of one individual to make himself understood by another, and activity on the part of that other to understand what was in the mind of the first..."
>
> O. Jespersen, *The Philosophy of Grammar* (1924, p. 17)

And the most obvious non-arbitrary structure-function relation is that of **isomorphism**, where major **nodes** and their **relations** in the coded function are reflected -- more or less one-to-one -- in the corresponding nodes and relations of the coding structure.

In this paper I will first summarize briefly the main iconic principles found in syntax. Next, I will discuss a few representative examples of the phenomenon alluded to by Peirce, where transparent iconic principles and more arbitrary ('symbolic') elements interact in making up syntactic structure. We will then inquire into two aspects of iconicity that are yet to be dealt with systematically in linguistics:

(a) Its cognitive basis; and
(b) its biological antecedence and motivation.

2. **Principles of iconic coding**

2.1. **Preamble**

The most remarkable thing about an entity as complex and multi-dimensional as grammar is how its complexity is built up componentially, from a relatively small number of general, cognitively transparent iconic principles. In each grammatical domain, these principles then combine with more domain-specific -- and seemingly more arbitrary -- structural conventions. But even those arbitrary conventions tends to yield a measure of iconicity -- either by themselves, or when combined with iconic elements in domain-specific context. Again, as C.S. Peirce put it:

> "...Particularly deserving of notice are icons in which the likeness is *aided* by conventional rules..."
> Peirce (1940, p. 105; italics added)

2.2. **The quantity principle**

One finds the footprints of this principle all over the syntactic map, in the assignment of larger segmental size or more prominent intonation to information that is either semantically larger, less predictable, or more important. This principle may be given as:

(1) **The quantity principle**:
(a) "A larger chunk of information will be given a larger chunk of code".
(b) "Less predictable information will be given more coding material".
(c) "More important information will be given more coding material".

Principle (1a) is reflected in the larger size of, and more prominent stress on, lexical words, as against grammatical morphemes. For example, 'have' as a <u>main verb</u> in (2a) below is stressed and unreduced. When used as the <u>perfect</u> grammatical marker, as in (2b,c), it is unstressed and contracted:

(2) a. I *have* two books
b. I'*ve* got two books
c. I'*ve* read two books

Principle (1a) is also reflected in the larger size of derived lexical words as against un-derived ones:

(3) a. act ===> act-*ive* ===> act-iv-ate ===> act-iv-at-ion

It is also reflected, perhaps somewhat trivially, in the fact that multi-event descriptions tend to be longer that single-event descriptions:

(4) a. He slept.
b. He slept, then got up.
c. He slept, got up and took a shower.

Principle (1b) is reflected in the size (and stress) gradient:

(5) FULL-NP >
INDEPENDENT PRONOUN >
UNSTRESSED PRONOUN >
ZERO ANAPHORS

as in:

(5') a. Once there was <u>A wizard</u>. <u>He</u> lived in Africa.
<u>He</u> went to China to [<u>∅</u>] get a lamp. <u>The wizard</u>...
b. Joe told Bill and then [<u>∅</u>] Sally.
c. Joe told Bill, then <u>he</u> told Sally.
d. Joe told Bill, then **HE** told Sally.

Principle (1b) is also reflected in the more prominent stress on contrastive, contrary or counter-unexpected information, as in:

(6) a. ...I saw Bill leave, and then Sally...
b. I saw **BILL** leave, not John!

It is also reflected in the deletion under identity of the co-referent NPs in verb complements (7a), REL-clauses (7b), participial ADV-clauses (7c) and chain-medial clauses (7d), as in, respectively:

(7) a. Mary wanted *to [∅] leave*
b. The house *that Jack built [∅]*
c. *[∅] Stepping into the room*, she paused.
d. Mary paused, *[∅] looked around and [∅] froze*.

Principle (16c) is reflected in the deletion of the less-topical agent-of-passive and patient-of-anti-passive, as in:

(8) a. **Active**: John drank the beer in a hurry
b. **Passive**: The beer was drunk in a hurry
c. **Antipassive**: John drinks [<u>∅</u>] a lot

The cognitive basis of the quantity principle must be sought in the areas of **attention** and **mental effort** (Posner and Warren, 1972; Posner and Snyder, 1974; Schneider and Shiffrin, 1977), as well as **priority assignment** (Schneider, 1985). Haiman (1983, 1985a), following Zipf (1935), labels this 'economic motivation'. But since economy of mental processing is presumably a constraint on <u>all</u> mental operations, it is not clear that the designation of economy here is specific enough. And the relevant notion of economy must be cognitive, i.e. **processing time** and the **cognitive complexity** or **mental effort**.

Principle (1) does not, by itself, create an **iconic topographic map** of a word, a sentence or a chunk of discourse, like the retinal or cullicular visual maps (see further below). It is nonetheless reflected in the preservation of **spatial proportion** in such maps, whereby larger objects command larger map-space in the retinal (and its derivative brain-maps) than smaller objects.

2.3. **The proximity principle**

This is again a widely-attested principle of syntactic organization, noted earlier by Behaghel (1932) and Bolinger and Gerstman (1958). It may be given as:

(9) **The proximity principle**:

(a) "Entities that are closer together functionally/conceptually/cognitively will be placed closer together at the code level, i.e. temporally or spatially".

(b) "Functional operators will be placed closest, temporally or spatially at the code level, to the conceptual unit to which they are most relevant".

Principle (9a) is reflected in the degree of integration of complement clauses with their main clauses, as in:

(10) a. She *let-go* of him
b. She *let* him *go*
c. She *wanted* him to *go*
d. She *wished* that he would *go*
e. She *forgot* that he had *gone*
f. She *said*: "He's *gone*".

Principle (9a) is also reflected in the tight rhythmic packaging of clauses under a single intonational contour, as against the high frequency of inter-clausal pauses (Eisler-Goldman, 1968; Chafe, 1987; Givón, 1988b/1990). Thus consider:

(11) **Construed as separate events**:
a. She talked to Bill, then to Sally, then to Joe...
b. She came over, then she sat down...
Construed as a single event:
c. She talked to Bill, Joe and Sally...
d. She came 'n sat down...

It is also reflected in the strong correlation between period punctuation and disruptive inter-clausal coherence , as against comma or zero punctuation and continuative coherence (Hayashi, 1989), as in:

(12) a. She came in 'n talked to me...
b. She came in, and she talked to me...
c. She came in. Later on, she talked to me.

It is also reflected in the general tendency to keep restrictive modifiers near their head nouns, and place the noun phrase under a unified intonational contour, as in:

(13) a. the *red* horse...
b. *the *red*, horse...
c. the man *I met*...
d. *the man, *I met*...

It is also reflected in the strong tendency to give non-restrictive REL-clauses (and parenthetical clauses) their own separate intonational contour, but to package restrictive REL-clauses under the same intonation contour with the head noun, as in:

(14) a. You know the guy *I'm talking about*
b. *You know the guy, *I'm talking about*
c. The man, *whom I met a while back*, is a crook
d. The man *I met* is a crook
e. *The man is a crook, *I met*
f. The man is a crook, *the one I met*

Principle (9b) is reflected in the general tendency to keep grammatical <u>operators</u> near their <u>operands</u>. That is, to place grammatical (and derivational) morphemes that are conceptually relevant to the noun (case-markers, determiners, classifiers, pluralizers) near the noun or cliticized to it; to let operators that are conceptually relevant to the verb cluster near the verb or cliticize on it; and to place operators that are conceptually relevant to inter-clausal coherence between the clauses (Hopper and Thompson, 1984; Bybee, 1985; Slobin, 1985b), as in:

(15) a. Child-*ren* are clever
b. *Children are-*ren* clever
c. She was looking for some act-*ion*
d. *She was looking for some-*ion* act
e. He went *to*-work early
f. *He *to*-went work early
g. She work-*ed* late
h. *She-*ed* work late
i. She sat *and* he stood up
j. *She sat he stood up *and*

It is also reflected in the placement of focused negation markers, contrastive focus markers and focused question markers near (or cliticized to) the word they focus, as in:

(16) a. *It's* **JOHN** that I'm looking for
b. ***JOHN** that I'm *it's* looking for
c. *Only* **JOHN** met Mary
d. John *only* **MET** Mary
e. John met *only* **MARY**

Principle (9b) is also reflected in the use of relative proximity of grammatical morphemes to the stem to indicated conceptual **scope** relations, as in the ordering of tense-aspect-modality morphemes (Givón, 1982) or other verbal categories (Bybee, 1985). Thus consider:

(17) a. **Verb scope**: I <u>am</u> working
b. **Proposition scope**: I <u>may</u> work
c. I <u>may</u> <u>be</u> working
d. *I <u>am</u> <u>may</u> work

The cognitive basis of principle (9) is fairly transparent. The temporal code-contiguity of conceptually-contiguous or conceptually relevant mental entities reflects the general requirements of **associative memory**, **spreading activation** and **priming**.[FN 2] One cannot for the moment guarantee that conceptually-closer mental entities are stored at contiguous <u>locations</u> in the brain. However, if the activation of a concept indeed primes the activation of closely related concepts, then to code related concepts at <u>contiguous times</u> would in fact guarantee faster processing, given associative memory and priming. We will return to this issue further below.

2.4. **Sequential order principles**

There are at least two separate principles of natural sequential order used extensively in syntax. The first one is <u>semantic</u> and transparently iconic. It may be given as (cf. Haiman, 1980):

(18) **Semantic principle of linear order**:
"The order of clauses in coherent discourse will tend to correspond to the temporal order of the occurrence of the depicted events".

Principle (18) is reflected in the strong tendency to order clauses in connected discourse according to the temporal sequence of events. Thus consider:

(19) a. He opened the door, came in, sat and ate.
b. *He sat, came in, ate and opened the door.

It is also reflected in the strong statistical tendency to place *cause* clauses before their paired effect clauses, and *condition* clauses before their paired *entailment* clauses (Greenberg, 1966b; Haiman, 1978). That is:

(20) a. **Likely**: He shot and killed her
b. **Unlikely**: *He killed and shot her
c. **Frequent**: She shot him, and he died.
d. **Infrequent**: He died. She had shot her.
e. **Frequent**: After she shot him, he died.
f. **Infrequent**: He died after she shot him.
g. **Frequent**: If he comes, we'll do it.
h. **Infrequent**: We'll do it if he comes.

Principle (18) It is also reflected in the placement of the terminative-perfect morpheme derived from 'finish' after the verb in many languages that otherwise place tense-aspect-modal morphemes before the verb.**[FN 3]** This can be illustrated by data from Krio, an English-based Pidgin:

(21) a. **Durative**:
dis man-yaso **de**-wok
DEF man-TOP **DUR**-work
'The man is working'

b. **Future**:
dis man-yaso **go**-wok
DEF man-TOP **FUT**-work
'The man will work'

c. **Perfect-i**:
dis man-yaso **bin**-wok
DEF man-TOP **PERF**-work
'The man had worked'

d. **Perfect-ii**:
dis man-yaso **bin**-wok-**dọn**
DEF man-TOP **PERF**-work-**TERMIN**
'The man had already finished working'

Principle (18) is presumably motivated by the same cognitive factors that motivate the **proximity principle** (9), namely that it is easier to **associated** mental entities that should be closely associated if they are coded in close temporal (and spatial?) proximity.

The second sequential order principle involves the pragmatic use of word-order to indicate the topicality of referents -- either in terms of importance or in terms of accessibility. This principle may be given as:**[FN 4]**

(22) **Sequential order and topicality**:
"More *important* or more *urgent* information tends to be placed first in the string".

The use of principle (22) is reflected in the clause-initial placement of *important* full-NP referents in languages with flexible word-order (Payne, 1985; Givón, 1988a). It is also reflected in the clause-initial placement of contrastive topics, cleft-focused topics, L-dislocated topics and WH-questioned constituents, as in, respectively**:**

(23) a. **Neutral**: John milked the goat.
b. **Contrast**: He milks the cow, but the **GOAT** he wouldn't milk.
c. **Focus**: It's the **GOAT** that John milked.
d. **L-dislocation**: The *goat*, John milked it.
e. **WH-question**: **WHAT** did John milk?

3. **Combining iconic and conventional ('symbolic') elements**

3.1. **Preamble**

As C.S. Peirce (1940) has suggested, syntax is a composite device in which more iconic -- cognitively transparent -- elements combine with more symbolic -- cognitively arbitrary -- ones, to yield complex structure. Somewhat paradoxically, the combination does not detract from the overall iconicity of grammar. Rather, it reinforces it. In this section I will briefly recapitulate two examples of this paradox in the syntax of complex clauses. As we shall see later on, the combination of more iconic and more arbitrary elements within a single complex code pre-dates human language.

3.2. **Verb complements**

The so-called *binding scale* in complementation (Givón, 1980;2001, ch. 12) codes syntactically the degree of semantic integration of two simple events into a single complex events. The scale is re-capitulated in a somewhat condensed form below.

(24) **The binding scale of event integration**:

MOST INTEGRATED

	Semantic scale of main verbs	**syntax of complement**
M	a. She *let go* of the knife	CO-LEXICALIZED
A	-------------------	
N	b. She *made* him *shave*	BARE-STEM COMP
I	--------------------	
P	c. She *caused* him *to leave*	INFINITIVE COMP
U	d. She *told* him to *leave*	
L	e. She *wanted* him *to leave*	
	--------------------	
	f. She *wished* that he *would leave*	SUBJUNCTIVE COMP
	g. She *agreed* that he *should leave*	
C	--------------------	
O	h. She *knew* that he *left*	INDIR. QUOTE COMP.
G	i. She *said* that he *left*	
N	--------------------	
	j. She *said*: "He *might leave* later"	DIR. QUOTE COMP.

LEAST INTEGRATED

At the code level, four devices are used together to code the degree of syntactic integration of complement clauses into their main clauses. Two of them are transparently iconic, having to do with the degree of spatial-temporal separation of the main and complement clauses, i.e. our **proximity principle** (9a):

(25) **Co-lexicalization and event integration**:
"The more integrated the two events are, the more likely is the complement verb to be co-lexicalized--i.e. appear contiguously--with the main verb".

(26) **Subordinating morphemes and event integration**:
"The less integrated the two events are, the more likely it is that a subordinating morpheme will separate the complement clause from the main clause".

The two other coding devices are much less iconic. Their naturalness is in large measure **norm-dependent**, deriving from **grammatical conventions**. They are:

(27) **Subject case-marking and event integration**:
"The more integrated the two events are, the less likely is the subject-agent of the complement to receive the case-marking most characteristic of a subject-agent of main clauses; with the scale of prototypicality of main- clause subject being:
(i) AGT > DAT > PAT > OTHERS
(ii) SUBJ > DO > OBLIQUE"

(28) **Finite verb-form and event integration**:
"The more integrated the two events are, the less main-clause like-- finite-- will the morphology of the complement verb be; with the scale of finite- ness of prototype main-clauses being:
FINITE > SUBJUNCTIVE > INFINITIVE > NOMINAL > BARE STEM

The norms upon which principles (27, 28) depend are themselves motivated by clear cognitive, communicative and socio-cultural considerations. Thus, by conceding that the principles are norm-dependent, one need not ignore the non-arbitrary nature of the norms themselves.

The remarkable thing about the integrated syntactic scale that code the continuum of event integration in (24), however, is the fact that the use of the transparently iconic principles (25), (26) and norm-dependent principles (27), (28) is **intermingled**. The result is a unified syntactic scale of clause integration that now mirrors isomorphically the unified semantic-cognitive scale of event integration.

3.3. **Passives**

The treatment of the agent in passive or de-transitive clauses in some way reflects its "fall from grace" as the erstwhile primary topic of the prototype active-transitive clause. The scale of degree of "demotion" of the agent may be recapitulated as follows:

(29) **The scale of de-transitivization**:

MOST TOPICAL AGENT

construction	**example**
a. **Active**:	The woman shot the deer
b. **Inverse**:	The deer, the woman shot it
c. **Agented passive**:	The deer was shot by the woman
d. **Passive**:	The deer was shot

LEAST TOPICAL AGENT

The syntactic scale in (29) reflects the use of two iconic principles discussed earlier above. The **pragmatic order** principle (22b) is pressed into service in constructions (29b,c,d), where the more topical patient occupies the clause-initial position, and the less topical agent the clause-final position in (29c). The **quantity principle** (1c) is pressed into service in the passive (29d), where the non-topical agent is deleted altogether. In addition, all across the continuum, a more norm-dependent **case-marking scale** is reflected, one similar to that in (27). In (29a) and (29b) the agent is coded as a subject/agent of the prototype active clause; in (29c) it is coded as an oblique. Similarly, the patient in (29a) is coded as direct-object; in (29b) it is double-coded as both topic and object; and in (29c,d) it is coded as subject. Once again, the use of more iconic principles is interspersed with the use of norm-dependent conventions, to yield a unified complex scale, in this case one that reflects isomorphically the degree of topicality of agent and patient.

4. **The biological basis of iconic codes**

4.1. **Functionalism and iconicity in biology**

Biology has been a profoundly functionalist discipline ever since Aristotle dislodged, more or less single-handedly, the two structuralist schools that had dominated Greek biological thought since the pre-Socratics. Both earlier schools sought to understand live organisms componentially, much like inorganic matter. Empedocles proposed to explain organisms by their component *elements*. Democritus opted for explaining organisms through their component parts and structure.

In his *De Partibus Animalium*, Aristotle first argues against Empedocles, pointing out the relevance of *histological* and *anatomical* structure:

> "...But if men and animals are natural phenomena, then natural philosophers must take into consideration not merely the ultimate substances of which they are made, but also flesh, bone, blood and all the other homogeneous parts; not only these but also the heterogenous parts, such as face, hand, foot..." (*De Partibus Animalium*, McKeon, ed., 1941, p. 647)

He next notes the inadequacy of Democritan structuralism:

> "...Does, then, configuration and color constitute the essence of the various animals and their several parts?... No hand of bronze or wood or constituted in any but the appropriate way can possibly be a hand in more than a name. For like a physician in a painting, or like a flute in a sculpture, it will be unable to do *the office* [i.e. 'function'] which that name implies..." (ibid., p. 647; italics added)

Next, he offers a **teleological** interpretation of living things, using the analogy of usable artifacts:

"...What, however, I would ask, are the forces by which the hand or the body was fashioned into its shape? The woodcarver will perhaps say, by the axe and auger; the physiologist, by air and earth. Of these two answers, the artificer's is the better, but it is nevertheless insufficient. For it is not enough for him to say that by the stroke of his tool this part was formed into a concavity, that into a flat surface; but he must state *the reasons* why he struck his blow in such a way as to affect this, and what his final *object* was..." (*ibid.,* pp. 647-648; italics added)

Finally, he outlines the governing principle of both functionalism (and iconicity) -- **form-function correlation**:

"...if a piece of wood is to be split with an axe, the axe must of necessity be hard; and, if hard, it must of necessity be made of bronze or iron. Now exactly in the same way the body, which like the axe is *an instrument*-- for both the body as a whole and its several parts individually have definite operations *for which* they are made; just in the same way, I say, the body if it is to do its *work* [i.e. 'function'], must of necessity be of such and such character..." (*ibid*., p. 650; italics added)

Ever since Aristotle, structuralism -- the idea that structure is either arbitrary or explains itself -- has been a dead issue in biology. In the early 20th Century, however, it somehow reemerged in the nascent social sciences. To these infant disciplines, philosophers of science sold the analogy of physics, dismissing the post-Darwin functionalism of Radcliffe-Brown and Malinowski as crude anthropomorphism, or at best a heuristic.**[FN 5]**

Common-sensical functionalism is still taken for granted in biology, like mother's milk. As one contemporary introductory textbook puts it:

"...anatomy is the science that deals with the structure of the body... physiology is defined as the science of function. Anatomy and physiology have more meaning when studied together..." (Crouch, 1978, pp. 9-10)

In sounding out the major themes in the study of organisms, Eckert and Randall (1978) write in their introduction to animal physiology:

"...The movement of an animal during locomotion depends on the structure of muscles and skeletal elements (e.g. bones). The movement produced by a contracting muscle depends on how it is attached to these elements and how they articulate with each other. In such a relatively familiar example, the relation between structure and function is obvious. The dependence of function on structure becomes more subtle, but no less real, as we direct our attention to the lower levels of organization -- tissue, cell, organelle, and so on... The principle that *structure is the basis of function* applies to biochemical events as well. The interaction of an enzyme with its substrates, for example, depends on the configuration and

> electron distributions of the interacting molecules. Changing the shape of an enzyme molecule (i.e. denaturing it) by heating it above 40 C is generally sufficient to render it biologically nonfunctional *by altering its shape*..." (1978, pp. 2-3; italics added)

The critical element that makes something a biological code -- in Peirce's words "...something by knowing of which we know something more..." -- is the presence of some **teleology**, **purpose**, or **function**. What is more, the notion 'function' is the sine qua non of the definition of 'biological organism', but has no rational sense whatever in the pre-organic universe.

In this section I will outline, somewhat tentatively, some of the reasons why one must consider the pervasive iconicity of human language merely the latest manifestation of a pervasive preference for isomorphic coding in bio-organisms. Further, the iconicity of biological codes simply reflect the fact that biological design is function-based, and biological evolution is inherently adaptive, or function-guided.**[FN 6]** To illustrate the long antecedence of isomorphic coding in biology, I will cite a number of examples that range over almost the entire range of biological evolution.

4.2. **Chemical iconism: The genetic code**

One of the oldest instances biological coding, dating all the way back to the protozoan dawn of life, is the isomorphic match between the sequence of *nucleotide triplets* in the DNA or RNA, and the sequence of *amino acids* in protein. The DNA code is transmitted out of the nucleus by an isomorphic nuclear polymer, messenger RNA, whose triplet sequence is then translated isomorphically into the sequence of amino acids in protein. Proteins of specific linear sequence **[FN 7]** make up the various enzymes, immuno-proteins, and other active agents in the cell.

The DNA genetic code, however, consists of more than just a linear sequence of nucleotide triplets. Some positions on the chain do not translate directly into the linear structure of RNA or protein. Rather, perform various more global meta-functions, such as processing instructions, blocking, deletion, splicing, recombining etc. While nominally a linear chain, DNA is in fact a **rhythmic-hierarchic** coding structure. More general controlling loci match their respective functions in a less iconic, more abstract fashion.**[FN 8]** But at least at the lower levels of the hierarchy, controlling loci govern contiguous sub-sequences of the linear code.**[FN 9]**

The mix of iconic and abstract elements in a complex code, so characteristic of grammar, is thus already attested in the cell's chemical code. The rise of more abstract coding and rhythmic-hierarchic structure is common to both. This rather ubiquitous feature of biological codes is probably an adaptive response to the very same inherent limitation -- the *paucity* of iconic coding dimensions. As the functional complexity of a biological domain increases, the code-level presses into service less isomorphic, more abstract dimensions. This gives rise to unified but complex codes, which in a sense mirrors unified but complex functions -- and organism.

4.3. **The tonotopic map of pitch**

The pitch of a sound wave is a scale of vibration frequency were perceived 'higher' notes are produced by higher frequency of vibration, and 'lower' notes by lower. In the auditory cortex of the brain, this frequency scale is represented isomorphically, by the so-called **tonotopic map** along a single spatial-linear dimension.**[FN 10]**

4.4. **Cognitive iconism: The brain's spatial maps**

In the neurological coding of visual, auditory or tactile sensory input pertaining to the representation of objects in three-dimensional physical space, one finds recurrent, and evolutionarily separate, instances of iconic representation. Such iconicity begins in the camera-like **retina**. Perhaps by default, the retinal iconic map is transferred intact through the optic nerve into the brain.

4.4.1. **Spatial auditory maps in barn owls**

In the barn owl, the visual spatial map is located in the *superior culliculus* (or <u>optic tectum</u>), an old brain-stem (mid-brain) structure. The representation of *auditory* spatial information is found in the *inferior culliculus*. Auditory input is transmitted from the ear through three separate channels, each responsible for one spatial dimension. At the lower layer of the inferior culliculus, the three dimensions are coded at separate locations--i.e. *non-iconically*. But in the next layer, closer to the visual-iconic map, the three dimensions are integrated into an iconic auditory-spatial map. And in the next layer, adjacent to the visual map, spatial information from *both* sensory modes is represented jointly -- in a *bi-modal* iconic map. in an area that is closer to the *superior culliculus'* visual iconic map.**[FN 11]** This arrangement may be represented, somewhat schematically, as:

(30) **Location of the spatial representation**
in the Owl Barn's culliculus [FN 12]
(from Takahashi, 1989)

There is strong evidence suggesting that the construction of the iconic auditory spatial map in the mid-brain of neonate owls is trained by the *visual* iconic representation system in the *superior culliculus*.**[FN 13]** This can also be inferred from the pattern spatial contiguity within the *culliculus* -- visual-iconic next to bi-modal-iconic, next to auditory-iconic, next to auditory-non-iconic. It may also be inferred that the retina-guided ('default') visual iconic map in the *superior culliculus* is also *phylogenetically* responsible for the rise of the *auditory* iconic spatial map -- from information that is originally transmitted in a non-iconic fashion.**[FN 14]** The adaptive advantage of iconic mapping is thus underscored here by the iconic re-translation of spatial information derived originally from a non-iconic modality.

4.4.2. **Spatial-tactile maps in mice**

Another iconic spatial map, this time assembled from tactile input, is found in the brain of the mouse, where each whisker around the snout is coded by a specific brain location. The brain locations, in turn, represent iconically the spatial pattern of the whiskers.**[FN 15]**

4.4.3. **Primate visual maps**

In primates, the iconic mapping of visual-spatial information, originally in the superior culliculus, has been augmented by another, equally iconic, spatial map in the striated cortex, part of the posterior new brain. This new representation, in a different brain structure, is still iconic.**[FN 16]** But further, at least seventeen visual information locations in the cortex are involved in the representation of spatial information that arrived first at area 17 of the striated cortex. All of them, in spite considerable degradation, are iconic maps or two-dimensional space.**[FN 18]**

4.4.4. **Why should neural mapping be iconic?**

The recurrence of iconic neural coding of space, in different neural structures (retina, superior culliculus, inferior culliculus, striated cortex, other cortical regions), at different evolutionary stages (fish, amphibian, reptile, avian, mouse, primate), and out of different sensory modalities (auditory, visual, tactile) could hardly be a biological accident. This is especially true in the case of the owl's auditory map, where the three dimensions come in on separate channels, then reassembled into an iconic map. The phylogenetic template for such recombination may have been the old retina-guided visual map. But still, what processing advantage is derived from such recombination?

The most obvious answer, I believe, has to do with the use of **temporal contiguity** -- or **co-temporal activation** -- to represent the **spatial contiguity** of objects in perceived space. When the parts of an object are coded contiguously in an iconic spatial neural map, it may be easier to insure that the impulses transmitted from those locations will be experienced **co-temporally**. If, on the other hand, the various parts of an object were represented at non-contiguous brain locations, provisions for co-temporal experience of the parts may be much harder to institute. The co-temporal experience of an object is thus a prerequisite for construing it as **spatially compact**.

What we find here, in essence, is one more manifestation of our proximity principle (9), noted earlier above in the syntactic code. In this connection, Kaas' (1989) observations are compatible with this interpretation:**[FN 18]**

> "...One implication [of spatial-iconic maps; TG] is that selection for *correlated activity* [i.e. co-temporal information; TG] would tend to create and preserve retinotopic and visuotopic organization... Neurons in the same retinal location are likely to *fire together*, both initially and because they are likely to interrelated by local, perhaps initially random, interconnections, and later in development because they have a higher probability of being activated together by the same stimuli..." (1989, p. 129; italics added).

4.5. **Communicative iconism: The coding of aggression and submission**

Chomsky (1968) suggested, probably erroneously, that iconic coding in communication is characteristic only of animal but not human communication.:

> "...the selection of a point along a linguistic dimension determines and signals a certain point along an associated non-linguistic dimension..." (1968, pp. 69-70)

In this section I will briefly suggest why in fact the converse is true. That is, pre-human communication had already incorporates more arbitrary symbolic conventions into its iconic-scalar codes. As an illustration, consider first the coding of dominance and subordination in Bonnet Macaques (after Simonds, 1974):

(31) **Dominant-subordinate coding scale in Bonnet Macaques**:

	6 Attack
	5 Lunge
dominant	4 Open-mouth threat
signals	3 Eyelid threat
	2 Stare
	l Look
	1 Lip-smack slowly
	2 Lip-smack rapidly
subordinate	3 Grimace
signals	4 Grimace widely
	5 Grimace and present
	6 Run off, grimace and tail-whip

On the dominant portion of the scale, an increase in code intensity is seen from points 1 to 2 to 3, coded by increased eye-signal intensity. This reflects our iconic **quantity principle** (1c). On the other hand, the transition from 3 to 4 involves switching to another code modality, the open mouth. And while that escalation is natural and obvious, the integration of eye-signal and mouth-signal into the same scale involves an increase in the arbitrariness of code -- thus a more symbolic representation.

A similar mix of naturalness and arbitrariness can be seen when one compares the coding of aggression and submission in dogs and horses. Dogs broadcast aggression by raising their head and propping their ears *up and forward*. Horses broadcast aggression by lowering their head and flattening their ears *down and back*. Both display a similar **quantity scale** in coding the degree of aggression. In horses, this scale is roughly as follows:**[FN 19]**

(32) **Scale of aggression code in mares**:

weakest signal

======================

a. flattened/lower ears
b. (a) + lowered head
c. (b) + back turned to target
d. (c) + rear-legs kick
e. (d) + repeated (e)

=======================

strongest signal

+

The explanation of the seeming arbitrariness in ear positions may be now clarified: Dogs attack by biting, and signal aggression by raising their head and chest to create a maximally threatening frontal *image* --enhanced by the propped-up ears and raised hair. Mares attack by turning their back and hind-kicking, whereby the head is automatically lowered and extended forward -- which results in an automatic flattening of the ears. In both cases, the primary attributes of aggressive behavior are discarded when mere behavior becomes a **communicative signal**. While behavior facets that were incidental, automatic or the secondary are retained as the new -- now symbolic -- code. But now they are devoid of their original rationale. As mere behavior becomes more systematically communicative, the arbitrariness of the code increases.

5. **Markedness as meta-iconicity**

From a functional perspective, the notion of markedness in grammar entails a systematic relation between <u>structural</u> and <u>cognitive</u> complexity, i.e. the tacit traditional assumption that:

(33) **The meta-iconic markedness principle**:
"Categories that are *cognitively* marked--i.e. complex--tend to also be *structurally* marked".

Principle (33) is of course reflected in the traditional belief that some idealized one-to-one correlation exists between *form* (the code) and meaning (what is coded). This belief is expressed perhaps most boldly by Bolinger (1977):

> "...The natural condition of language is to preserve one form for one meaning, and one meaning for one form..." (1977, p. x)

As Haiman (1985a, pp. 21-22) has pointed out, Bolinger's version is somewhat over-extended: First, because both **polysemy** and **homophony** are common in language, while **synonymy** is rare. And second, because the iconicity ('fidelity') of the linguistic code is subject to corrosive diachronic pressures from both ends:

(i) The code is constantly eroded by **phonological attrition**. (ii) the message is constantly changed by **creative elaboration**. In spite of the disruptive effect of both processes, the overwhelming *tendency* is for the code to be iconic-isomorphic. That this tendency has both a long biological antecedence and an unimpeachable biological motivation simply underscores the fact that language -- as well as culture and cognition -- however complex and fancy, remain embedded in a profound biological context.

5. **Closure**

The linguistic discussion of iconicity in the past decade has been guided tacitly by the Peircean assumption that sentences and their grammar are isomorphic with mental propositions or thoughts. Grammatical structure is, however, at least partly *automated*, being a speech-processing system whose evolution has been guided by processing requirements that are mostly inaccessible to conscious reflection.**[FN 22]** It is therefore unlikely that the traditional sense of iconicity -- isomorphism between utterances and thoughts -- will take us the whole distance toward understanding how the system works, and why it evolved into this particular form. If we are to make sense of both the synchronic workings and diachronic evolution of the grammatical code, we may have to seek the roots of iconic coding at the cognitive and neurological levels. That the three levels --utterance structure, cognitive structure, neurological structure -- may turn out to run in parallel, and to have co-evolved interactively, is a comforting prospect, if we are to gain better understanding of the older antecedents--perhaps even the older antecedence--of consciousness.

FOOTNOTES

*

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1

That is, in the proposition 'John gave the book to Mary', each nominal word stands for a mental referent (which may in turn stand for an external referent); and perhaps the verbal word stands for 'the action'. Perhaps less trivial is the iconicity of word-structure, whereby an array of morphemes attached to a nominal or verbal word correspond -- roughly one-to-one -- to the array of semantic or pragmatic functions that apply to the word.

2

See Anderson (1976, 1983), Dell (1986), Gillund and Shiffrin (1984), McKoon, Ratcliff and Dell (1985), Ratcliff, Hockley and McKoon (1985), Ratcliff and McKoon (1978, 1981a, 1981b, 1989), Swinney (1979), inter alia.

3

See discussion in Givón (1975).

4

See Givón (1984a, 1988a).

[problem with numbering of FNs]

7

See Cirilo and Foss (1980), Glanzer et al (1984), Haberlandt (1980) for paragraph-initial effects; Aronson and Ferres (1983), Aronson and Scarborough (1976), Chang (1980), Cutler and Foss (1977), Marslen-Wilson et al (1978), Gernsbacher and Hargreaves (1987) for clause-initial effects.

8

See Hempel (1959), Hempel and Oppenheim (1948), inter alia.

9

For a general discussion of functionalism in biology and the social sciences, see Givón (1989, chapters 8, 10).

10

A functioning protein also has a secondary ('twisting') and tertiary ('wrapping') structure, thus eventually assuming a particle shape (rather than chain). But the specificity of both the secondary and tertiary structure is determined by the linear primary structure.

11

Leder (1982), Tonegawa (1985), Alt et al (1987), Rajewsky et al (1987).

12

See Futuyma (1986, chapter 3).

13

See Pantev et al (1989).

14
See Takahashi et al (1984), Takahashi and Konishi (1986), Wagner et al (1987), Takahashi (1989).
15
Terry Takahashi (in personal communication).
16
See Knudsen (1985, 1989a, 1989b), Knudsen et al (1984a, 1984b), Knudsen and Knudsen (1990); Rafal (1989).
17
There is nothing inherently iconic in the auditory input about the three spatial dimensions. Nocturnal birds are a later adaptation from birds of prey that were presumably just as heavily dependent on the vision for primary spatial information as most avians. This evolutionary inference, if correct, would represent an instance of ontogeny recapitulating phylogeny (Gould, 1977).
18
See Woolsey (19xx, 1984).
18
See Sparks (1989), Rafal (1989).
19
See van Essen (1985), Kaas (1989).
20
One must note, however, that the motivation for iconic mapping may in some cases be just the opposite. For example, Pantev et al (1989) argue that the coding of near-by pitch values next to each other on the auditory tonotopic map serves as a suppression mechanism, i.e. to prevent the simultaneous firing of neurons sensitive to very near pitch-values. This is a provision for delicate fine-tuning of neural pitch representation
21
From my own field observations. The scale for stallions is more complicated by the use of both frontal and hind-side attack.
22
Grammatical information in utterances is preserved only in the immediate-recall buffer ('working memory'), and decays rapidly within 5-10 seconds. For a discussion see Gernsbacher (1985) and Carpenter and Just (1988).

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