Digitalization in the Evolution of Language

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PART 1: Introduction

1. Overview
1.1 Possible evolutionary sequence
1.1.1 A bottleneck

In pre-language hominids, the vocal auditory channel, as it was then constituted,
may have been inadequate as a means of transmission for communication involving
certain levels of thought and interaction

This circumstance, if regarded metaphoriclly in terms of conflicting evolutionary
pressures / forces, could be seen as a bottleneck -- one consisting of a
conflict between these two factors:
A) the selective advantage of communicative transmission involving increased levels
of 1) thought and 2) interaction
B) limitations in the means of transmission as then constituted

As to A1): within an individual, the capacity for thought --
i.e., conceptual content (including that pertaining to affective states) and its processing --
perhaps had the near potential to increase or was already increasing, in (the range of):
- the qualitatively different kinds of concepts dealt with
- the granularity of concepts, from broad to fine
- the abstractness of concepts, from concrete to abstract
- the complexity of concepts and conceptual interrelations, from simple to intricate
- speed

As to A2): communicative interactions among individuals perhaps had the potential to increase in:
- the encoding and decoding of advanced individual thought
- speed

As to B): limitations in the vocal-auditory means of transmission may have involved:
1) relatively few independently variable parameters = low parallelness
2) little relevant iconicity
3) relatively limited distinctional capacity
4) a relatively low-fidelity medium
5) due to the preceding, relatively low speed of transmission

1.1.2 Digitalization as a resolution to the bottleneck

Proposal: the bottleneck became resolved through an evolutionary change
on the means-of-transmission side of the bottleneck;
whereas the vocal-auditory channel had been largely analog,
it now greatly increased its capacity for "digitalness", which overcame its limitations

It thus shifted from being a largely analog system to being a mainly digital system

"Digitalness" has a lesser or greater extent, cumulatively built up from 4 successive factors:
A) discreteness: distinctly chunked elements, rather than gradients, form the basis of the domain
B) categoriality: the chunked elements function as qualitatively distinct categories
rather than, say, merely as steps along a single dimension
C) recombination: these categorial chunks systematically combine with each other
in alternative arrangements, rather than occurring only at their home sites
D) emergentness: these arrangements each have their own new higher-level identities
rather than remaining simply as patterns
(Note: digitalness here does not involve binary representation / a computational model of the brain)

The most important part of digitalness in the evolution of language is--
"recombinance": where recombination is present and at least some of it also exhibits emergentness

The increase of digitalness, and especially recombinance, in the vocal -auditory channel
compensated for its low parallelness, iconicity, and distinctional capacity
and afforded greater fidelity and speed
thus allowing the transmission of advanced thought with fidelity in rapid communication

1.2 Steps in the examination
A. demonstrating the limitations in the vocal-auditory means of transmission
B. demonstrating the extensiveness of digitalness in modern language
and concluding that it must have evolved with language and overcome the limitations
C. surveying other cognitive systems as possible sources for digitalness in language
D. examining whether the character of thought coevolved with digitalization in language

PART 2: Limitations in the Vocal-Auditory Means of Transmission

The following are limitations in the vocal-auditory channel perhaps overcome by
the introduction or increase of digitalness in general and recombinance in particular

The first 2 limitations of spoken language below are set in relief by contrasting
spoken language -- SpL -- with signed language -- SiL -- specifically:
with one of its subsystems, the "classifier system" -- SiL-CS (characterized below)

Each of these communication channels involves a specific pairing of production
and perception modalities
- SpL: vocal-auditory
- SiL: manual-visual
("manual" here also includes systematic facial and bodily expression)

SiL-CS will be seen to have much greater parallelness and iconicity
which are advantageous to transmitting concepts and would have eased the bottleneck
SiL-CS thus gives an existence proof of their cognitive feasibility

2. Extent of Parallelness: spoken language vs. signed language classifier system

= the number of independently varying parameters
with the potential of representing conceptual content
that can be produced and perceived concurrently -- i.e., "in parallel" --
together with the degree of their use

More parameters: "broad bandwidth" / fewer parameters: "narrow bandwidth"

The advantage to greater parallelness in communication:
more conceptual content can be transmitted in the same unit of time
or: the same amount of conceptual content can be transmitted quicker

2.1 SpL has many fewer independently variable concurrent parameters than SiL-CS
2.1.1 independently variable parameters in spoken language

Table 1. Proposed set of parameters in spoken language
A. the main parameter -- a discrete recombinant system (digital)
1) phonetic quality
B. parameters constituting "vocal dynamics" -- a gradient system (analog)
2) loudness
3) pitch
4) timbre
5) vocal effects (e.g., nasality, tenseness, breathiness, creakiness)
6) distinctness (= enunciation, from sharp clarity to loose approximation)
7) rate
8) duration (e.g., relative segment length, spacing between words)

The analog vocal-dynamic subsystem may be more ancient and have been carried over
as the digital system of language evolved
(Note: some vocal dynamic parameters have also entered the discrete subsystem, e.g.,
pitch --> tones / loudness --> stress)

2.1.2 Independently variable parameters in the classifier subsystem of signed language
Every signed language includes certain subsystems
One subsystem, involving lexical signs and their manipulations, largely behaves
like the lexical and grammatical (open- and closed-class) subsystems of spoken language
Another subsystem has no counterpart in spoken language: the (poorly named)
"classifier" subsystem, dedicated to the schematic representation of objects moving
or located with respect to each other in space
It has a large number of concurrently realized parameters that
vary independently, are generally gradient and iconic, and hence
correspond in an individualized way to the referent situation
without any pre-set combinations of values.

One contrastive example of a spoken-language sentence and a signed-language classifier expression in English: The car drove past the tree.

In American Sign Language (ASL): dominant hand (= Figure) in "3" handshape (= vehicle)
moved horizontally across nondominant (= Ground) vertical forearm with "5" handshape (= tree)
But ASL can add successive parameters to this basic classifier expression to represent more for:
- path: curved road; uphill course
- manner: bumpy ride; swift pace
- Figure-Ground relations: distance of car from tree; approach length vs. trailing length

Table 2. Proposed set of parameters in the classifier subsystem of signed language
-- many of which can be realized concurrently in a single classifier expression
itself often in conjunction with lexical signs + inflections / face + body expressions

A. Entity properties
1) identity of Figure / instrument / manipulator
2) identity of Ground
3) magnitude of some major entity dimension
4) magnitude of a transverse dimension
5) number of entities

B. Orientation properties
6) an entity's rotatedness about its left-right axis ("pitch")
7) an entity's rotatedness about its front-back axis ("roll")
8) a. an entity's rotatedness about its top-bottom axis ("yaw")
b. an entity's rotatedness relative to its path of forward motion

C. Locus properties
9) locus within sign space

D. Motion properties
10) motive state (moving / resting / fixed)
11) internal motion (e.g. expansion/contraction, form change, wriggle, swirling)
12) confined motion (e.g. straight oscillation, rotary oscillation, rotation, local wander)
13) translational motion

E. Path properties
14) state of continuity (unbroken / saltatory)
15) contour of path
16) state of boundedness (bounded / unbounded)
17) length of path
18) vertical height
19) horizontal distance from signer
20) left-right positioning
21) up-down angle ("elevation")
22) left-right angle ("direction")
23) transitions between motion and stationariness (e.g. normal, decelerated, abrupt as from impact)

F. Manner properties
24) divertive manner (e.g., quick jerks out from straight path representing bumpiness)
25) dynamic manner (e.g., different speeds of motion along a path)

G. Relations of Figure or Path to Ground
26) path's conformation relative to Ground
27) relative lengths of path before and after encounter with Ground

28) Figure's path relative to the Path of a moving Ground
29) Figure's proximity to Ground
30) Figure's orientation relative to Ground

2.2 The use of the whole range of parameters is less in SpL than in SiL-CS

To transmit more conceptual content concurrently, it is important
not only for more independent parallel parameters to be available
but also for all the available parameters to be used to a significant extent
and perhaps to a comparable degree

Not only does SiL-CS have more parameters available than SpL,
but it also uses what it has to a greater and comparable extent

Positing a category of "parameter range" for the diversity of means
used in representing conceptual content in some modality
- SiL-CS has "parameter spread", using its 30+ parameters to a comparable extent
- SpL has "parameter concentration":
the main parameter of phonetic quality is used to represent conceptual content
much more than all the vocal dynamic parameters combined

E.g., in a signed classifier expression,
the Figure's type is represented by a handshape
the Figure's path by a linear hand movement
the Figure's Manner by quick hand motions outside this linear path
the Figure's angle relative to the path of motion by the angle at which the hand is held
the distance between the Figure object and the Ground object by
the distance between the dominant hand and the non-dominant hand

In stark contrast, all these different aspects of a motion event are represented in SpL
by one parameter: phonetic quality (formed in turn into morphemes and expressions)

Thus, SiL-CS uses a wide range of formats to represent different kinds of conceptual content;
but SpL channels its representation of most kinds of conceptual content into a single format.

Why this difference in parameter range?
Possible general principle: a modality will tend to extend its pattern of use
to virtually all the parameters available to it, as in SiL-CS
SpL then breaks this principle due to its need for digitalness, characterized below
relying on its discrete recombinant parameter of phonetic quality
disproportionately more than on its gradient vocal dynamic parameters

2.3 Unavailable parameters

To round out the analysis: parameters not used to represent some category of content--

2.3.1 because the parameter is available to only one branch

of a modality's production-perception pairing

SiL: visually perceiveable, not manually produceable: color / texture
manually produceable, not visually perceiveable: degrees of pressure
(though this parameter IS available in the manual-manual communication system of the deaf-blind)

SpL: auditorily perceiveable, not vocally produceable:
- the locations and paths of sound emitting objects
since a speaker cannot "throw his voice", as some think ventriloquists do
- many sounds, e.g., rustling leaves, thunder claps, cacophony,
vocally produceable, not auditorily perceiveable: mouth formations without breath

2.3.2 perhaps due to constraints on neuromuscular control (as it has evolved in humans)

SiL: angle at which elbows are held; SpL: respiratory direction / accompanying whistle

2.4 In sum

As a joint production-perception modality, SiL-CS, by contrast with SpL,
has available to it more independently variable parameters for representing conceptual content
and puts a greater proportion of its parameters to actual use
hence has the capacity to transmit more content faster

3. Extent of Iconicity: spoken language vs. the signed language classifier system

The advantage to greater iconicity in communication:
fewer arbitrary symbols are needed to represent conceptual content
and, if extensive, an entire system of symbols is not needed
thus presumably lessening the cognitive load otherwise involved in
establishing stable symbols, encoding concepts into them, and decoding them into concepts

3.1 Characterizing iconicity

3.1.1 Minimal iconicity

Given some *form* that represents some *entity*:
an aspect of the form that is the same as an aspect of the entity,
and that also represents it, is iconic of it.

Example:
Against the background that the form: *way*
represents the entity: (the concept of) the spatial configuration 'at a great distance'--
the form *waaay* as in *It's waaay over there.*
represents the entity 'at a very great distance'
One aspect of this latter form, "extra magnitude along a scalar dimension"
-- here realized as extra vowel duration --
is the same as one aspect of the latter entity
-- here realized as 'extra length in the distance' --
and this aspect of the form also represents that aspect of the entity
Hence, it is iconic of it

3.1.2 "Strong iconicity"

A gradient of increasingly strong iconicity occurs with the largely cumulative addition of the following iconic features between a form and its represented entity

a. Covariation: the form can exhibit any of a set of alternative aspects each of which equals and represents a corresponding alternative aspect of the entity

e.g., the basic morpheme *way* can exhibit different extra magnitudes along a scalar dimension (here, differently longer vowel durations), as in:

It's waay / waaaay / waaaaaay over there.

and these equal and represent a corresponding set of different extra magnitudes in the entity (here, different extra lengths in a distance)

b. Proportionality: the variations that correspond across form and entity, as in (a) are not just qualitatively different from each other but can be ranked according to degree in a sequence of correspondences

e.g., *waay / waaaay / waaaaaay* are not just qualitatively distinct variants of *way* but fall into the sequence just shown according to vowel duration
The same holds for the 3 extra lengths of distance in the example in (a)
and the two sequences correspond -- i.e., the form and entity aspects vary proportionally

c. Proportional directness: the ordered sequences of the form's variations and of the entity's variations in (b) both increase or decrease in correspondence with each other
i.e., their covariation is directly proportional, not inversely proportional

e.g., increasing vowel duration in *way* corresponds in the entity to increasing length of distance, not to decreasing length of distance

d. Cogranularity: the directly proportional sequences corresponding across form and entity in (c) are both gradient or both discrete: "cogradient / codiscrete"

e.g., vowel length increase in *way* is gradient
and corresponds to a gradient increase in length of distance in the entity
Hence the two exhibit cogranularity -- specifically, they are cogradient

Example of non-cogranularity: the number of repetitions of *up* is discrete in

The bird flew up up / up up up / up up up up and away.

but it shows directly proportional covariation with a gradient:length of distance in the entity

e. Codimensionality: the aspects of a form and the corresponding aspects of an entity are in the same qualitative dimension / domain

e.g., covariation in *way* and in distance are not codimensional because one is in temporal duration while the other is in spatial length

thus, this form and entity are:
covariant, coproportional, proportionally direct, and cogradient, but not codimensional
But if the form *loud* can be uttered with increasing loudness to represent
increasing loudness in the entity referred to by the form,
then this form and entity have all 5 forms of strong iconicity, including codimensionality

3.2 SpL has a much lesser extent of relevant iconicity than SiL-CS

"extent" = the number of distinct forms of iconicity both available and in use in a modality
-- distinct forms of iconicity perhaps = number of independent parameters that have iconicity
"relevant" = relevant to communication: involving referential areas that occur
in communication more frequently, more pervasively, or more ramifiedly
(for reasons that themselves can be separately examined)
e.g., the motion and location of objects more than their temperature

3.2.1 The extent of relevant iconicity in the classifier system of signed language

a. Parameters available and relevant

In SiL: of the 30 parameters in Table 2 for the classifier subsystem,
all but the first two are iconic with the conceptual content they represent,
all these 28 are available, communicatively relevant, and in use

E.g., particular placements/motions of the hand(s) correspondingly represent an entity's:
rotatedness about its left-right axis [6], locus in space [9], motive state [10],
path contour [15], path length [17], vertical height [18], manner of motion [24],
rate of motion [25], Figure's proximity to Ground object [29]

Most of these hand movements have the strongest iconicity with their referents:
covariant directly proportional cogradient codimensionality
they are codimensional because both form and represented entity are in the same domain: space
E.g., greater motion of the dominant hand upward represents greater motion of the Figure object upward
not, say, greater motion downward / more circular motion / more beauty
Greater speed of the dominant hand can represent greater speed of the Figure
not, say, slower speed / larger size / brighter color

b. Parameters unavailable though relevant

Parameters that are iconic and seemingly moderately relevant, but not available to SiL
because they are not in the production-perception pairing seen above:
only visual, not manual:texture / color; only manual, not visual: pressure

3.2.2 The extent of relevant iconicity in spoken language

a. Parameters available but of little relevance

In SpL: of the 8 parameters in Table 1, all but the first -- i.e., all the vocal dynamic parameters
can be iconic, some strongly so

but they are largely of little communicative relevance, hence in little use

E.g., a speaker can use timbre [5] to represent other people's voices
with covariant directly proportional cogradient codimensional iconicity
but this is not of pervasive relevance to communication

b. Parameters available and relevant but not in use

Curiously, both temporal parameters, rate [7] and duration [8],
can be strongly iconic and COULD be relevant
but they are not used to represent rate / duration for depicted events

Attempted example of using vocal rate to represent rate of motion:
uttering the 3 phrases below successively faster iconically with the depicted speeds:
The pen lay on the table, rolled to the edge, and fell off.

Attempted example of using duration in speech to represent duration in occurrence:
inserting successively longer pauses between the phrases below
iconically with the successively longer intervals between the depicted events:
I entered, sat down, and fell asleep.

The reason for not taking advantage of the available temporal iconicity?
Perhaps due to the commitment SpL, in evolving, took to the single format
of the phonetic quality parameter [1] to represent conceptual content

c. Parameters unavailable though relevant

Parameters that are iconic and relevant, but not available to SpL
because they are not in the production-perception pairing seen above:

only auditory, not vocal: the location / path of a (sound-emitting) object

Thus, SpL simply lacks any iconic means for representing highly relevant spatial properties
that SiL-CS has in abundance

3.3 Why the SpL/SiL difference in extent of relevant iconicity?
Possible general principle: a modality will tend to extend its pattern of use
to virtually all the relevant iconicity available to it
Basically, this is done by both SiL and SpL (with that SpL exception for temporal iconicity)
But, as a modality, SiL simply contains more, especially the many spatial parameters

4. Other Limitations
The following are further possible limitations in the vocal-auditory channel
that digitalness may have compensated for

4.1 Limited distinctional capacity

Within the vocal-auditory channel, vocal production may be relatively limited in
the number of readily distinguishable sounds or short sound complexes (such as calls) it can make
-- perhaps less than manual production in the manual-visual channel
If each sound or complex were to holophrastically represent a single concept,
the channel could not represent the large inventory of basic concepts within advanced thought
Digitalization -- specifically, recombinance -- may have overcome this

4.2 Low Fidelity of the medium

The transmission of information from one point in a brain to another largely is effectively analog
but it involves multiply parallel pathways, with much redundancy, over short distances
in a medium dedicated to such transmission, hence with less noise
Accordingly, it has relatively high fidelity
It can thus afford to be largely analog

However, vocal-auditory communication between separate organisms
involves few pathways over long distances in a noisy common medium
Accordingly, it has relatively low fidelity
Digitalization may have overcome this

PART 3: Demonstrating the Extensiveness of Digitalness in Spoken Language

Whereas SpL has little parallelness and relevant iconicity -- much less than SiL-CS
it has extensive and elaborated forms of digitalness
-- much more than SiL-CS (as periodic contrasts below show)
This level of digitalness would seem to have evolved with spoken language
How it surmounted the limitations in the means of transmissioncan be shown

5. Characterizing digitalness

5.1 Digitalness can be lesser / greater -- comprised of four cumulative factors

the extent of digitalness = the cumulative extent along 4 successive factors
Each factor has a less digital pole and a more digital pole
and each successive factor builds only on the more digital pole of the preceding factor

1) state of discreteness (granularity)
   a. gradience vs.
   b. distinctly chunked elements
2) state of categoriality -- applying only to distinct chunked elements [1b]
   a. simply discrete steps along a parameter vs.
   b. qualitatively distinct categories with separate identities in their own right
3) state of recombination -- applying only to qualitatively distinct categories [2b]
   a. occurring solely with their own identities at sites relevant to those identities vs.
   b. also combining systematically in alternative arrangements with respect to each other
4) state of emergentness -- applying only to alternative arrangements [3b]
   a. simply patterns resulting from the process of arranging vs.
   b. new higher-level entities with their own identities

Note: new identities are associated with both categorial and emergent entities; the difference:
in categoriality, there is a new identity in association with discreteness
in emergentness, there is a new identity in association with an arrangement.

5.2 The factor of recombination: a finer characterization

Recombination: a system in which discrete categorial units with distinct identities
-- drawn with various selections and in various numbers from an available inventory --
combine in alternative arrangements of a certain type
in accordance with a system of constraints on possible arrangements,

Note: each variable in the above formulation is spelled out in the specific cases below

5.3 The factor of emergentness: a finer characterization

Emergentness: a cognitive system in which the different combinations of 5.2
represent new higher-level entities with their own separate novel identities.
These identities bear no systematic relation to the identities or arrangements
of the component units that make up the combinations,
and they bear no systematic relation to each other due to
any commonalities among the identities or arrangements of those component units.
Hence, the higher-level identities are not predictable from the components' identities or arrangements
-- that is, they are "arbitrary"

5.4 "Recombinance" is based on both recombination and emergentness

I distinguish recombination and recombinance
Recombinance is a system in which recombination exists
and in which some forms of the recombination exhibit emergentness

6. The Forms of Digitalness in Spoken Language: Discreteness and Categoriality

6.1 Gradient

In vocal-dynamics, parameters 2-8 (in both production and perception)

Compare SiL-CS:
many of the parameters, e.g., locus of a hand within sign space,
contour or length of a path of motion, distance between Figure and Ground

6.2 Discrete but not categorial

Only low-pertinence cases, e.g., the phoneme count of morphemes

Compare SiL-CS:
size of an object represented by a classifier, commonly in 3 discrete values
e.g., handshapes for a small / medium / large planar disk
these are just chunked steps along the single parameter of size, not independent categories

Note: it is mainly this case in SiL-CS that has justified
my establishing a distinction between discreteness and categoriality

since most other relevant cases are both discrete and categorial

6.3 Discrete and categorial

Phonetic quality (parameter 1) is perceived categorically as distinct types of entities
(and perhaps also produced categorically as distinct types of entities?)
e.g., sound series from exaggerated [b] through [p] heard as either "b" or "p",
with the switch occurring at one point in the continuum

Compare SiL-CS:
handshapes for Figure / instrument / manipulator / Ground represent discrete and categorically distinct types of entities (hence the term "classifiers")
Thus, the handshapes, e.g., for ‘ground vehicle’ vs. ‘aircraft’
cannot be gradually morphed one into the other to represent a series of hybrid machines that progress in design from a ground vehicle to an aircraft

7. The Forms of Digitalness in Spoken Language: Recombination and Emergentness

Applying only to the discrete categorial entities of the "categorial" pole above,
recombination is extensive in spoken language
-- both formally and semantically (treated separately below)
Formal recombination occurs on 4 levels, roughly one feeding into the next
features --> phonemes --> morphemes --> idioms --> expressions
Semantic recombination occurs on 2 levels, roughly one feeding into the next
semantic components --> morpheme meanings --> expression meanings
Any unit at each level is composed of units from the prior level(s)
Each kind of recombination has its own
a) type of arrangement
b) set of constraints on the arrangements
Some of the levels of recombination also exhibit emergentness

7.1 In the formal structure of spoken language

7.1.1 Non-recombinational -- as a foil against which to compare the recombinational types
vocal-dynamics parameters 2-8 (not phonetic quality, parameter 1)
these are realized independently, without entering rearrangements relative to each other,

7.1.2 Phonetic features --> phonemes: recombinational and emergent

A. Description
Phonetic features with certain identities, drawn with a certain selection in a certain number
from a language’s phonetic inventory -- itself a subset of a universal inventory --
combine to constitute a higher-level entity, a phoneme, with a particular new identity
Different combinations of phonetic features constitute different phonemes

B. Arrangement properties
1) type of arrangement: cooccurrence (of the features comprising the phoneme) -- the simplest type
2) constraint on arrangements: compatibility (of the cooccurringphonetic features with each other)

7.1.3 Phonemes --> morphemes: recombinational and emergent

= Martinet's (1949) "double articulacion" / Hockett's (1958) "duality of patterning"

A. Description

Phonemes with certain identities, drawn with a certain selection in a certain number
from a language's phonemic inventory
combine to constitute a higher-level entity, a morpheme, with a particular new identity,
This identity includes a particular associated concept
Different combinations of phonemes constitute different morphemes

B. Arrangement properties

1) type of arrangement: mostly sequential and contiguous
exceptions: tone is concurrrent; Semitic triconsonantal roots keep sequence, not contiguity
2) constraints on arrangements: phonotactics

C. Demonstrations of noncorrelation between phoneme identities and morpheme identities

1) /k/, /t/, /æ/ --> cat, tack, act
2) /k/ occurs first in cat, cut, can, cold with no systematically shared meaning component
3) phonemically unrelated morphemes represent successive spectrum colors: red/orange/yellow
not morphemes showing successive places of articulation: red/*redge/*reg
4) conversely, morphemes showing successive places of articulation: rib/rid/ridge/rig
do not represent succession of bone types: rib / *vertebra / *sternum / *clavicle

7.1.4 morphemes --> idioms: recombinational and emergent

A. Description

Morphemes with certain identities, drawn with a certain selection in a certain number
from a language's morphemic inventory -- i.e., its lexicon --
combine to constitute a higher-level entity, an idiom, with a particular new identity,
This identity includes a particular new associated concept
Different combinations of morphemes constitute different idioms

B. Arrangement properties

1) type of arrangement: mostly sequential -- not necessarily contiguous --
locations of morphemes within a wordor expression
2) constraints on arrangements: largely those of morphology and syntax
i.e., of the usual compositional kind for morphemes in nonidiomatic constructions

C. Demonstrations of noncorrelation between morpheme identities and idiom identities

1) morphemes within a word
considerable: (literal 'able to be considered' or idiomatic:) 'fairly great'

2) morphemes / words within an expression:
have it in for: 'nurse a grudge against with the intent of getting revenge on' (state)
vs. *have it out with*: 'finally air openly a implicit growing dispute with' (event)

Table 3. the English verb *turn* plus particular satellite and/or preposition
- turn up ‘become found’ *My cufflink turned up at the bottom of the clotheshamper.*.
- turn down ‘reject’ *I turned the offer down.*
- turn in ‘go to sleep’ *I turned in for the night.*
- turn out ‘eventually be realized’
  It turned out that he had been telling the truth all along.
- turn X on to Y ‘rouse X’s interest in Y’ *She turned him on to Rilke.*
- turn on X ‘suddenly attack X after being allied with X’
  When he objected, his friends turned on him.
- turn X over (to Y) ‘give X to the authorities Y’
  They turned the stolen property over to the police.

7.1.5 Morphemes and idioms --> words and expressions: recombinational, not emergent

A. Description

Morphemes and idiomatic combinations of morphemes with certain identities,
drawn with a certain selection in a certain number
from a language’s inventory of morphemes and idioms -- i.e., its "expanded lexicon" --
combine in different arrangements to constitute a complex word or an expression

Word formation and expression formation are treated separately here
because they involve different patterns of recombination

B. Arrangement properties for:
bound morphemes (and idiomatic combinations of these) --> a word

1) type of arrangement: mostly contiguous
2) constraint on arrangements: morphology

e.g., Atsugewi word consisting of:
V root: -meq’- ‘for a building to move thereby losing structural integrity’
Cause prefix: miw- ‘as a result of fire acting on the Figure’,
idiomatic suffix chain: -tip ‘out of liquid’ plus -uu ‘extendedly’ = tip-uu ‘down into hole’
deictic: -m ‘thither’
--> miw-meq’-tip-uu-im "the house burned down into the cellar"

C. Arrangement properties for:
free morphemes and words (and idiomatic combinations of these) --> an expression

1) type of arrangement: mostly contiguous
2) constraint on arrangements: syntax

Example incorporating the morphological idiom *considerable*
and the phrasal idiom *turn up* (see above):
Considerable evidence has turned up in their probe.

7.1.6 Comparison with the classifier system of signed language

A. Non-recombinational

The majority type: parameters 3-30 mostly occur independently of each other,
included if relevant, omitted if not,
each occupying its own designated part of the whole classifier expression,
without entering into rearrangements relative to each other

b. Recombinational

Minimal, occurring mainly for parameters 1-2
namely, dominant handshape for Figure, nondominant for Ground: can be interchanged
e.g., car passing plane vs. plane passing car

7.2 In the semantic structure of spoken language

7.2.1 Semantic components --> the meaning of a morpheme or idiom: recombinational; and emerge

A. Description

Semantic components with certain identities, drawn with a certain selection in a certain number
from either an open or a closed inventory (see below)
combine to constitute the meaning of a morpheme (or idiom)
The same components can combine in different arrangements to constitute different meanings
where their type of arrangement is not simple conjunction

Components forming the meaning of an open-class morpheme (or idiom)
are largely not drawn from any defined inventory
But components forming the meaning of a closed-class morpheme
are drawn from (a language's subset of) a roughly closed universally available inventory
(see Talmy 2000, ch. 1; 2006)

B. Arrangement properties

1) Type of arrangement: concurrent and with various relationships among the components
from simple conjunction to a complexly patterned schema
sometimes including disjunction or hierarchical nesting
2) Constraints on arrangements: conceptual compatibility of components
-- both locally and globally when within a schema -- but otherwise little understood

C. Problem in assigning emergentness status

1) Argument that the meaning of a morpheme is non-emergent:
the overall meaning of a morpheme does, after all, largely equal
the meanings of the semantic components in their particular interrelationships

2) Arguments that the meaning of a morpheme is emergent:

a. In any given language, the meaning of a morpheme is a stable "pre-packaged" assembly,
a fixed bundling of particular components in a specific arrangement

like a phoneme of the language, with its fixed featural components
and unlike an expression, whose form and meaning are constructed on the spot

In representing space, the pre-packaged spatial schemas of closed-class SpL morphemes contrast with SiL-CS: a signer selects a conceptual category for inclusion independently of other categories and selects a member element within each category independently of other selections

b. Cognitively, the meaning of a morpheme might have an autonomous unity,
apart from whatever semantic components may underlie it

D. Comparison with the classifier system of signed language
The 30 spatial factors represented by the SiL-CS parameters of Table 2 are not pre-packaged,
but largely vary independently in correlation with the separate factors they represent
Hence, the system contrasts with the fixed schemas of SpL morphemes
thus buttressing argument C2a above for morphemic meaning as emergent

E. Example: the overall meaning of the closed-class spatial preposition *past*
as a complexly patterned schema that equals the following semantic components
-- each drawn from the indicated category -- in the indicated interrelationships
(see Talmy, 2006)

Table 4. Semantic components of *past* as in: *The ball sailed past my head at exactly 3 PM.*
a. There are a Figure object and a Ground object (here, the ball and my head, respectively)
[members of the "major scene components" category].
b. The Figure is schematizable as a 0-dimensional point
[a member of the "dimension" category].
c. This Figure point is moving
[a member of the "motive state" category].
d. Hence it forms a one-dimensional line, its path
[a member of the "dimension" category"].
e. The Ground is also schematizable as a 0-dimensional point
[a member of the "dimension" category].
f. There is a certain point P at a proximal remove
[a member of the "degree of remove" category] from the Ground point.
g. Point P forms a 1-dimensional line
[a member of the "dimension" category] with the Ground point.
h. This line is parallel
[a member of the "relative orientation" category[to the horizontal plane.
i. In turn, the horizontal plane is a part
[a member of the "intrinsic parts" category] of the earth-based grid.
j. And the earth-based grid is a Secondary Reference Object
[a member of the "major scene components" category].
k. The Figure's path is perpendicular
[a member of the "relative orientation" category]
to the line between point P and the Ground.

l. The Figure's path is also parallel to the horizontal plane of the earth-based grid.
[same as h/i/j above].
m. If the Ground object has a front, side, and back
[members of the "intrinsic parts" category],
then it is the side part to which point P is proximal.
n. There is a certain point Q of the Figure's path that is not one of its boundary points
[a member of the "state of boundedness" category].
o. Point Q becomes coincident
[a member of the "degree of remove" category] with point P at a certain point of time.

7.2.2 Meanings of morphemes and idioms --> meanings of complex words and of expressions -- recombinational, not emergent

A. Description

The meanings of morphemes and of idioms with certain identities,
drawn with a certain selection in a certain number,
from a language's inventory of morphemes and idioms -- i.e., its expanded lexicon --
combine in different arrangements to constitute the meaning of a complex word or an expression

Complex word meaning and expression meaning are treated separately here
because they might involve different patterns of semantic compositionality

B. Arrangement properties for:
the meanings of bound morphemes (and of idiomatic combinations of these) -->
the meaning of a complex word

1) type of arrangement: semantic compositionality within a word
-- whether in or out of correspondence with any morphological compositionality
2) constraints on arrangements: internal coherence of the larger concept

E.g.: tested / retested / pretested / testable / retestable / pretestable
untested / unretested / unpretested / untestable / unretestable / unpretestable

C. Arrangement properties for:
the meanings of free morphemes and words (and of idiomatic combinations of these)
--> the meaning of an expression

1) type of arrangement: semantic compositionality over an expression
-- whether in or out of correspondence with syntactic compositionality
2) constraint on arrangements: coherence of the overall conception

E.g.: The dog likes the cat, but the cat doesn't like the dog.

8. Summary and implications of the extensiveness of digitalness in spoken language

8.1 Summary of findings

Part 3 has shown that digitalness is a highly extensive and elaborated

system of organization in spoken language, specifically:

8.1.1 Digitalness in language is extensive

Digitalness in spoken language encompasses 4 levels, from discreteness to emergentness
and figures in from 6 to 8 kinds of recombination
This is much more than signed language's classifier system
and perhaps more than any other cognitive system (see section 9)

8.1.2 Digitalness in language is hierarchically structured

A. The 4 factors that make up digitalness roughly nest one within the next:
discreteness --> categoriality --> recombination --> emergentness

B. The 4 or 5 levels of formal recombination roughly nest one within the next:
features --> phonemes --> morphemes --> idioms --> complex words --> expressions

C. The 2 or 3 levels of semantic recombination roughly nest one within the next:
semantic components --> morpheme meanings --> complex word meanings --> expression meanings

8.1.3 Digitalness in language is diverse

--cf. Jackendoff's (2002) distinct organizing principles for different components of language
there are at least 6 and perhaps as many as 8 different types of recombination
distinguished by their different properties of arrangement

A. Formal structure in language has 4 or 5 distinct types of arrangement properties, seen in:
phonetic features in phonemes / phonemes in morphemes / morphemes in idioms /
bound morphemes|idioms in complex words / free morphemes|words|idioms in expressions

B. Semantic structure in language has 2 or 3 distinct types of arrangement properties, seen in:
semantic components in the meanings of morphemes|idioms /
the meanings of bound morphemes|idioms in the meanings of complex words /
the meanings of free morphemes|words|idioms in the meanings of expressions

8.2 How the extensiveness of digitalness may have overcome the bottleneck to language

Extensive and elaborated digitalness presumably did not exist in pre-language communication,
but it exists today, so it must have appeared with the evolution of language
hence, it may have been the mechanism that resolved the earlier bottleneck
by circumventing the limitations of the means of transmission

8.2.1 Compensating for the low fidelity of the medium

were certain aspects of digitalness:
A. the discreteness at 4 levels of organization: features / phonemes / morphemes / idioms
B. the fact that the discrete units at each level belong to relatively closed inventories
C. the arrangement properties constraining each type of recombination
These together enable the hearer to reconstitute the original signal better

8.2.2 Compensating for low parallelness
was the increased speed in the transmission of concepts
itself enabled by the increased fidelity from digitalness

8.2.3 Compensating for little relevant iconicity
was the symbolic representation enabled by recombinance, specifically:
the arbitrary association of a concept with a recombinational emergent
hence, the formation of a whole system of symbols for representing concepts,
which is not needed in iconic representation

8.2.4 compensating for limited distinctional capacity
was recombinance, specifically:
A. The capacity to form numerous morphemes recombinationally from phonemes
each with its own emergent identity in association with a distinct concept
thus accommodating the sizable inventory of basic concepts in advanced thought
B. The capacity to form indefinitely many expressions from morphemes
thus accommodating the open-endedness of conceptions in advanced thought

8.3 Different aspects of digitalness may have entered language at different points in its evolution
The full panoply of digitalness currently evident need not have entered language all at once
Rather, different aspects of it could have entered in successive steps during language evolution

What sequence such different aspects may have entered in is not clear,
but the following aspects seem partly independent of each other:

- The number of distinct holophrastic calls -- all "morphemes" -- may have increased to a point
that strained the hominid capacity to produce and distinguish them
and led to a system of morphemes composed of recombinant sound units

- Such sound units, which may have at first been an idiosyncratic collection of various sounds,
may have become at least partly systematized in terms of recombinant phonetic features

- Morphemes, perhaps originally produced one at a time,
may have started to be presented in short combinations
perhaps under no constraint beyond simple contiguity -- the simplest form of recombination

- More complex constraints may have then entered governing
the order and hierarchical grouping of contiguous morphemes

- Morphemes may have begun to recombine into emergent idioms
(a simple form of this might already occur in vervet communication where, apparently,
a certain call when uttered once has one significance, but when doubled has another significance)

PART 4: Sources and Concomitants in the Evolution of Digitalness in Language
9. The Origins of Digitalness in the Evolution of Language

Question: Did the digitalness in SpL, perhaps greater there than in any other cognitive system
elaborate on digitalness already present elsewhere or appear anew in language evolution?

To begin to address this question, we here undertake an initial survey of
the Extent of Digitalness across Other Cognitive Systems.
Of the 4 levels of digitalness sketched above, it will be seen below that:
instances of discreteness and categoriality--the lower types of digitalness--
seem greater in number and more certain
but instances of recombination and emergentness--the higher types of digitalness = recombinance--
seem fewer in number and less certain

So language is likelier to have acquired the lower types of digitalness from other cognitive systems
and to have developed recombinance itself

In any case, though, these are the basic possibilities:
Other cognitive systems might have a) much, b) little, c) no recombinance
As the language system evolved, it may have accordingly:
a) adopted full recombinance from another cognitive system, increasing it somewhat
b) adopted minor recombinance from another cognitive system, elaborating it greatly
c) developed full recombinance newly as an innovation

Major "substantive" cognitive systems perhaps distinguishable
at least in animals with more complex nervous systems:
perception (in its various modalities) / motor control / affect /
thought (including basic inferencing / reasoning / anticipatory projection)
themselves in interaction with major "organizing" cognitive systems such as
attention / memory
(as analyzed in what I call the "overlapping systems model of cognitive organization")

Further substantive cognitive systems that perhaps largely evolved as humans evolved
and perhaps coevolved with each other
language / gesture / music / culture
(see Talmy 2000, vol. II ch. 7, for arguments for the existence of a cognitive culture system)

In addition, concerning any developments in pre-existing cognitive systems as humans evolved,
a. perhaps most retained their original level of organization and complexity
e.g., perception, motor control, attention, memory
b. perhaps affect increased somewhat in complexity
(including the addition / expansion of, e.g., humor?)
c. but thought developed prodigiously, much like the new substantive cognitive systems

Since gesture, music, culture, and advanced thought may have coevolved with language,
they cannot be cited as precursor sources of recombinance in language
but only as perhaps having incorporated recombinance in parallel with language
Some considerations of music appear in this vein here; all those about thought are in the next section

9.1 Discreteness and categoriality

9.1.1 Gradient -- considered first as a foil for comparison

A. in visual perception: an object's locus in space, path of motion, speed, size, brightness, saturation

B. in motor control: a body part's locus of placement, path of motion, speed of motion, pressure exerted

C. in the affect system: the intensity of an emotional value

9.1.2 Discrete and categorial

A. In visual perception:

1) the discrete classificatory identity of objects
   e.g., seeing a certain long thin pointed object and identifying it as a knife
   i.e., perceiving it as a) a discrete entity
   b) that is a member of a category with its own identity
2) perhaps the vertices, edges, planes of a perceived solid object are each processed as discrete elements in qualitatively distinct categories
3) perhaps hue is perceived with partially discrete categorial character in a way that, say, brightness / saturation are not

B. In motor control: perhaps it structurally incorporates provision for distinct units of movement (motons?)
   e.g., the movement of one leg forward in walking

C. In affect: perhaps emotions are processed in categories with qualitatively distinct characters rather than shading off continuously into one another

and also found:

D. in music: a scale or a melody consists of discrete notes, not of a pitch continuum.

9.2 Recombination and emergentness

9.2.1 Perhaps non-recombinant -- considered first as a foil for comparison

A. In visual perception: a set of identified objects
   e.g. a fork/plate/napkin/glass viewed near each other
   At most, in a certain arrangement, constitute a place setting as a kind of higher-level unit
   But the objects don't lose their separate identities while in that combination
   And they do not combine systematically in other arrangements to form other higher-level units

B. In affect: perhaps distinct emotions do not recombine in distinctive structured patterns

9.2.2 Perhaps recombinant and perhaps also emergent

A. in visual perception:

1) vertices/edges/planes --> distinct object shapes?
2) "geons" --> distinct object shapes?
3) contour integration: minute oriented line segments perceived from tiny receptive fields on retina --> perception of larger-scale contour?

B. in motor control:

1) "motons" --> motor pattern / behavioral unit?
   a. e.g., forward bend at waist (as for leaning over)

plus bend at knee (plus others)
--> motor pattern of sitting down

b. in vervet monkeys: distinct behavioral complexes (in response to distinct heard calls)

2) behavioral units --> behavioral sequence

a. innately fixed sequence:e.g., action-and-response courtship ritual between male and female stickleback fish

-- perhaps hierarchical, since each action itself can consist of iterated subunits

b. learned fixed sequence based on partially recombinant innate capacity: e.g., mating calls in some bird species

c. partially recombinant sequence: e.g., in mockingbird calls / perhaps aspects of whale song

C. in olfaction: particular conjunction of detected molecule segments --> particular odor

and also found:

D. in music: sequence of notes (with their own identities) --> melody (with its own identiy)

9.3 Variations in combination

The above cross-cognitive cases suggest that simpler patterns exist for the combination of discrete categorial units into larger constellations -- short of full-blown recombination -- and that these patterns may evolutionarily precede, and perhaps lead to, full recombination

9.3.1 Iteration

e.g., a single moton can be iterated to constitute a larger behavioral unit, as in head-bobbing in geese (<Lorenz)

9.3.2 Fixed sequencing

e.g., the fixed sequence of behavioral units in the stickleback courtship ritual

10. Effects on thought due to the evolution of digitalness in language

In the evolution of language, was the means of transmission the only thing that changed or did the contents and use of this transmission also change?

That is, did individual thought and communicative interaction coevolve with the increasing digitalness in the means of transmission?

Here addressing only thought (not interaction), it seems that:

certain aspects of thought remained the same in character, with only the representation of some of these having changed in character

while other aspects of thought changed in character in parallel with or due to digital representation

Continuation vs. change in the character of thought or of its representation include these domains: digitalness / crispness, / voluntariness of control and of meta-cognition

10.1 Continuation vs. Change in the Digitalness of Thought

10.1.1 Continuation of already digital aspects of thought

A. With respect to discrete and categorial aspects

1) Types of discrete and categorial concepts perhaps present in non-human cognition:
distinct concepts of--
a. so-perceivedly specific objects or events
or of the identity or categorial membership of any of these, e.g., banana / eat
b. abstract properties, e.g., animate and inanimate
c. roles that objects have in a so-conceived event or relationship,
e.g., groomer vs. groomee / mother vs. child
d. a so-perceived sequence of events; e.g.? securing a shellfish, -> flying up with it,
-> dropping it onto a rock -> flying down to eat the exposed innards

2) Discrete-categorial aspects of language that correspond to such comparable cases of thought

a. Individual morphemes in a lexicon that represent discrete categorial concepts as in [1a,b,c]
e.g., *banana, eat, alive, mother*
Constructions that represent sequences of distinct events as in [1d]
e.g., *The bird grabbed the shellfish, flew up with it, dropped it, flew down, and ate it.*

B. With respect to recombinational aspects

1) Types of recombinational concepts perhaps present in non-human cognition:
the concepts that underlie--
a. Reordering the components of a sequence
e.g., subordinate chimp redoing sequence of visiting food locations
to mislead nearby dominant chimp <Hauser
b. Selecting and assembling components into a suitable complex
e.g., chimp connecting 2 rods to form a longer rod to reach food
c. Undoing and redoing components within a larger maneuvering of components
e.g., fish spitting out babies held protected in mouth, then eating nearby prey,
then regathering babies into mouth (<Lorenz)

2) Recombinational aspects of language that correspond to such comparable cases of thought

a. Reordering the components of a sequence as in [1a]
e.g., *I cleared the yard before I had lunch. / I had lunch before I cleared the yard.*
Selecting and assembling components into a suitable complex as in [1b] = any well-formed
sentence, e.g., I brought the groceries into the kitchen.

10.1.2 change toward digitalness only in the *representation* of analog aspects of thought

A. Types of analog thought perhaps already present in non-human cognition without correspondingly analog representation in language

1) Degree in the conceptual counterpart of perceiving / experiencing phenomena like

distance / speed / brightness / tactile pressure / affect

2) Locus in the conceptual counterpart of perceiving phenomena like
position in space

3) Relative proportion in the conceptual counterpart of perceiving or in assessing phenomena like
size / strength of oneself against that of another

4) Pattern in the conceptual counterpart of perceiving phenomena like
path contour / object configuration / texture

B. digital linguistic representations of analog aspects of thought

1) of analog degree as in [A1] above
e.g., by the addition of a morpheme or by the choice in the morpheme added
The moon is bright / very bright / extremely bright today.

2) of analog relative proportion as in [A3] above

An analog conception that can range over the ratio, say, of affection between a dog and a cat can at best be linguistically represented by digital "cross-sections" of the continuum:

Table 5.
a. The dog likes the cat, but the cat doesn't like the dog.
b. The dog likes the cat a lot, and the cat likes the dog a little.
c. The dog and the cat like each other equally.
d. The cat likes the dog a lot, and the dog likes the cat a little.
e. The cat likes the dog, but the dog doesn't like the cat.

Points along the analog conceptual ratio are represented digitally
through semantic and syntactic compositionality including:
a. the order of the two clauses
b. the use of *but* vs. *and* as a conjunction,
c. the presence vs. absence of a negative
d. the use of a reciprocal vs. a nonreciprocal construction,
e. the appearance vs. nonappearance of adverbials of quantity like *equally, a lot, a little*,
f. the assignment of the nouns to subject vs. object position

3) of analog pattern as in [A4] above

One's conceptual counterpart of a visual Gestalt
with all its components concurrently in particular interrelationships
is represented linguistically through a selection of only a few components and relationships
presented sequentially
e.g., *Bay trees stand around the pond with some blackberry shrubs growing in between.*

4) different digital linguistic representations of the same analog conception

What might be roughly the same conceptualization held by 2 individuals
-- analog because continuously variable --
will be represented in 2 different digital patterns if they speak different languages
patterns with different selections of components in different relationships

e.g., English: *You tracked up my house.*
Atsugewi: m'w-ma-st'aq'-ipsnu-ik:
you by.acting.on.it.with.your.feet
[caused it that] runny.icky.material.move into.a.volumetric.enclousre hither
[each grouping of words translates a single Atsugewi morpheme]

10.1.3 Expansion/introduction of digitalness in thought where it had been modest/absent

Considering here just smaller-scale, not larger-scale, portions or stretches of thought--
the digital expansion in language perhaps brought with it or elaborated:

A. concepts set into particular relationships within larger structures, as in:

1) the embedding of one concept within another
e.g., *Our new lawyer, who had been active in the civil rights movement,*
has started revising our defense.
2) the establishment of parallelisms or analogies across concepts and conceptual structures
e.g., *For Christmas, WE gave our DOG a STEAK, while THEY gave their CAT a FISH.*
3) the equating of two occurrences of the same concept
e.g., *We went to see a movie, and they did too.*

B. the recognition of component concepts within a larger conceptual whole

Even if a speaker starts with or a hearer ends up with a Gestalt conception,
both can still be aware of the component concepts and relationships
as these are represented in sequence by the individual morphemes and constructions of an expression

Thus, speaker and hearer need not experience as indivisible the thoughts
represented by such earlier expressions as:
The moon is very bright today.
The dog likes the cat, but the cat doesn't like the dog.
You tracked up my house.
but can also cognize the component concepts, as their language has shaped them,
in their overt sequence and relationships

C. The sequentializing of parts of a static whole

A speaker can start with and a hearer can end up with a conception of a static whole conception
but can also experience the sequence in which its parts or described in an expression
e.g., as in the earlier expression:
Bay trees stand around the pond with some blackberry shrubs growing in between.

10.2 Continuation vs. Change in the Crispness of Thought

The proposed parameter of "crispness" with its two opposite poles: crisp vs. vague
can apply to any entity in consciousness
The characteristics of such an entity when cognized as crisp vs. vague:
- clear vs. hazy or murky as to its particular content
-evoking an experience of certainty as to the identity of its content
vs. evoking uncertainty or not evoking certainty
- having well-defined, sharp boundaries vs. approximative, fuzzy boundaries
- having fine and detailed vs. coarse internal differentiation
- if involved in any change, amenable only to discrete jumps vs. also to gradient shifts
- available vs. elusive to focused attention or introspection

Within the perceptual modalities, vision and audition tend toward the crisp
smell and touch tend toward the vague
Across substantive cognitive systems, perhaps motor control tends toward the crisp,
and the affect system tens toward the vague

As digital language evolved
the older systems of communication continued on and are co-present today :
vocal dynamics (loudness, rate, pitch, etc.) / facial expressions / "body language"
and gesture either coevolved with language or elaborated on an older precursor

The content conveyed by the older systems of communication
is generally vague and murky -- although gesture can range toward greater crispness
The content conveyed by the new digital system of language with its morphemes and constructions
is generally crisp
It may have introduced or greatly expanded crispness in thought

Further, the content of the older systems (excluding gesture) generally pertains to affect
-- a cognitive system that already tends toward the vague
while the content of the new digital system is largely conceptual,
with concepts pertaining to any domain

Acts of communication among individuals in nonhuman animals species seem to be largely involuntary
e.g., vervet monkey calls seem largely to be made spontaneously on perceiving certain stimuli
(though reaction to a call can apparently be inhibited)
Possible exceptional forms of voluntary communication:
- female chimp can apparently suppress her call while mating with a lower-ranked male
- bird of certain species can sound a danger call to induce conspecifics to flee
and so give it access to a prey item (<Hauser)

In humans, certain forms / aspects of communication are also involuntary
a. certain facial muscles yielding particular expressions only fire spontaneously
b. a hearer’s understanding of ongoing speech in a language he knows is an involuntary process

but the production of speech and the selection of its contents is largely voluntary

It remains to be determined whether such voluntariness is due to the rise of digitalness in language or is a separately evolved characteristic

References

Biederman, I. 1987. Recognition-by-Components: A Theory of Human Image Understanding. Psychological Review, 94, 115-147.

Emmorey, Karen. 2003. *Language, cognition and the brain: Insights from sign language research*. Lawrence Erlbaum.

Haiman, John. 1985. Natural Syntax: Iconicity and Erosion. Cambridge: Cambridge University Press.

Jackendoff, Ray. 2002. Foundations of language: brain, meaning, grammar, evolution. Oxford University Press.

Liddell, Scott. 2003. Sources of meaning in ASL classifier predicates. *Perspectives on Classifier Constructions in Sign Language*, ed. by Karen Emmorey. Mahwah, NJ: Lawrence Erlbaum.

Talmy, Leonard. 2000. *Toward a Cognitive Semantics*. volume I: *Concept structuring systems*. i-viii, 1-565. volume II: *Typology and process in concept structuring*. i-viii, 1-495. Cambridge: MIT Press.

Talmy, Leonard. 2003. The representation of spatial structure in spoken and signed language. In *Perspectives on Classifier Constructions in Sign Language*, ed. by Karen Emmorey. Mahwah, NJ: Lawrence Erlbaum.

Talmy, Leonard. 2006. The fundamental system of spatial schemas in language. In: *From perception to meaning: Image Schemas in Cognitive Linguistics* ed. by Beate Hamp. Mouton de Gruyter

Talmy, Leonard. In press. Recombinance in the Evolution of Language. in Proceedings of the 39th Annual Meeting of the Chicago Linguistic Society: The Panels. eds. Jonathon E. Cihlar, David Kaiser, Irene Kimbara, and Amy Franklin. Chicago: Chicago Linguistic Society.
(Note: a pre-final draft can be found on my website: http://linguistics.buffalo.edu/people/faculty/talmy/talmyweb/index.html)