Origins of language:
A conspiracy theory

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Models of Language Class
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I. Introduction: *language is puzzling*

Is language a species-specific adaptation?

All humans acquire and use language, *in all of its complexity*, while no other animals can; similarities in languages and development patterns across cultures; (common patterns in language formation too).

Is language is an **instinct**, a genetically scripted for acquisition and use, as Pinker (1994) claims?

OR is Innateness an over-simplistic explanation?

Genome is required for **all sorts of behaviors,**
Scant evidence of specifically **genetic** linguistic defects
Consider **complexity** of gene function, *versus Pinker's claim*

I. Introduction: *language is puzzling*

Alternative to language instinct:

Connectionist perspective on language acquisition

Biology and development interact to produce lang.
Certain forms of innateness are plausible, others not

Goals: 1. Taxonomy of Innateness
2. Two connectionist simulations
3. How results fit into *Conspiracy Theory*

II. Ways to be innate

What does it mean to be innate?

Innateness would impose constraints on some level:

1. **Representational constraints (*brain-state*)**
   Could genes pre-specify brain circuitry & connectivity?
   Pinker's favorite, but it is the most unlikely…
2. **Architectures: unit, local, global constraints**
   Could genes specify some specific brain hardware for language?
   Maybe connection pattern among modular systems is important…
3. **Chronotopic constraints (timing)**
   Could genes affect endogenous and exogenous interactions?
   Small changes in development could make language happen…

II. Ways to be innate

What does it mean to be innate?

Re-framed in connectionist terms: figure 1

Most specific/direct → Least specific/indirect

Source of constraint		Examples in brains	Examples in networks
Representations		synapses; specific microcircuitry	weights on connections
	unit	cytoarchitecture (neuron types); firing thresholds; transmitter types; heterosynaptic depression; learning rules (e.g., LTP)	activation function; learning algorithm; temperature; momentum; learning rate
Architectures	*local*	number of layers; packing density; recurrence; basic (recurring) cortical circuitry	network type (e.g., recurrent, feedforward); number of layers; number of units in layers
	global	connections between brain regions; location of sensory and motor afferents/efferents	expert networks; separate input/output channels
Timing		number of cell divisions during neurogenesis; spatio-temporal waves of synaptic growth and pruning/decay; temporal development of sensory systems	incremental presentation of data; cell division in growing networks; intrinsic changes resulting from node saturation; adaptive learning rates

III. Problem w. representational innateness

Representational Innateness is wrong

Numbers don't work: Nematodes have identical connectivity, with only 959 neurons. No two humans share exact patterns; we have trillions of synapses.

Recycling: Even for fruit flies, most genes play a role in multiple expressions and interact.

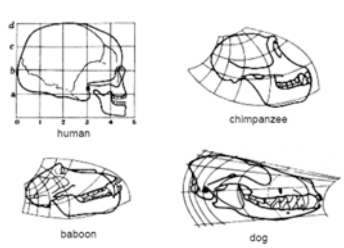
Specifying particular language microcircuits in human brains is too much of a burden for individual genes.

IV. The importance of time

Architectural and timing constraints

In closed systems, **internal timing is critical**

ex 1: *temporal growth gradients: allometric changes in bone length*

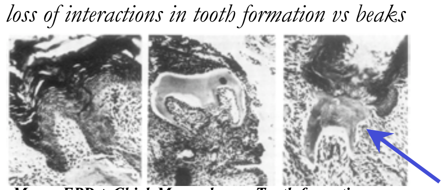


IV. The importance of time

Architectural and timing constraints

In closed systems, **internal timing is critical**

ex 2: *loss of interactions in tooth formation vs beaks*



Mouse EPD + Chick Mesenchyme: Tooth formation

"The ability of chick epithelium to participate in odontogenesis and to secrete enamel matrix proteins suggests that … an alteration in the behavior of cranial neuralcrest cells must have blocked the initiation of tooth development…" – Kollar & Fisher (1980)

V. The importance of starting small

Children must learn to communicate

Symbolic activity: function decoupled from content

Symbols have an arbitrary correspondence to referents

Structures have a complex relation to constiuents

1. Theory of Semantics: meaning from sentence constituents

2. Theory of Syntax: what sort of structures are grammatical

Embedded information can then be successfully detangled:

The cat who the dogs **chase** runs toward me.

V. The importance of starting small

Embedding is plausible candidate for innate language ability.

Gold's Proof (1967)

Embedding cannot be learned inductively using positive input only. *Violations should occur, then be corrected or identified.*

Direct negative evidence is not present.

(*parents ignore children's grammar, tend toward truthfulness*)

Critical knowledge about grammar must be innate.

Learning involves fine-tuning child's UG to environment.

How specific is constraint to learn embedding?

Do constraints even need to be of a linguistic sort?

V. The importance of starting small

Artificial Language Time!

1. **Grammatical categories:** words belonged to diff categories (eg. noun, verb, etc.)
2. **Basic sentence structure:** noun followed by a verb; transitive verbs followed by a second noun (eg. cat chased dog)
3. **number agreement between subject noun & verb** (eg. cat runs, dogs chase)
4. **verb argument structure:** some verbs transitive; others intransitive; others were optionally transitive (eg. lions eat vs. lions eat dogs)
5. **relative clauses:** nouns could be modified by a relative clause (e.g., who the dogs chase); both subject relatives (girl who sees the boy) and object relatives (girl who the boys see) were possible.

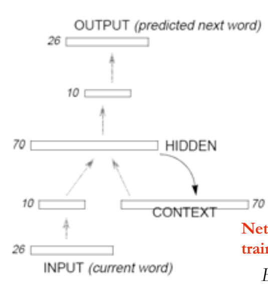
Elman used these rules to generated a bunch of non-repeating artificial sentences in the form of orthogonal [0,1] sentence vectors (each entry is a random word in the artificial language).

ex. sentence: **[00010000001100000000000000]**

V. The importance of starting small

Can network **learn embedding** from positive evidence?

ex. sentence: **[00010000001100000000000000]**



Simple recurrent network used for prediction task

Rectangles: layer of nodes

Arrows: connections between layers.

Broken lines: changing weights.

Solid line: fixed weight = 1.

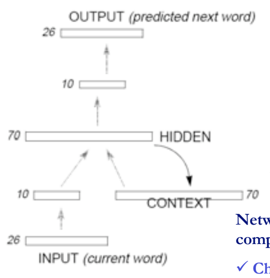
Network failed even to predict words from the training sets. Relative clause number agreement:

*Ex. The boys who the girl*chase see the dog.*

V. The importance of starting small

Network learns embedding with increasingly complex sets

ex. sentence: [00010000001100000000000000]



FIVE EPOCHS: 10k Sentences Each

1) 100% Simple Sentences
2) 75:25 Ratio Simple:Complex sentences
3) 50:50 Ratio Simple:Complex sentences
4) 25:75 Ratio Simple:Complex sentences
5) 100% Complex sentences

Network predicts grammatical output for complex and simple sentences.

✓ Children start w producing simple sentences

✗ *but their input is usually complex*

V. The importance of starting small

A reasonable way to limit input complexity?

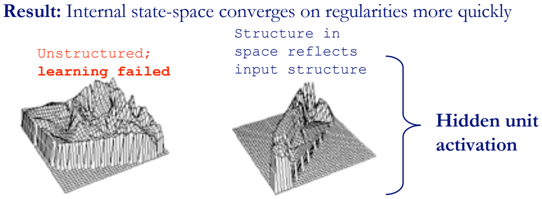
Sentences do not change, but child's internal abilities do change.

Children do not start with mature memory or perceptual systems.

Interaction of available resources and language learning

1. Limited but expanding capacity for context
2 Noisy input, but decrease noise over time

Result: Internal state-space converges on regularities more quickly



V. The importance of starting small

Timing-Structure interact in language acquisition

Development of memory capacity and perception can **limit search space** enough for learning to succeed.

Limitations instead of a specialized acquisition system that *comes on-line*

Less is more: critical periods as mature systems settling on unstructured solutions – *too many possibilities.*

Evidence from the kinds of error at different stages of maturity:

Adult L2 learners: incomplete control, frozen morphology

Young native learners: errors of omission

VI. Where cortical structure comes from

Functionally specialized *language* areas in cortex

First simulation demonstrates that developmental *constraints* could explain acquisition pattern instead of an *innate LAD.*

BUT how does specific functional organization arise *across individuals*, if the architecture is not pre-specified genetically?

Innate architecture or convergent development?

VI. Where cortical structure comes from

Convergence: Shrager & Johnson's XOR Model

Fun Biological Facts:

Cortex begins with **high pluripotentiality**, and over time becomes a cascade of specialized, nearly modular filters.

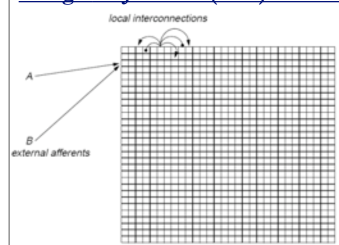
Arborization and thinning begin in primary sensory and motor areas, and spread anteriorly through the cortex from ages 4-25.

Changes do not happen everywhere simultaneously - do functional specializations result from *trophic waves of plasticity*?

VI. Where cortical structure comes from

Convergence: Shrager & Johnson's XOR Model

Shrager & Johnson (1996) Model:



30x30 Instant Cortex

A, B: Send input to all neurons

Each neuron also sends output to nearby units.

Each neuron receives external input, plus neighbor-transformed input

Hebbian Learning Rule: strength grows among correlated-output units

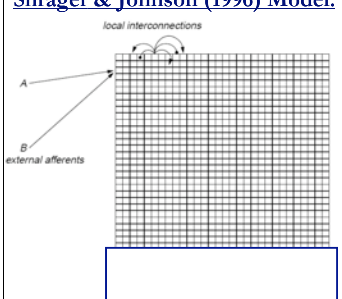
Units develop functions:

AND and OR, But not XOR

VI. Where cortical structure comes from

Convergence: Shrager & Johnson's XOR Model

Shrager & Johnson (1996) Model:



Trophic Wave Component

Leftward columns change first, while holding rightward columns static.

Then freeze left-most columns, and allow next column to learn.

Results in spatially distributed, functionally distinct areas.

Primary change: lower-level detection
AND, OR, not XOR

Subsequent areas: higher-level
AND, OR, A>=B, ~[A and B], etc.

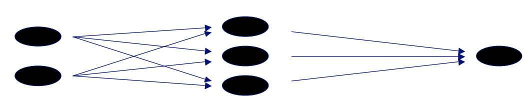
VI. Where cortical structure comes from

Spatial Trophic Plasticity Waves

Shrager & Johnson found that first order functions present in fast traveling trophic waves, second order functions increase with slow trophic waves.

Rebotier & Elman replicated that result, and found XOR detectors using a spatial wave of trophic change.

Demonstrates that powerful non-linear relationships could be learned with plausible unsupervised Hebbian learning over time and space.



VII. Conclusion

Conspiracy Theory of Language

Language is unique to human species, and it takes a constrained set of possible forms. But this is not evidence for a radical evolutionary change, or a *language gene,* per se.

Biological basis of language be can explained

1. Nonlinear effects of **small developmental changes** on outcome
2. Conservative genome, nature of **interactions** within development

Phenotypic variation, even if a single gene leads to it – involves complex interplay of developmental and regulatory mechanisms

Tweaks and twiddles in communicative behaviors are allometric in nature

Account of the processes involved in language is the ultimate goal