Beyond the symbols vs signals debate

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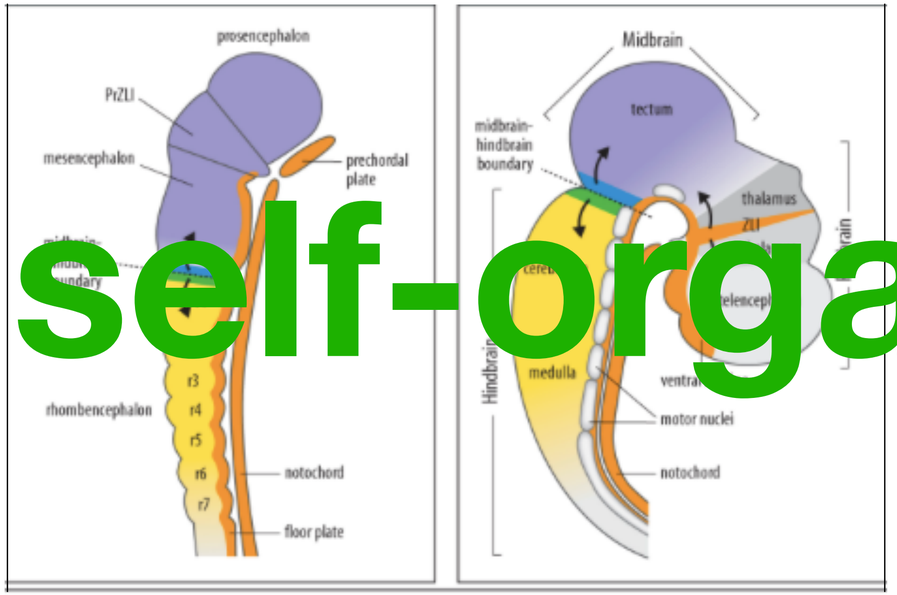
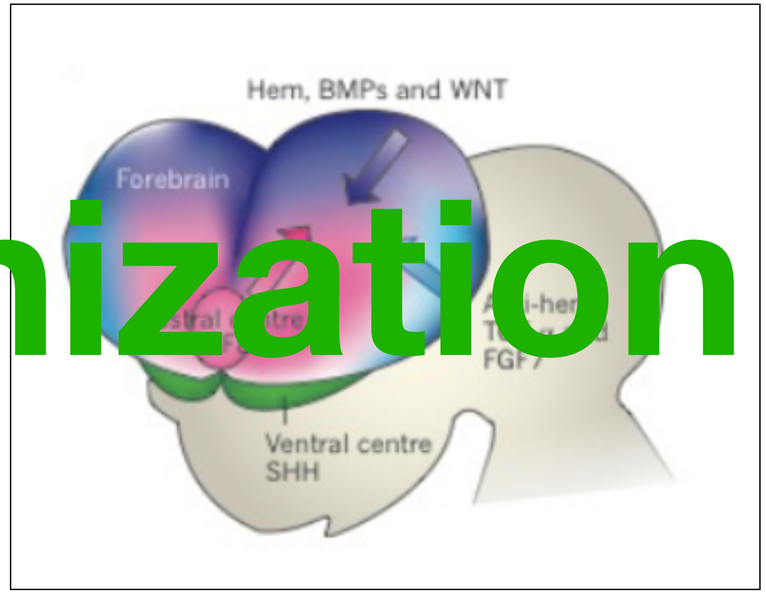
Neither nature nor nurture
The semiotic infrastructure of symbolic reference

Terrence Deacon, U C Berkeley

1. self-organization

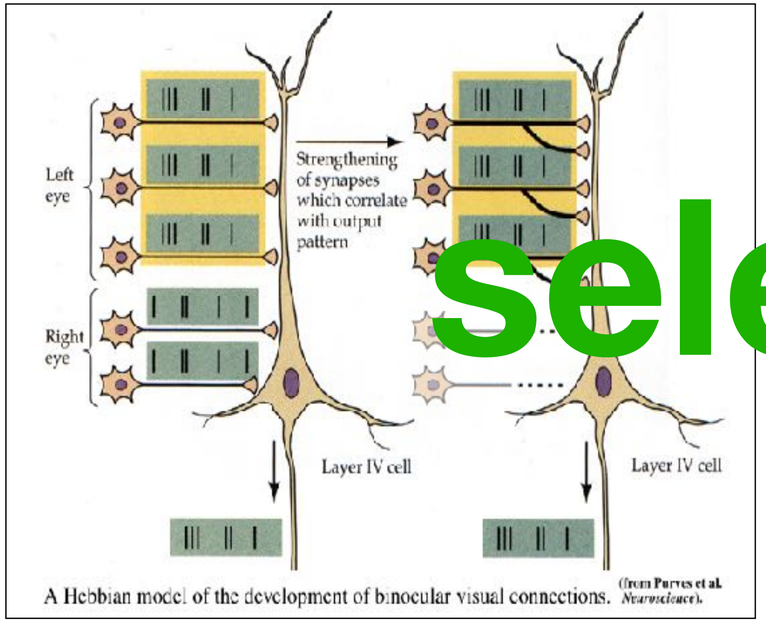


Fgf8 Wnt Shh Gbx2 Otx2 gene partitioning

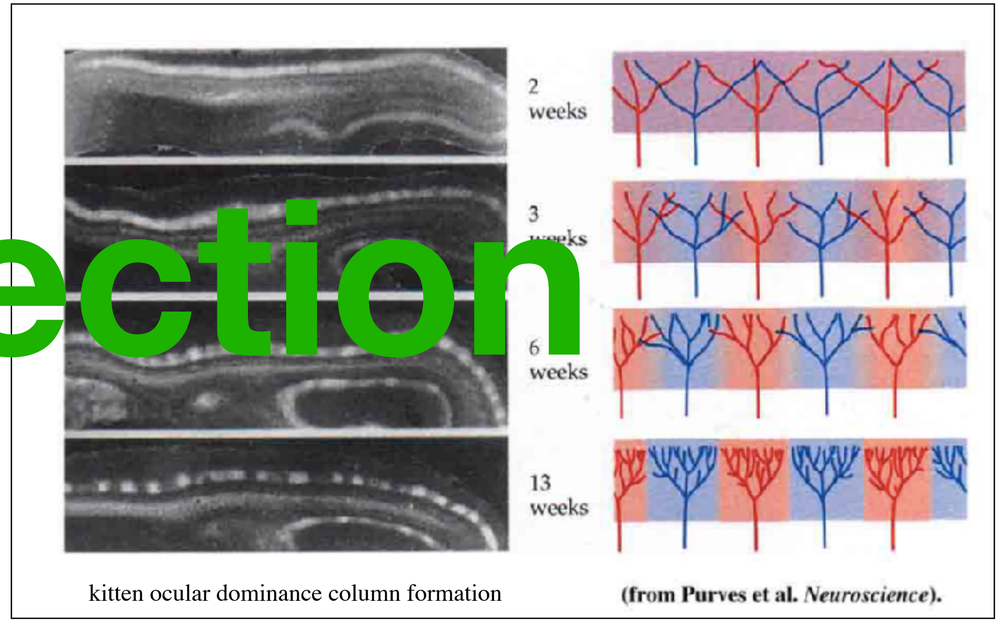


combinatorial gene expression gradient overlap in cortex

2. selection

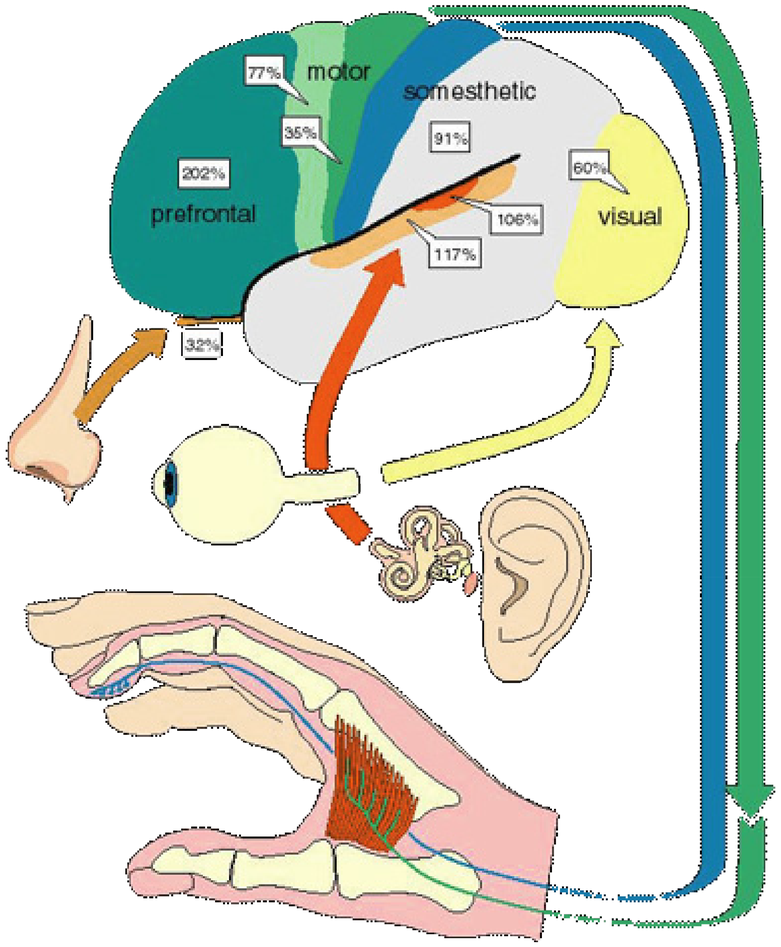


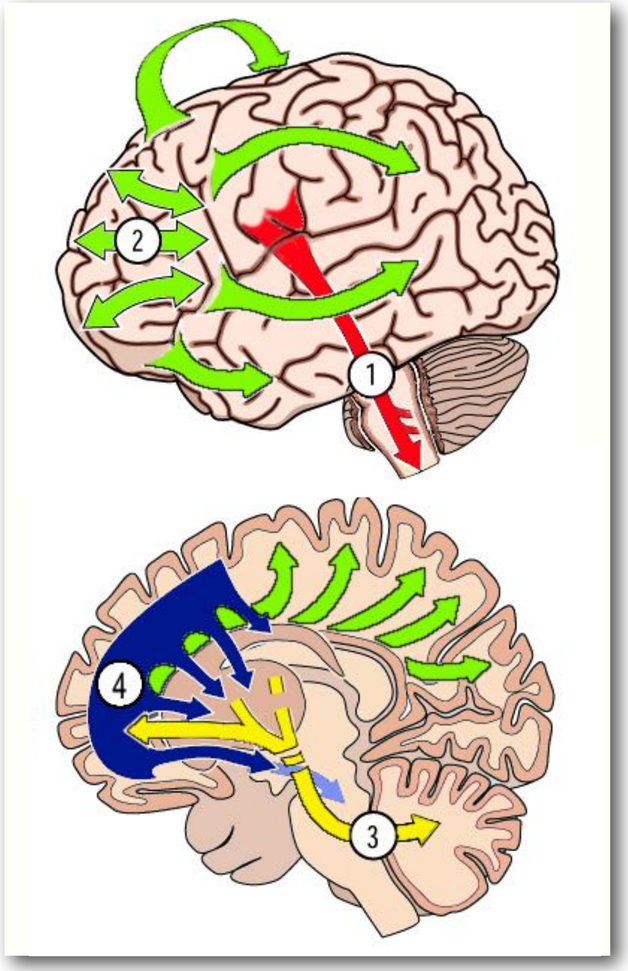
synaptic competition, axonal elimination, apoptosis



initial exuberant projections become progressively restricted

Competitive shifts in connectivity?





Embryological divergence of brain/body proportions should affect axonal competition, favoring connections from relatively enlarged structures.

= reduced peripheral representations (left), cortical recruitment of visceral motor targets (1), prefrontal dominance (2, 4), greater cortico-cerebellar connectivity (3).

why can a chimpanzee do better than humans?

shorter inspection time = higher g

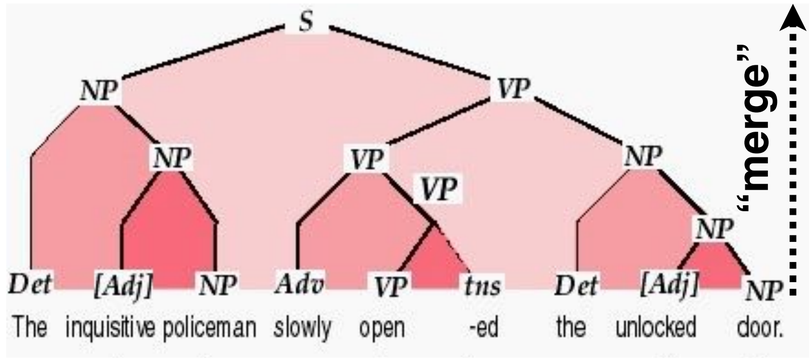
Reusing old systems in new combinations

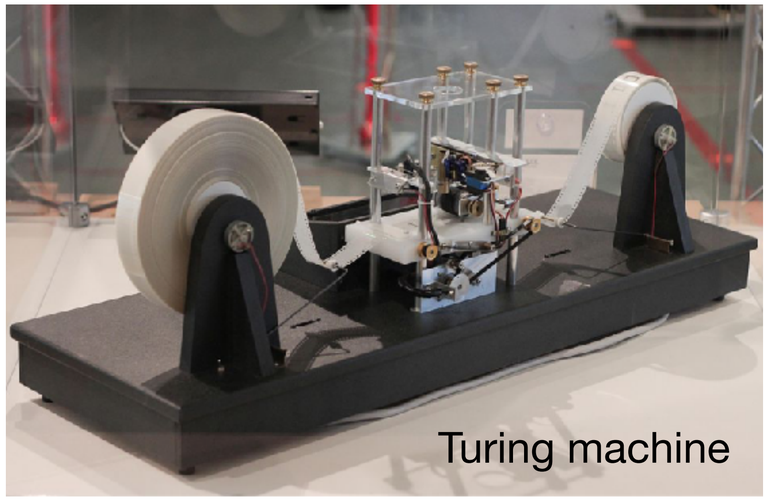
Although language-specific functions are localized, the generation and interpretation of meaning is not localized to only a few cortical areas but involves *complex relations between multiple cortical areas that previously evolved to serve other functions* but are now recruited to aid this novel task.

NO NEW CORTICAL AREAS

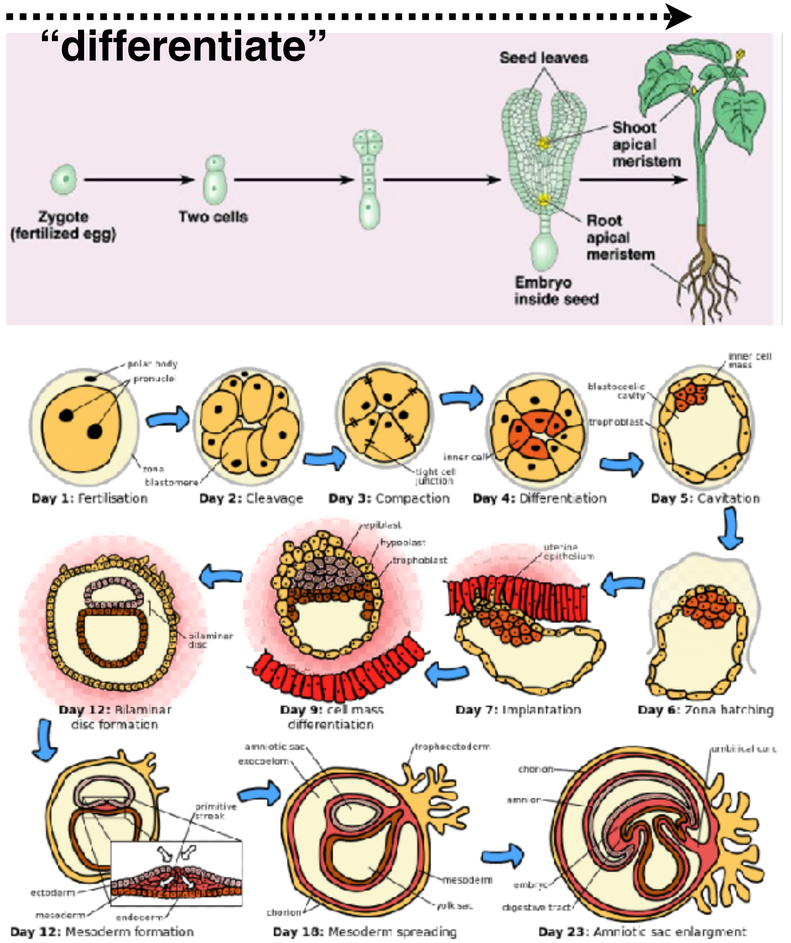
"Natural speech reveals the semantic maps that tile human cerebral cortex." Huth et al. Nature, 2016

Engineering logic vs organic logic



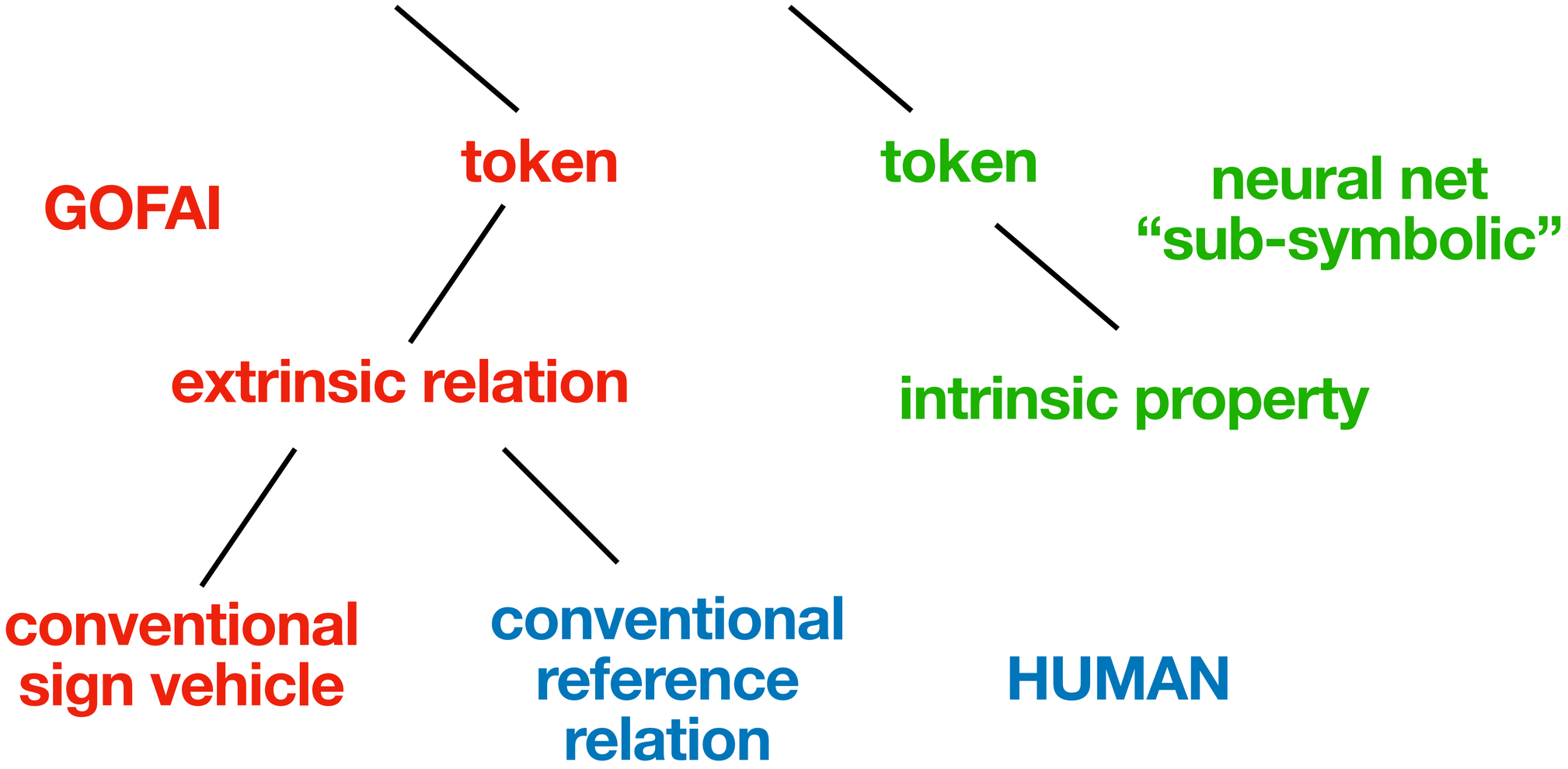


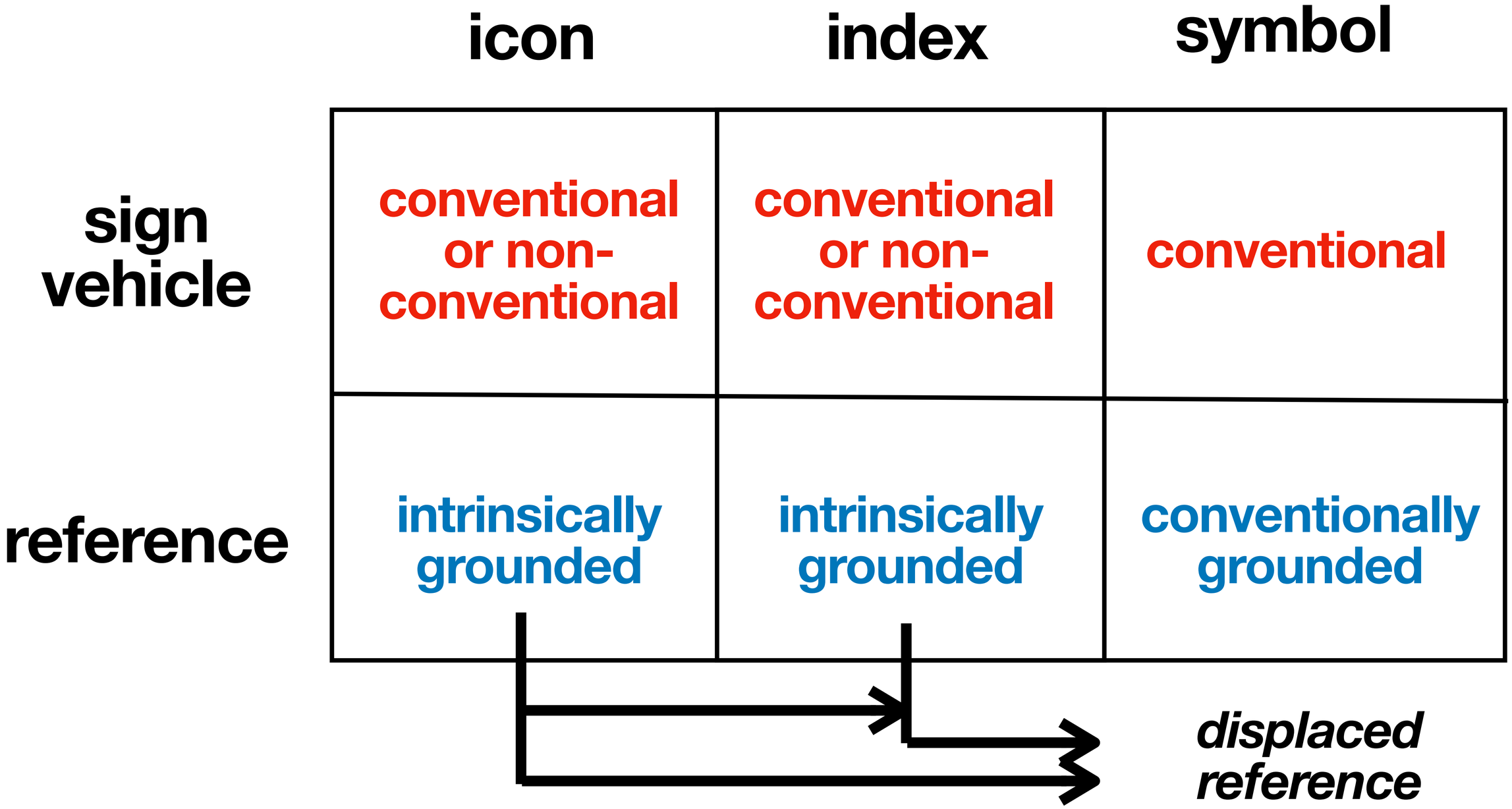
ASSEMBLY: Parts precede the whole, step-by-step additive assembly, function emerges after completion



DIFFERENTIATION: Whole precedes the parts, parts differentiate via interaction, continuously functioning

symbol / signal confusions




icon
index
symbol
sign vehicle
reference
conventional or non-conventional
conventional or non-conventional
conventional
intrinsically grounded
intrinsically grounded
conventionally grounded
displaced reference

Naive semiotics

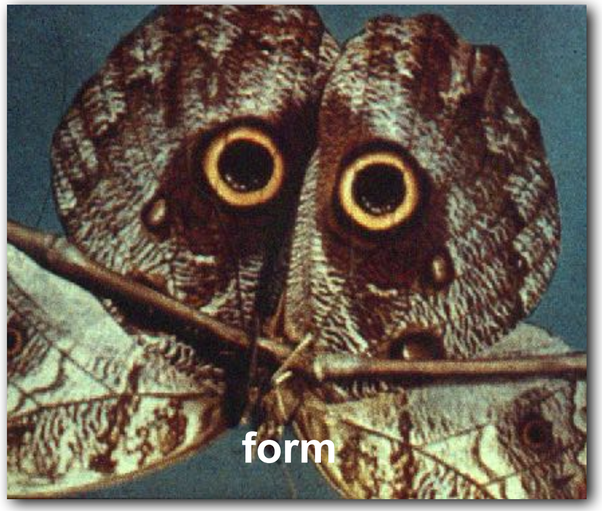
- Symbolic reference is often distinguished from iconic and indexical modes of reference in terms of an "arbitrary" mapping to its referent; a negative attribute.
- But some degree of arbitrarity is characteristic of all modes of reference, nor is being a conventional type of token sufficient to define symbolic reference; e.g., is ;-D symbolic?
- This begs the question of what distinguishes symbolic interpretation from iconic and indexical interpretation and how they are related to one another, as well how all are related to the physical signal properties that provide the interpretive affordances that are chosen as referential cues.

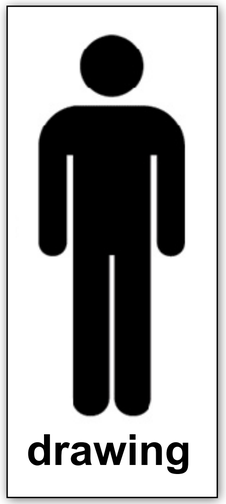
The concept of semiotic ground

- The fundamental problem of epistemology is explaining how sign vehicles can provide causally useful *connection to properties of objects and processes in the physical world*.
- This has traditionally been described as the *"symbol grounding problem"* * in which the "ground" is the real-world foundation which supports the representation relation.
- The two major affordances for intrinsic grounding are 1 shared formal properties between sign vehicle and object (*iconicity*), and 2 physical-temporal correlation or contiguity (*indexicality*).

* Harnad 1990

Semiotically “grounded” forms of reference





icon (form)

indices (correlation)

- Both iconic and indexical interpretive processes are “grounded” (i.e., linked to an external referent) by sign vehicle properties that are shared in some respect with what the signs refer to.
- Sign vehicle properties can thus invoke reference by cuing interpretants that share these properties.

Symbols are “ungrounded” sign vehicles

- Sign vehicle properties shared in common with what is referred to are ***irrelevant*** for interpreting symbols. Tokens refer only by convention.
- ***Convention*** is itself a semiotic relationship that must be constructed using already grounded semiotic processes.
- This ***displacement*** from grounding affords unrestricted referential possibility but at the cost of no clues to help ground reference

Establishing a convention via prior semiosis

- The philosopher David Hume used the analogy of rowers in a boat prevented from explicitly communicating to demonstrate *how* ***implicit conventionality*** *can emerge*
- The establishment of a solution to ***a coordination problem*** is intrinsically semiotic even if none of the participants explicitly communicates about it.
- Participants implicitly interpret the responses of others as ***indices*** of the other's intentions.
- These ***unintended indices*** afford predictions that the participants use to discover shared goals and to develop shared and complementary habits to achieve them.

interpretive scaffolding >>> displaced

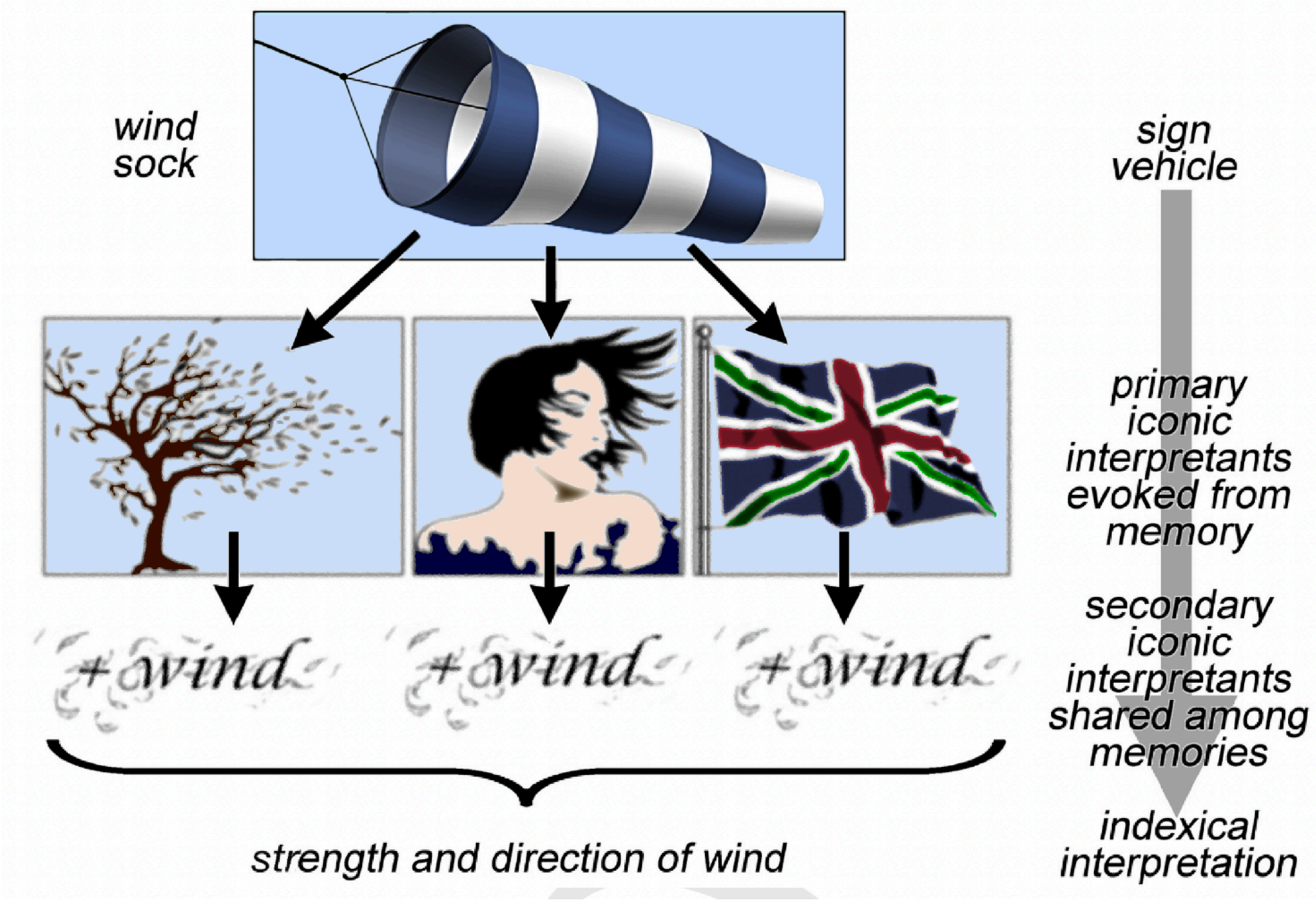
displaced

intrinsically grounded

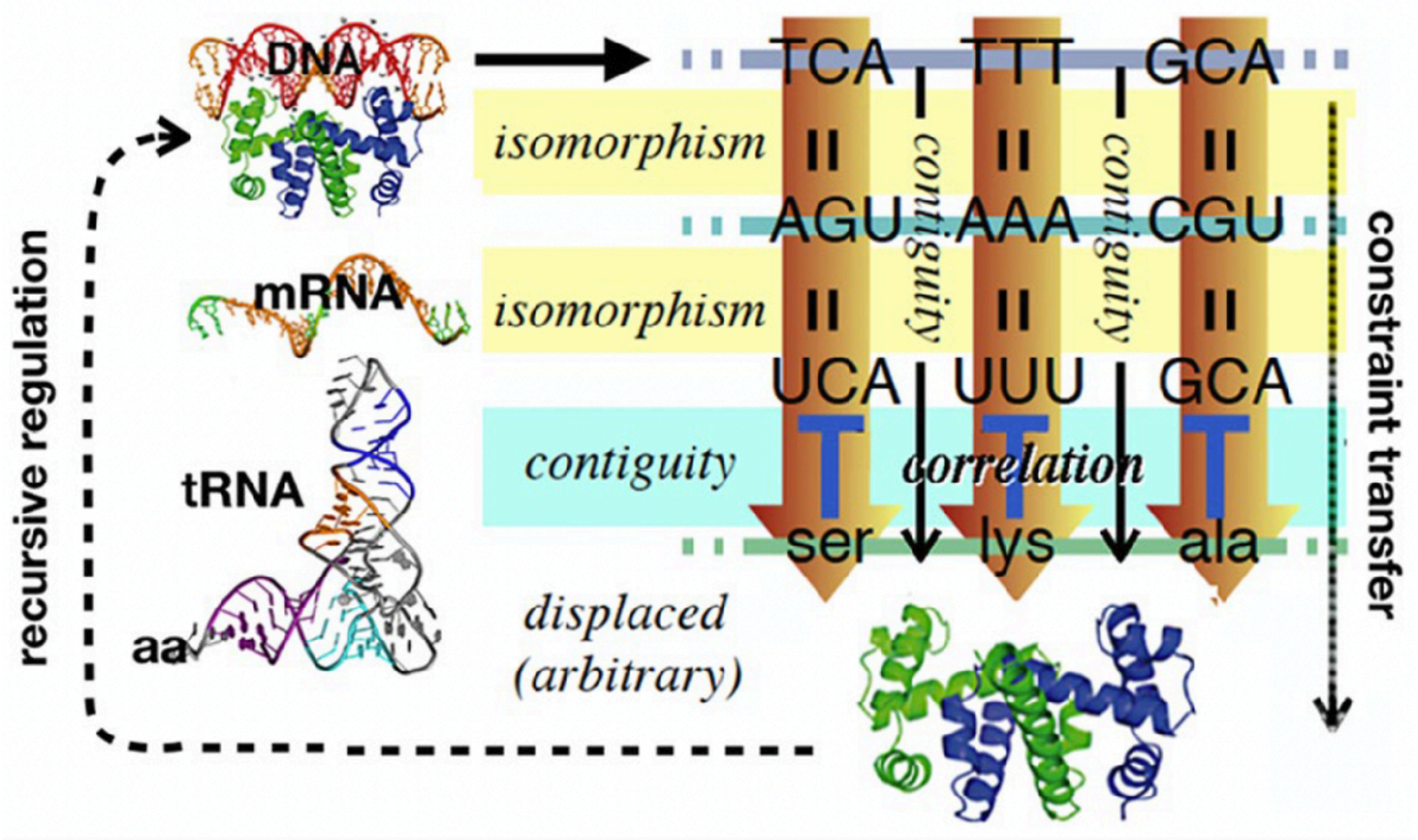
(symbolic)

(indexical)

(iconic)


wind sock
sign vehicle
primary iconic interpretants evoked from memory
secondary iconic interpretants shared among memories
indexical interpretation
+wind
+wind
+wind
strength and direction of wind

DNA structure is displaced from function



displacement requires isomorphic (iconic) and correlational (indexical) mediation
displacement dissociates semiotic constraints and introduces novel affordances
that can provide a recursive level of isomorphic and correlational relations

sound iconism

iconism

iconism

iconism

“boy” “boy” “boy”

“eat” “eat” “eat”

“fruit” “fruit” “fruit”

iconism of indexing

iconism

abduction: implicit injunction to discover the non-obvious iconism among the co-indexed referents

index index index index index index index index index

indexical linking

contrasting instances

cryptic iconism

iconism?

iconism?

iconism?

by ignoring contrasting properties

Neither nature nor nurture

- The concept of a “universal grammar” has been hotly contested over the past half century.
- What is the source of the many convergent language structures in the worlds many diverse languages?
- *But nature and nurture do not exhaust the possible sources.*
- *Not “rules” (assembly instructions) but minimizing referential ambiguity due to constraints on iconic and indexical differentiation*
- *Universal grammatical constraints* are effectively “discovered” in the history of linguistic evolution and change and during process of language acquisition, analogous to the discovery of math universals.
- Analogous to mathematical universals.

Major classes of “universal” language constraints

Semiotic constraints

1. Recursive affordance (displacement removes intrinsic affordance constraints)
2. Predication structure (symbols must be index-linked)
3. Quantification (symbolized indices need re-specification)
4. Embedding constraints (indexicality requires immediate correlation/contiguity)

Processing constraints due to real time interpretation requirement

5. Chunking-branching condensation (mnemonic constraint)
6. Algorithmic regularization (diadic aids to automatization)

Social communication constraints

7. Discourse asymmetries and pragmatic requirements

Sensorimotor schemas & phylogenetic biases

8. Standard schema/frame units (via cognitive borrowing)
9. Optimizing medium replicability (e.g. vocal takeover)

inference as higher order displaced semiosis

cancel the redundant term

ICON

Given: Socrates is a man

Known: Every man is mortal

Inferred: Socrates is mortal

infer the remaining correlation

INDEX

deduction (necessary)

Given: ~~Socrates is mortal~~

Known: Every man is ~~mortal~~

Inferred: Socrates is a man

abduction (possible)

= prediction irrespective of reference

Given: Socrates is mortal

Given: Socrates is a man

Inferred: Every man is mortal

induction (probable)

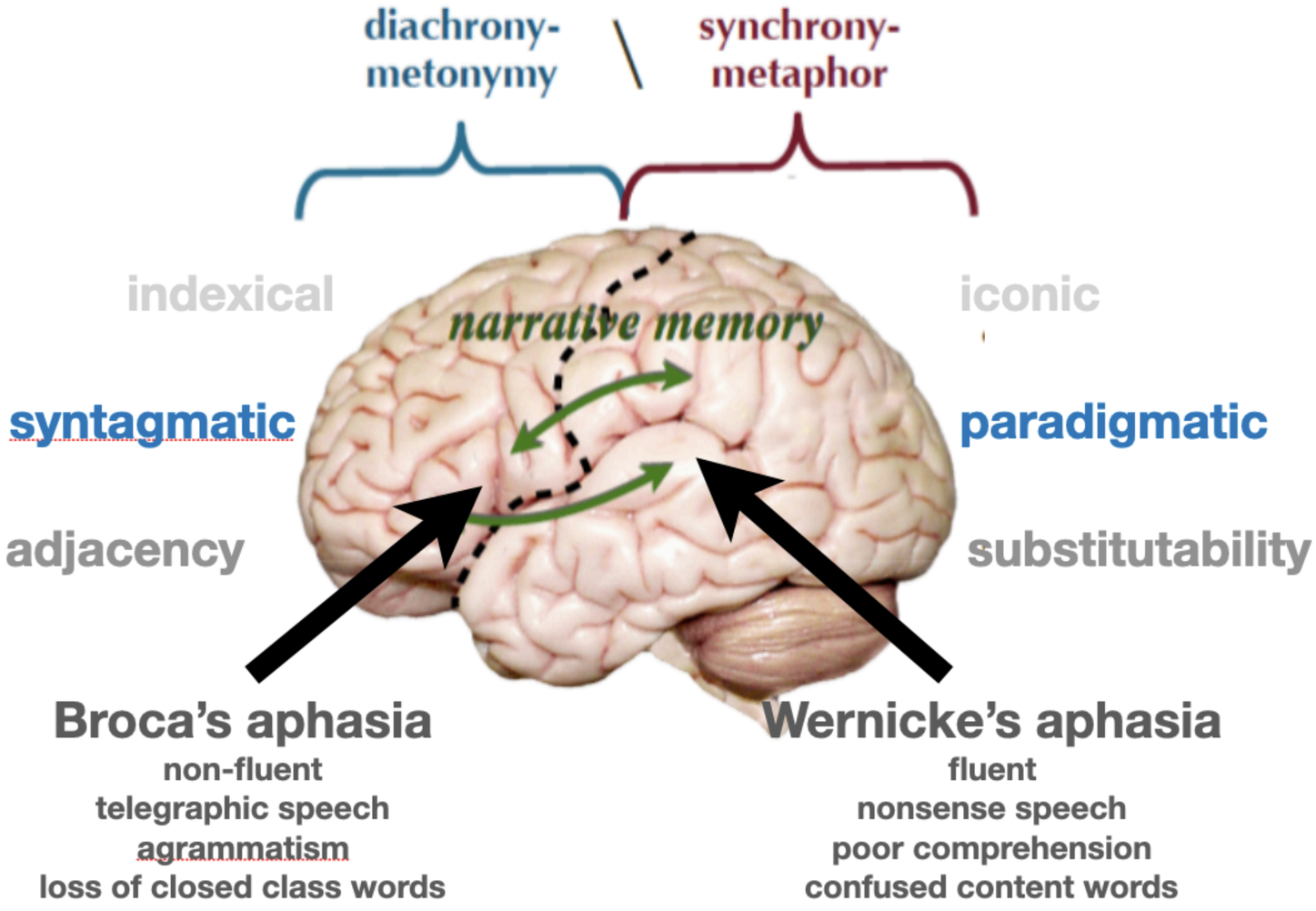
implications for the neurology of language

- Child language acquisition is the inverse of LLM self-supervised learning
- minimal training data vs maximal training data
- human mnemonic-attentional limitations and real time processing demands => evolution of automatization & language area specialization to minimize semiotic processing depth
- under what circumstances is bottom-up differentiation better or worse than top-down prediction-assembly?

Jakobson's orthogonal semiotic operations

paradigmatic
axis of selection

syntagmatic
axis of combination

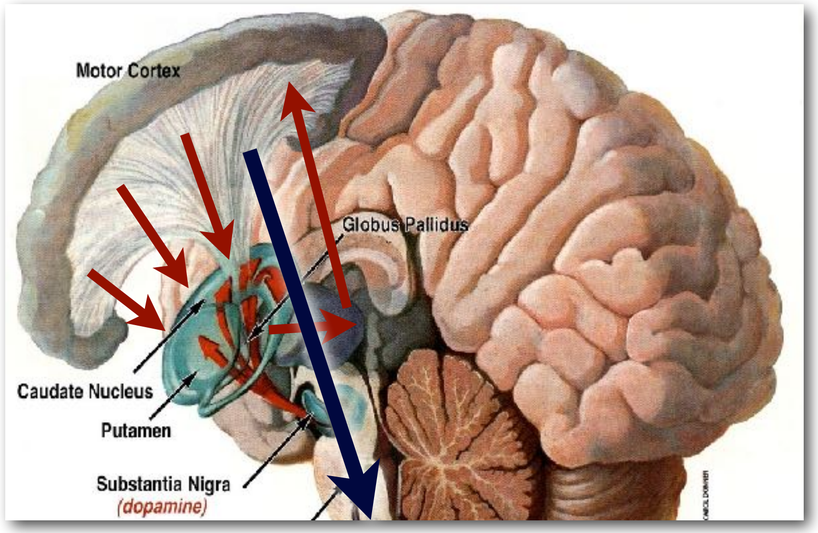


automatizing

- displacement enables sign-vehicle simplification
- maximal reduction of token features to 0/1 digital distinction
- enables extremely rapid token manipulation = computation
- this allows AIs and other LLMs to make statistically realistic predictions irrespective of referential grounding
- Depending on the size and diversity of the training data, the recursive depth of training, and the size of working memory (attentional frame) there can be asymptotic approach to fully re-groundable symbolic communication.

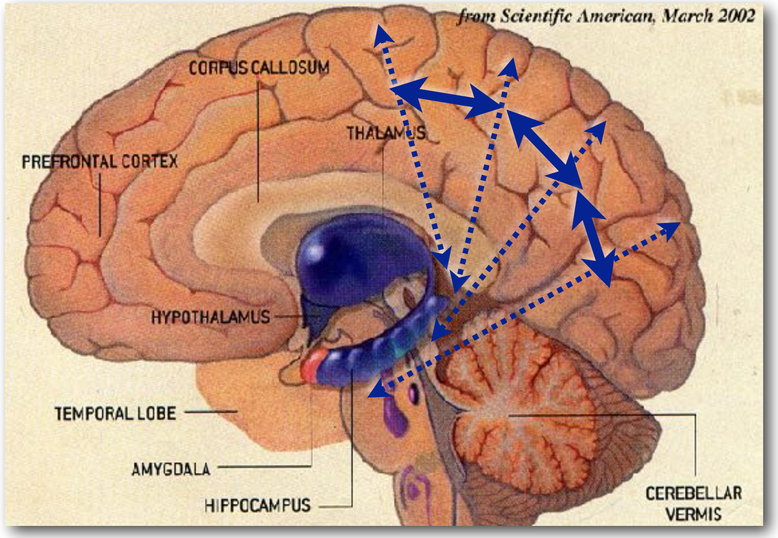
Mutually exclusive memory systems

Procedural (skill) memory



Frontal-striatal-cerebellar circuit creates memory traces for skilled action by constant repetition & fine tuning

Episodic (declarative) memory



Sensory-hippocampal circuit creates memory traces for singular experiences by multiple correlations of features

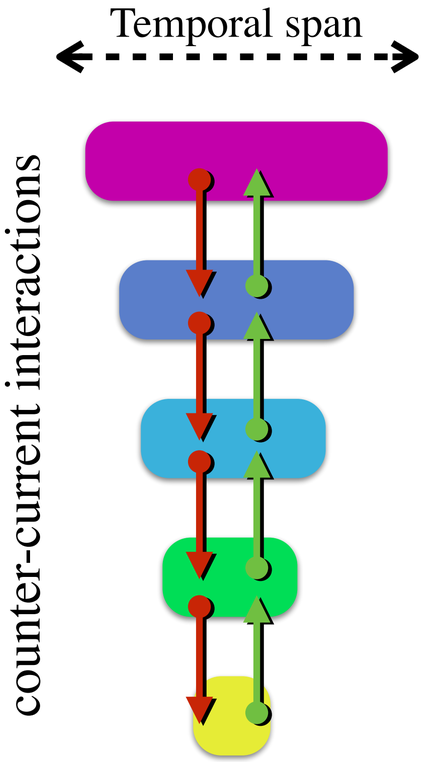
How language restructures memory

Procedural (skill) memory **Episodic (declarative) memory**

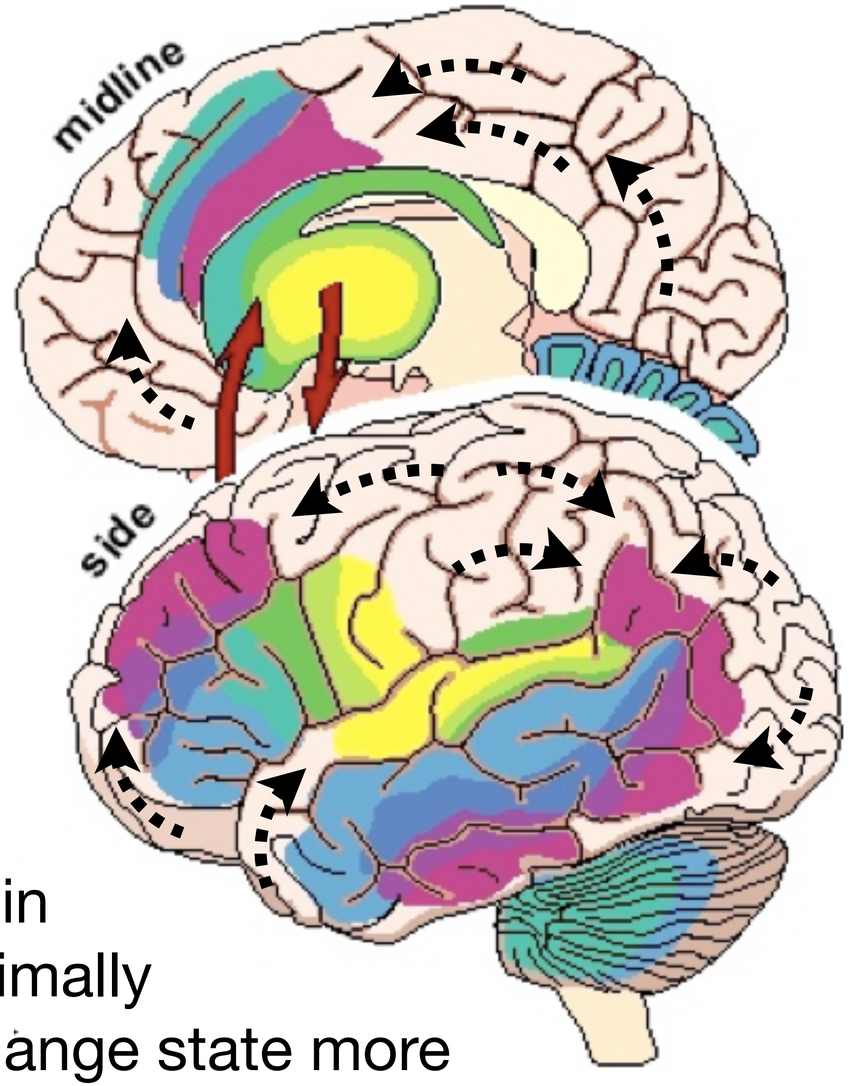
- Articulatory and syntactical combinatorial skills are acquired procedurally and semantic relationships are acquired episodically.
- Language allows each mnemonic system to reciprocally cue the other.

= *Narrative memory provides the mental framework for organizing large lists, etc.; identity, explanation, description, planning, theorizing, …*

Sentence differentiation in nested temporal frames



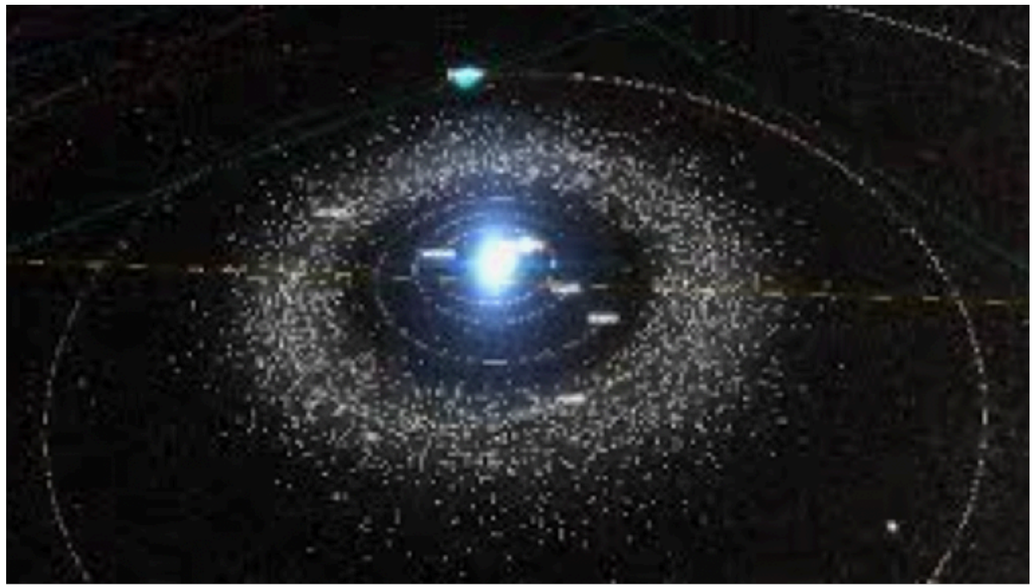
arousal
intention
undifferentiated
proto-abstract
conceptual
semantic
morphological
syntactic
phonological
articulatory



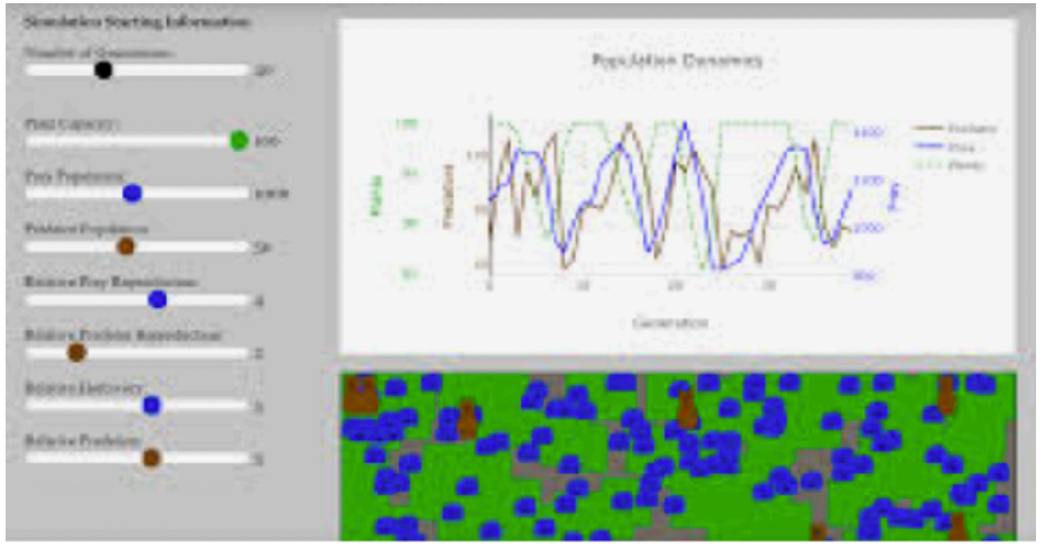
Language production and comprehension requires that different cortical areas function in parallel within different temporal frames. Minimally differentiated processes near limbic areas change state more slowly than highly differentiated processes near peripherally specialized areas. Language *reuses* sensorimotor architecture a higher order level.

AI grounding problem?

- Because it only has access to the system of iconic and indexical relations of already displaced semiotic artifacts the "simulated" intelligence of LLMs is hermetically insulated from the pragmatic semiosis that produced its generative constraints.

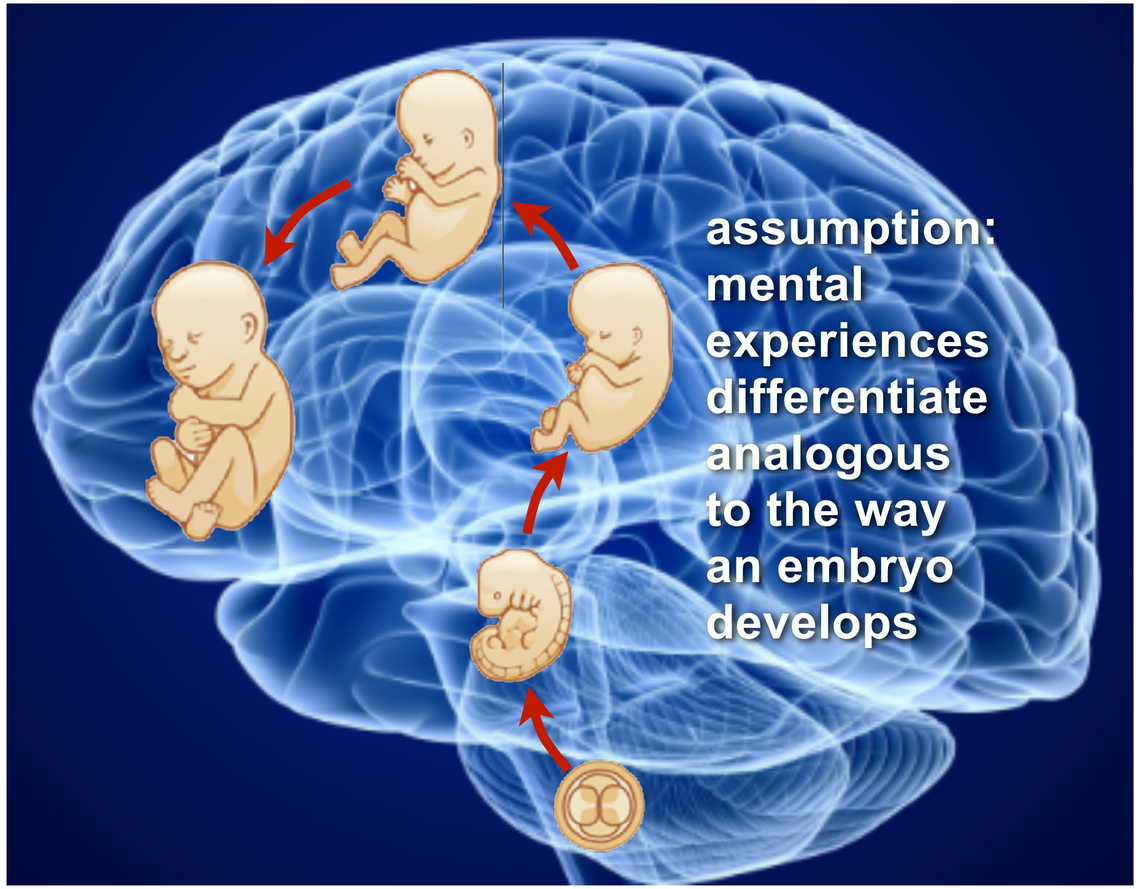


- Like a highly accurate simulation of galaxy formation which lacks mass, gravitation, nuclear fusion, movement, etc. the simulated sentence generation of LLMs lacks meaning and reference, but can still be interpretable and informative. Does the difference matter?



Re-biologizing cognition

- LLMs generate output using a top-down assembly logic, based on the prior token sequence (compare to the hypothetical “Merge” logic of Chomsky)
- Neurological language production and interpretation use bottom-up differentiation logic, emerging from an undifferentiated sensori-motor-mnemonic precursor, analogous to embryogenesis.
- The-linguistic ground from which a sentence is generated is undifferentiated and distributed across many structures



Simulated language interpretation

- Recruitment of whole brain (sentence differentiation & pre-sentence)
- The segregation of language-specific processing areas from other areas evolved in response to biological limitations of mnemonic capacity, processing rate, and the requirement that interpretive processes must be rapidly completed and replaced
- LLMs can simulate the production of grounded language responses because their high-dimensional long-distance Markovian statistics preserves the global pragmatic discourse-communication constraints that were the major causes of the structure in the petabytes of training data
- As a result its token-string generation can be humanly re-grounded by human interpretation despite the fact that the LLM responses are not generated from an intrinsic grounding.