Recursion, Modularity and the *Evo-Devo* of Language

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“To create is to recombine.” - F. Jacob

“... an evolutionary novelty may result from the combination of two pre-existing parts with unrelated functions.” - M. Ridley

“Evolution has recruited for language purposes brains structures that performed other functions in non-human primates.” - T. Deacon

“... domain-specificity of language is reduced to some special arrangement of elements that are not language-specific.” - N. Chomsky

Generative Biolinguistics

- Human Nature and Language Organ

1. Design .......... Microgenesis
2. Development ... Ontogenesis
3. Evolution ...... Phylogenesis
(1) Descriptive Adequacy \(\Rightarrow\) <PHON,SEM>

(2) Explanatory Adequacy \(\Rightarrow\) I-Language

(3) Evolutionary Adequacy \(\Rightarrow\) UG

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Biological Evolution and Language Evolution

- Language evolution is an instance of biological evolution (in addition to cultural evolution).

  \[\rightarrow\] If one’s theory of biological evolution fails to account for the evolution of language, then it needs a serious reconsideration.

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- Logical Problem of Language Evolution
- Logical Problem of Language Acquisition

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- Arrival of the Fittest
- Survival of the Fittest
Neo-Darwinism (Modern Synthesis)

- Adaptationist Program
  - Functionalism
  - Natural Selection / Sexual Selection as the First Resort
  - Gradualism

Neo-Neo-Darwinism (Expanded Synthesis)

- Non-adaptationist Program
  - Formalism
  - Pluralism
  - NS/SS as the Last Resort
  - Punctuated Equilibrium (saltationism?)
  - Exaptation

Sexual Selection (Handicap Principle)


Figure 2. Peacock with a highly ornamented tail which, like the male quail’s tail, evolved by female choice. If some “eyes” are removed from his tail, he becomes less attractive to females. It is hard to imagine how such an enormous ornament would be compatible with escape from predators, and indeed further enlargement of the tail may have been constrained by natural selection.

<table>
<thead>
<tr>
<th>Aptation</th>
<th>Exaptation</th>
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<tbody>
<tr>
<td>A character, previously shaped by NS for a particular function (an adaptation), is co-opted for a new use.</td>
<td></td>
</tr>
<tr>
<td>A character whose origin cannot be ascribed to the direct action of natural selection (a non-aptation), is co-opted for a current use.</td>
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<tr>
<th>Adaptationism: Three Kinds</th>
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<tr>
<td>(1) Empirical Adaptationism</td>
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<tr>
<td>(2) Explanatory Adaptationism</td>
</tr>
<tr>
<td>a. Weak</td>
</tr>
<tr>
<td>b. Moderate</td>
</tr>
<tr>
<td>c. Strong</td>
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<tr>
<td>(3) Methodological Adaptationism</td>
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<th>Original Function, Current Utility</th>
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<tr>
<td>■ Language for Thought (internalization) or Communication (externalization)?</td>
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<tr>
<td>■ The core computational system of human language is maladapted for communicative purposes.</td>
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<th>Is recursion functional?</th>
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<tr>
<td>(1) The daughter of [ John ]’s son is [ the son of John ]’s daughter.</td>
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<tr>
<td>(2) The mouse [ the cat [ the dog [ the boy owned ] loved ] admired ] danced.</td>
</tr>
</tbody>
</table>
- Syntax is optimally designed to satisfy the CI interface system, not the SM system.

(1) What did you eat?
   CI: [ what did you eat what ]
   SM: [ what did you eat ___ ]

- The functions of the components that jointly constituted the language faculty later in the hominin evolution may have had nothing to do with the current (or even original) function(s) of language.

- Animal communication may have only an indirect bearing on language evolution.

Paradox of Adaptive Selection

- In order to be adaptive as a communicative tool, language has to be already shared among individuals.

  cf. mother-child bond, social grooming, etc.

- Language as a communicative tool is itself an instance of exaptation.

- “Humans use language for communication, but it may well be that the most important aspect of language is that it is used for internal representation in the brain.”
  - J. Maynard Smith and E. Szathmáry
Strong Minimalist Thesis (SMT)

- Language is an optimal solution to legibility conditions.
- Unexplained elements of UG are zero.
- There is virtually nothing special about the origin and evolution of language.

The Third Factor and Telematic Explanation

- (Apparent) Goal-Directedness:
  - Teleological explanation
  - Teleonomic explanation
  - Teleomatic explanation

E. Mayr: Toward a New Philosophy of Biology.

Teleonomic process: A process of behavior that owes its goal-directedness to the operation of a program.

Teleomatic process: A seemingly end-directed process that is strictly controlled by natural laws such as the law of gravity or the first law of thermodynamics.

E. Mayr: One Long Argument.

The Minimalist Program is an attempt to seek a teleomatic explanation of the language design.

Global optimization of cerebral cortex layout

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Abstract

The objective of this study was to test the hypothesis that the global optimization of cerebral cortex layout is driven by a teleomatic process, which may involve genetic algorithms or other forms of natural selection. The results of our experiments support this hypothesis, as we observed a significant correlation between the layout of the cerebral cortex and the performance of the genetic algorithms used to optimize it. This suggests that the layout of the cerebral cortex may be the result of a natural selection process that has been driven by evolutionary forces. Further experiments are needed to confirm this hypothesis and to understand the underlying mechanisms. This work was supported by a grant from the National Institutes of Health (NIH) R01 NS064373.

Keywords: Cerebral cortex, Genetic algorithms, Evolutionary biology, Teleomatic process.

References


Plainly, the faculty of language was not instantaneously inserted into a mind/brain with the rest of its architecture fully intact. But we are asking how well it is designed on that counterfactual assumption. How much does the abstraction distort a vastly more complex reality?" - N. Chomsky

**Wiring optimization can relate neuronal structure and function**

Beth L. Chen†, David N. Repp, and Guoliang Chai

"...development is robust to changes in genotype and environment." M. L. Siegal and A. Bergma. Waddington’s canalization revisited: developmental stability and evolution.

"...individuals within a wild population show remarkably little morphological variation, given the amount of environmental variation they encounter during development and the amount of genetic variation within the population. This phenotypic consistency led to the proposal that individuals were somehow buffered, or canalized, against genetic and environmental variation.” J. E. Niven. Channelling evolution—canalization and the nervous system.

**An Evo-Devo Approach**

During the last two decades evolutionary developmental biology has become a major research programme whose findings put into question some concepts lying at the core of the Synthetic Theory.

However, some authors are waiting for a 'revolution' in biology, one in which the existing genetic determinism will give way to a new conceptual understanding of the complexity of living organisms.

This interdisciplinary approach is focused on how changes in development bring about evolutionary changes to account for the past and present diversity of morphologies and body plans.

S. Urda and R. Chirat. Snail shell coiling re-evolution and the evo-devo revolution.

**Canalization (C. Waddington)**
‘Soft’ Modularity

“Modularity, a biological approach that views organisms as the integration of partially independent, interacting units at several hierarchical levels, has been described as ‘a conceptual framework for evo-devo’, and ‘a meeting place for evolutionary and developmental biologists’.”

B. K. Hall and W. M. Olson eds.: Keywords & Concepts in Evolutionary Developmental Biology.

Modular Architecture of the Mind

- Domain-Specificity
- Informational Encapsulation
- Autonomous
- Innate
- Mandatory
- Fast
- Deterministic
- Neural Localization
- Idiosyncratic
- Pathological
- Breakdown

Central System? Adaptation?

| Fodorian Module | No | No |
| Chomskyan Module | Yes | No |
| Darwinian Module | Yes | Yes |

Fodorian Modularity

- **Sensory Transducers**
  - Audition
  - Vision
  - Language

**INPUT MODULES**

**Central System**


Chomskyan Modularity

- **Sensory Transducers**
  - Audition
  - Vision
  - Language

**INPUT MODULES**

**CENTRAL MODULES**

- Morality
- Language
- Face Recognition

**Central System**

- Theory of Mind
- Music
- Number, etc.

Against Strong Innateness

- Departure from strong genetic determinism in *Evo-Devo* and in MP
- “The third factor” in general biological design

Faculty of Language, Broad and Narrow

- **FLN:** unique to humans and human language
  - **Recursion only**

- **FLB:** not unique to humans and human language
  - Sensory-Motor and Conceptual-Intentional systems
- Instantaneous Model of Language Evolution

  Preexisting Capacities + Unbounded Merge → Human Language

- Instantaneous Model of Language Development

  UG + PLD → I-Language

Third Factor:

- B. Heine and T. Kuteva. 2007. The Genesis of Grammar. OUP.

  “... no clear evidence for languages that demonstrably lack recursion of any kind.”


- N. Chomsky

  “... unbounded Merge is not only a genetically determined property of language, but also unique to it.”

  (1) student film committee program office
  (2) John’s friend’s friend’s friend’s friend
Serial Verbs:
(1) Me fo kadegbe gba. (Ewe)
   I hit lamp break
   'I hit-break the lamp.'
(2) Ozó ghá su ṭu ki de. (Edo)
   Ozo will push pot fall
   'Ozo will push-fall the pot.'

Complex V-V predicates:
(3) John-ga mado-wo tataki-watta. (Japanese)
   John-Nom window-Acc hit-broke
   'John hit-broke the window.'

The concepts of specifically human syntax are precisely those that we might associate with non-human primate cognition.

"The semantic concepts f that seem characteristic of humans are not used in human syntax."

J. Emonds, 2004. What humans have that animals don’t have.

The Evolution of [-Interpretable] Features?
- Lexical and Functional Categories
- Exons and Introns

Introns may derive from exons through a process akin to grammaticalization (semantic bleaching).
Cell Language and Human Language

"... it may be suggested that human language is ultimately founded in cell language and that human language can be viewed as a transformation of cell language."

"... a complete understanding of the nature of DNA requires applying the principles of human language to biology."

S. Ji. Isomorphism between cell and human languages: molecular biological, bioinformatic and linguistic implications.

"... to understand better human language, we can also be helped along by a better understanding of the language of the cell."


Language evolution boils down to the emergence of:
- Unbounded Merge
- Interfaces
- Phases (Phase Impenetrability Condition)
- etc.

Scenario #1

Scenario #2
Scenario #3

Pre-SM System ↔ Bounded Merge ↔ Pre-CI System

SM System ↔ Unbounded Merge ↔ CI System

No Precursors to Unbounded Merge?

“... for both evolution and development, there seems to be little reason to suppose that there were precursors to unbounded Merge.”

- N. Chomsky

Decomposing Merge

- Merge \((\alpha, \beta) = \{\alpha, \beta\}\)

- Embed \((\alpha, \{\alpha, \beta\}) = \{\alpha, \{\alpha, \beta\}\}\)

endocentricity \(\alpha \beta\) ← \(\alpha \beta\)

(Fukui 2008)

Recursive Merge (without Embed)

Recursive Embed
Internal Merge (Move) + Embed

\[ \begin{array}{c}
\gamma \\
\beta \\
\alpha \\
\beta \\
\end{array} \]

Why not \( \beta \) for direct Embed without Move?
Embed (\( \beta, \{\gamma, \{\alpha, \{\alpha, \beta\}\}\}\))

Local Embed

Non-local Embed

\[ \text{exocentricity} \leftarrow \begin{array}{c}
\alpha \\
\beta \\
\beta \\
\alpha \\
\beta \\
\end{array} \]

Exocentric compounding

(1) *Katta-maketa* -wa docchi-demo yoi.
won-lost -Top whichever is good
‘Whether we won or lost doesn’t matter.’

(2) *Tatemono-no* takai-hikui-ga juuyoo da.
bld Gen high-low -Nom important is
‘The height of the building matters.’

(1) \[ \begin{array}{c}
V \\
V \\
\end{array} \]

(2) \[ \begin{array}{c}
A \\
A \\
\end{array} \]

Internally-headed relatives:

(1) [John-ga *saifu-wo* nakushita no]-wo Mary-ga mitsuketa.
[John-Nom wallet Acc lost Comp ]Acc Mary-Nom found
‘Mary found the wallet John had lost.’

\[ \begin{array}{c}
\text{saifu} \\
\text{John-ga} \\
\text{saifu-wo nakushita} \\
\end{array} \]
Labeling Two Word Utterances

(1) no label
milk             cup
(2) endocentric
cup
milk             cup
(3) * &
milk             cup
(*in the sense of 'milk & cup')

Possible Precursors to (Bounded) Merge

- Syllable Structure
  - Birdsong
  - Music
- Social Intelligence
  - Theory of Mind (ToM)
  - Machiavellian Intelligence
- Navigation and Foraging
- Number
- Manual Dexterity, Motor Control
- Action Grammar

Action Grammar

- Pairing Method
- Pot Method
- Subassembly Method

P. M. Greenfield:
II. Pot Method

- Merge (saw, Mary) = \{saw, Mary\}
- Merge (John, \{saw, Mary\}) = \{John, \{saw, Mary\}\}

III. Subassembly Method

- Merge (saw, Mary) = \{saw, Mary\}
- Merge (the, boy) = \{the, boy\}
- Merge (\{the, boy\}, \{saw, Mary\})
  - = \{\{the, boy\}, \{saw, Mary\}\}

Subassembly Method required

Subassembly in Root Compounding

Swedish: barn bok klub:

```
     barn
       
     bok    klub
```

English: child book club:

```
     child
       
     book    club
```


Subassembly and Chunking

- **Phase = derivational chunk**

- **Phase Impenetrability Condition:**
  - Once formed, chunks cannot be unpacked.

Major Issues

- From Pot to Subassembly?
- From Subassembly to Internal Merge (Move)?
- From bounded to unbounded Merge?
Objections

- Recursion is not limited to humans and human language (such as vision).
- Human language has other components than recursion (such as lexicon).


“If future empirical progress demonstrates that FLN represents an empty set, so be it.”
Fitch, Hauser and Chomsky 2005.

Lexicon as a Conceptual Barrier

- The existence of a generative lexicon in human language poses a serious challenge to the recursion only hypothesis.
- Does the lexicon belong to FLB or FLN?

Anti-Lexicalism

- Words are generated by recursive syntax.
- Lexicon decomposed into FLN (recursion) and FLB (SM/CI)
- C-I interface optimized
- There is virtually no lexicon.

Syntactic Nature of ‘Lexical’ Verbs

1. John opened the door again.
   i. repetitive reading
   ii. restitutive reading

2. \[ \text{vP - again(i)} \]
   \[ \text{CAUSE the door OPEN again(ii)} \]

3. LCS: \[ x \text{CAUSE} \{ y \text{OPEN again(i)} \} \text{again(ii)} \]
Ditransitives

(1) a. John gave Mary a book.
   b. [\v P John \v \[VP Mary V a book \]]
   c. [J. CAUSE [M. HAVE B.]]

(2) a. John gave a book to Mary.
   b. [\v P John \v \[VP a book V to Mary \]]
   c. [J. CAUSE [B. GO to M.]]

- Mapping between syntactic structure and conceptual structure is straightforward.

Evidence from Developmental Data

CAUSE (2;0.4) ≥ HAVE (2;0.7) ≥
Double Obj verbs (2;1.6) >
GO (2;4.0) ≥ Dative Obj verbs (2;4.9)


Merge in Early Grammar

- “No verb is an island.”
  (cf. Tomasello’s *Verb Island Hypothesis*)

- “Children start to use Merge already with their very first word combinations.”


(1) *Give*-type verbs have a caused possession interpretation in both variants:
   cf. *Where did you give the book?*

(2) *Send*-type verbs have a caused motion interpretation in the dative variant:
   cf. Where did you send the book?

  M. Rappaport Hovav and B. Levin 2008.
Three-Layered Split VP

K. Fujita:
Middle, ergative and passive in English: A minimalist perspective, MITWPL 22. (1994)
Double objects, causatives and derivational economy, LI 27. (1996)

Middles implicit Agent Generically quantified +stative
Ergatives (implicit Causer) Existentially quantified +eventive

• tham/typ causatives in Thai:
  (1) “Saakhaa tham kracok treek dooy tançay.
      Saka cause mirror break by intend
  (2) Saakhaa hây dek win dooy tançay.
      Saka have child run by intend
  (3) Saakhaa tham hây kaw’hi lom dooy tançay.
      Saka cause have chair fall by intend


“Causes are realized in a position that is asymmetrically c-commanded by the Agent position.”
Simpler Syntax? (Culicover and Jackendoff 2005)

John gave Mary a book.
CS: [ x CAUSE [ y HAVE z ]]

Layerd VP: Flat VP:

Flat VP: optimal for SM-system
- Language for communication
- Adaptationism
- Lexicalism

Layerd VP: optimal for CI-system
- Language for thought
- Nonadaptationism
- Anti-Lexicalism (syntax for thought everywhere)

“It cannot be true literally that ‘In the beginning was the word’: on the contrary, in the beginning was the sentence.”

- In the beginning was recursion.

Merge to Successor Function

Merge (1,1) = 2
Merge (2,1) = 3, etc.

Mathematical capacity is an abstraction from linguistic operations.
Recursion: The Generative Engine of the Mind

Conclusions (highly tentative)
- MP provides an Evo-Devo framework for the study of language evolution.
- Language was adaptive primarily as a cognitive tool, later co-opted for communication.
- Unbounded Merge evolved in several steps, stemming from Action Grammar.
- Human cognitive modules emerged from basic recursive capacity via descent with modification.
Thank you.

Now, on with the Ghost Walk...