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Recursion, Modularity and the Evo-Devo of Language

Koji Fujita
Kyoto University

“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

**Biological Evolution and Language Evolution**

- Language evolution is an instance of biological evolution (in addition to cultural evolution).
- If one’s theory of biological evolution fails to account for the evolution of language, then it needs a serious reconsideration.

**Logical Problem of Language Evolution**

**Logical Problem of Language Acquisition**

**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 ornamentation 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>Aption</th>
<th>Adaptation</th>
<th>NS shapes the character for a current use.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exaption</td>
<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>Exaption</td>
<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>
<td></td>
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</tbody>
</table>
Adaptationism: Three Kinds

1. Empirical Adaptationism
2. Explanatory Adaptationism
   a. Weak
   b. Moderate
   c. Strong
3. Methodological Adaptationism


Original Function, Current Utility

- Language for Thought (internalization) or Communication (externalization)?
- The core computational system of human language is maladapted for communicative purposes.

(1) John saw himself/*him.
(2) John thinks [ Mary saw *himsel*/him ].

If Condition A effect in (1) is functionally explained, why is the situation reversed in (2)?

- Is recursion functional?
  1. The daughter of [ John ]’s son is [ the son of John ]’s daughter.
  2. The mouse [ the cat [ the dog [ the boy owned ] loved ] admired ] danced.
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 Teleomatic 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

Christopher Checack*, Zdenka Rohlfskova*, Joel Rodriguez Colunga*, and Kelly Changp

1. Overview of the problem: The cerebral cortex is a complex network of neurons that is responsible for various cognitive functions. The layout of the cerebral cortex is not random but follows specific patterns that are thought to be optimized for efficiency.

2. Methods: The optimization of the cerebral cortex layout was approached using mathematical models and computational simulations. The goal was to find the most efficient layout that could support the required cognitive functions with the least amount of energy expenditure.

3. Results: The optimization process revealed that the layout of the cerebral cortex is not static but evolves over time. The optimization models showed that the layout is influenced by various factors such as neural connectivity and environmental factors.

4. Conclusion: The results of the optimization process provide insights into the evolution of the cerebral cortex layout and suggest potential avenues for further research in the field of neuroscience.

E. Mayr: One Long Argument.

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

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<table>
<thead>
<tr>
<th></th>
<th>Central System?</th>
<th>Adaptation?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fodorian Module</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Chomskyan Module</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Darwinian Module</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
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, Mosaic, Numbers, 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
  - Third Factor

- Instantaneous Model of Language Development
  - UG + PLD → I-Language
  - Third Factor

(1) student film committee program office
(2) John’s friend’s friend’s friend’s friend

- “… no clear evidence for languages that demonstrably lack recursion of any kind.”
  B. Heine and T. Kuteva. 2007. The Genesis of Grammar. OUP.


- “… unbounded Merge is not only a genetically determined property of language, but also unique to it.”
  - N. Chomsky
Serial Verbs:
(1) Me fo kadegbe gba. (Ewe)
   I hit lamp break
   ‘I hit-break the lamp.’
(2) Ozó gha su íkhé dë. (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.’

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

The concepts $F$ 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.”

RNA Splicing
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."

L. Jenkins. Biolinguistics.

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

(Fukui 2008)

Recursive Merge (without Embed)

Recursive Embed

\[ \gamma \alpha \beta \]
Internal Merge (Move) + Embed

Why not β for direct Embed without Move?
Embed (β, {γ, {α, {α, β}}})

Local Embed

Non-local Embed

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.
   building Gen high-low -Nom important is
   ‘The height of the building matters.’

(1) | N | V
(2) | A | A

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.’

   saifu
   John-ga
   saifu-wo nakushita
Labeling Two Word Utterances

(1) no label

(2) endocentric

milk \rightarrow cup

(3) \&

milk \rightarrow 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


I. Pairing Method
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

   barn

   bok
```

English: child book club:

```
  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) \[ \text{VP - again(i)} \]

- \( \text{CAUSE} \)
- \( \text{the door} \)
- \( \text{OPEN} \)

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

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

(2) a. John gave a book to Mary.
   b. \[ v P \] John \[ v [P 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) \geq HAVE (2;0.7) \geq
Double Obj verbs (2;1.6) >
GO (2;4.0) \geq 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.”

A. Ninio. 2006. *Language and the Learning Curve.* *QUP.*

(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


---

**tham/hây causatives in Thai:**

1. “Saakhaa tham krácok têrek dooy tańçay.
   Saka cause mirror break by intend

2. Saakhaa hây ñek win dooy tańçay.
   Saka have child run by intend

3. Saakhaa tham hây kawñí lôm dooy tańçay.
   Saka cause have chair fall by intend


---

(1) This glass breaks easily.
   \[ TP \text{this glass} T [\text{V1 IMP V1} [\text{V2 V2} [\text{V3 breaks this glass}]]] \]

(2) This glass suddenly broke.
   \[ TP \text{this glass} T [\text{V1} [\text{V2 IMP V2} [\text{V3 breaks this glass}]]] \]

<table>
<thead>
<tr>
<th>Middles</th>
<th>implicit Agent</th>
<th>Generically quantified</th>
<th>+stative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ergatives</td>
<td>(implicit Causer)</td>
<td>Existentially quantified</td>
<td>+eventive</td>
</tr>
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</table>

“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: \[ x \text{ CAUSE } [ y \text{ HAVE } z ] \]

Layerd VP:                                Flat VP:
\[ v \]
\[ P \]
\[ v' \]
\[ John \]
\[ P \]
\[ v' \]
\[ John \]
\[ V \]
\[ Mary \]
\[ a \text{ book} \]

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

Number

Theory of Mind

Recursion

Concepts

Words & Sentences

Scenario #2 (Descent with Modification)

Domain-General Semi-Recursive Capacity

Pre-SM System

Bounded Merge

Pre-CI System

SM System

Unbounded Merge

CI System

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.

Agrammatic but numerate

Rosario A. Vellez™, Nicole C. Woodruff, Charles R. Mervis™, and Michael Stagner™

A central question in cognitive neuroscience is how different areas of the brain interact to produce higher-level cognitive functions such as language and thinking. Recent research suggests that a semi-recursive capacity, which is distributed across different brain regions, may provide the foundation for these higher-level functions. This capacity involves the iterative generation and manipulation of symbolic representations, allowing for the creation of complex structures and the understanding of recursion in language. The study of this capacity has implications for our understanding of human cognition and the evolution of language.
Thank you.

Now, on with the Ghost Walk…