

Basal Ganglia Grammar*

The Neuronal Substrate as Common-Denominator Interface for Language

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So, as the story goes... ‘Some forty-thousand years ago (KYA) our perfect anatomy twin (Cro-magnum) got up and *wanted* to speak’. It goes without saying that this is indeed a very recent turn of events in the long trajectory of the development of our species. The notion of ‘wanted’ is of interest. What is typical of cultural-motivating norms these days is the belief that *capacity* follows *desire*, i.e., you just need to ‘want’ to do it badly enough for it to ‘happen’ (as the Nike logo goes, ‘Just do it’). Well, in biological evolutionary-developmental (evo-devo) terms, it’s quite the reverse: desire follows capacity². The cliché ‘You can do anything you put your mind to’ means exactly that: first, you must be *able* to put your mind to it. So, some 40-60KYA early modern man *wanted* to speak—just because *he could*. There are several theories and hypotheses about how this came about, with the spectrum ranging from external social interaction (Functionalism) to an internal innately driven language faculty providing a language algorithm (Generative), or, from slow gradual emergence to quick punctuated equilibrium. In any case, there is a *common-denominator interface* which holds for all such theories of language evolution—namely, that there must have been some newly-acquired ability, genetically predisposed or otherwise acquired via maturation (or saltation) which created this unique capacity for language. To be sure, there are plenty of antecedents as found in the evo-devo literature which may serve as evolutionary precursors to full fledge language: e.g., the abilities to mimic, trace, keep tempo, maintain hand-eye coordination, fashion tools, predict from a pattern, follow from analogy, etc. The holy grail of such antecedents is what is often referred to as ‘Theory of Mind’—viz., humans’ unique ability to empathize, be altruistic, be able to feel how another might feel and think *without recourse to the actual stimuli of the other*. In a sense, this holy grail (which some say leads to human consciousness) amounts to the ability to *categorize & abstract*. There is nothing in our physical nature which would suggest such exquisite behavior—it is an exclusively mental phenomenon.

*I was lucky enough to come across ‘*the grammar of the Basal Ganglia*’ in reading Lieberman’s 2006 model which largely attributes language to human outsized cortical growth with the afforded supplemental space deemed necessary to create overlapping neural circuitry connected to the basal ganglia. While Lieberman’s work is skeptical of the claim ‘language is special’ (believing there are anatomically homologous structures found across species), I believe an extension of his ‘Basal-Ganglia’ model jibs nicely with the Hauser et al. 2002 model which delimits ‘broad’ forms of the faculty of language (FLb) (voice, semantics, motor-control) with that of ‘narrow’ forms (FLn)—the latter of which cortical *recursive syntax along with its substrates is the predominant if not the sole component*. (Also see Friederici, Chomsky et al. 2017).

¹ <https://csun.academia.edu/josephgalasso> (Draft July 17, 2023). I thank Andrea Moro for pc. on this note.

² See my ‘Myth’ paper (2020). (There is an interesting caveat to this: Humans’ successful desire to fly, over a hundred years ago. In this case, humans were able to circumvent their physiological constraints for flight by creating a ‘work-around’ away from *bodily* flight towards *mental* flight. Because we could ‘think’ flight, we did so. In a sense, we hijacked the long-winding path of evolution of ‘physicality’ with this abstract shortcut of ‘mentality’: Humans ‘thought’ to fly, and so they did (to the heavens and beyond...while always leaving their humanoid forms firmly tethered to the ground). These unique ‘workarounds’ which fly in the face of evolutionary biology is the greatest feat humans have ever performed—and is tantamount to the recursiveness as found in humans’ unique ‘tool-making capacity’: [a tool [that can make a tool [that can make a tool]]]... *ad infinitum*.

The ideas herein are meant to only serve as a springboard for future researchers whose intention is to largely support a 'basal-ganglia-account' of human's unique ability for recursive syntax.

What follows is a brief research statement of what I think may be a neural 'common-denominator' behind all these inner-workings leading to language—namely, 'the *Basal Ganglia*' (BG), a subcortical region of the brain not dissimilar to what we know and find of the *insular cortex*, which serves as a switchboard-like operator for all inputs coming in from different regions of the brain, to be sorted and allocated—the accumulation of which leads to the manifestation of language (see e.g., Liebermann 2002/2006). Foremost in importance among these BG inner-workings is the ability for *movement*. For example, in Parkinson's disease we see BG neurological impairment leading not only to loss of *physical* 'noisy' movement control (Huntington's dance), but also to deficits in *mental* movement (so-called 'silent' movement) related to (syntactic) movement-based processes such as long-distance dependences exhorting by the brain/mind (i.e., hierarchical long-distant co-indexing which goes well beyond linear-ABABABA grammars, See Galasso 2023a). (Some of the best studies of such loss of mental, silent movement comes from Broca's Aphasia (BA) subjects who show loss of syntactic movement capabilities.³ Regarding the latter (silent mental movement) there may be similar maturation factors at play in the emergence of early child language syntax)⁴ (The Silent-Unspoken 'language of thought' is a perfect example of such silent movement (see Moro's Lecture)).

Suppose that language, for all of its shrouded glory, is nothing more than a species-specific *incidental acquisition*. We can describe Language-Incidental (LI) this way as a set of procedures which got subsequently established via a dual capacity: i.e., the interface between the actual external stimulus (being observed) and its given internalized proprioceptive-rehearsed representation which got strengthened over rehearsal episodes. (It has now become better understood that the *insular cortex* is quite valuable as a rehearsal mechanism and seems to be implicated as a pathway between short-term working memory and long-term memory)⁵. Hence, LI is a holistic 'external-to-internal' mapping which brings together all relevant compartmentalized language-specific tasks found of the brain. The research claim here amounts to little more than the notion that language (LI) is a byproduct (an *exaptation*) of a dual capacity: the capacity of a species to (i) first have the attention to notice some aspect of the environment, and then the ability to (ii) internally map it (via move-based repetitive rehearsal) to some inner-mental processing (a visual screen if you will). In this manner LI resides as a bridge, as a looping interface between this overt-to-covert (back to overt) procedure. (For repetitive rehearsal procedures as found in the *insular cortex*, see Posner et al. p. 124).

For instance, consider language as sound (phonology). Phonology may start out for an individual as a mere prosodic observable piece of sound, which then becomes mapped by the listener (internal) as a procedural/articulation action-plan. For example, consider the word BOY: the fact that a listener notices and perceives the first-order ambient sound gets you only halfway there—in order for LI to get

³ See Grodzinsky's work regarding syntactic impairment of BA subjects.

⁴ See Galasso, *From Merge to Move* (2016, monograph). The first significant maturational study I ever came across was the Wakefield & Wilcox (1995) study. (Also, see Radford (1990), Galasso (2003) for a maturational theory of child syntax). The idea taken here is that Broca's area suffers delayed onset due to myelination.

⁵ See my paper 'Squibbing against continuity claims...' (2023b) for a discussion on the aspects of *rehearsal* which come to bear on recursive neuronal circuitry. For insular cortex rehearsal, see Posner et al. (p. 124).

established in this minimal case, say, regarding the initial phoneme /b/, there must also be some second-order internal mapping and silent-repetitive rehearsal in order to secure the implemented language function. There must be silent movement. It seems to be the case that while a young child may initially only focus on the sound of an utterance, what the child is actually gaining access to is a simultaneous, internalized action-plan of both how to pronounce that same sound, and how to go about classifying and storing its content: theoretically, the phonologist amongst us sets out the features, say of the initial consonant 'B' /b/: [+voice], [+bilabial], [+plosive]...but these are merely *feature-tags* set out as labels in order to represent, store and retrieve what had been already rehearsed and subsequently acquired. Other than this tacit knowledge of relevant phonological features involved, the real trick to LI is in the features subsequent rehearsal, storage & retrieval mechanisms. (Kuhl's work on the 'Native Language Magnet Theory' shows precisely this—where phonemic targets move from broad to tightly narrow 'phoneme-clusters' over an experiential timespan).

This idea has been around for several years: Michel Paradis (McGill University) speculates⁶ that the interface implicates the basal ganglia, a subcortical part of the brain:

For example, individuals may focus on the acoustic properties of a word while acquiring the proprioceptive programs that allow them to articulate the word, or focus on the meaning of an utterance while internalizing its underlying syntactic form—which is not there to be observed. It is stored implicitly, in that it remains forever opaque to introspection, as is made clear by numerous unsuccessful attempts at characterizing the underlying structure of sentences since the emergence of Chomsky's early work on the representation of syntactic structures. (p 355)

In other words, the notion here is that while an individual may be focusing on the external stimuli, she is simultaneously mapping the external to the internal (a dual processing). In fact, it may very well be the case that almost all of 'what we "think" we perceive' (for all aspects of the world, language included) is nothing more than our unique ability to move from external observation to internal mapping (*unique in the sense that only homo-sapiens seem to have this capacity to move from first-order environmental stimuli to a second-order abstract procedural categorization). (Nb. In its strong version, this theory would have it that we never 'really' even see the *item (as pure object)* in front of us—we instantly *categorize* it, and proceed to map it onto its internal representational scheme even before there is time enough to appreciate its true substantive quality)⁷. Perhaps, in one extreme sense, we are always *doing language* (24/7), whether or not we are listening or speaking. The internal language-mapping screen is set to the 'on-button' 24/7—i.e., we are constantly *talking and listening*

⁶ Among others. See Paradis (2003) 'Cerebral Mechanisms in Bilinguals' (p 355), in *Mind, Brain, and Language: Multidisciplinary Perspectives* (Eds. Marie Banich, Molly Mack. Lawrence Erlbaum Ass. Publishers).

⁷ My favorite example of this can be found in George Santayana's quote: 'A 19th 20th century cognitive perspective would come to show how cued-representations (Icons) could only represent an individual or item, while a detached symbol could stand for an item without the unnecessarily burdening requirement of external stimulation—the former being triggered by direct, environmental stimuli, the latter by a delayed response of its memory. The sign that once expresses an idea will serve to recall it in the future'. Regarding the vision of an object in front of us, say, an 'orange'. Note how we can't make out the total spheric nature of roundness since the backside of the orange is hidden from view. Only through an internal theory of categorization (= round) does the object come to full view. (See Edwin Abbott's 1884 novella 'Flatland' for such wonders).

as a form of *silent movement*⁸. It seems the essential role of the subcortical basal ganglia—a role indeed unique to our newly-emergent species—is to provide a movement-based algorithm allowing this displacement from (i) noticing of item to (ii) mapping, storage & retrieval of category (insofar that this ebb and flow articulates a recursive feedback loop). To my mind, in addition to research presently being carried out on the basal ganglia area (a region which is predominately involved with both physical movement as well as mental movement, language being the quintessential silent movement), *Mirror Neurons* come closest to such an interface, where external stimulation triggers an already mapped trace of the observed behavior (see Corballis 2010, Tettamanti & Moro 2010).

The idea that a singular region of the brain might be largely responsible for language is contested by most neurolinguistics. However, there does seem to be evidence that some form of a ‘neuro loop’ is required in order for language to take hold, and that this recursive loop is what has evolved in our species, some say as early as 40-60KYA. For this internal inner-play to succeed—‘from notice and observation> to mapping> to rehearsal, storage and retrieval...’ begs the question of whether there too are neuro-substrates (so-called ‘neuro-nets’) which undergird such recursive looping. We await for future research into recursive neurons and their implications to regions associated with the basal ganglia.

What we currently know of the Basal Ganglia (BG) and its interface implications to language.

1. In defining language as essentially a *recursive* operation, we can tease out operator distinctions between so-called (broad) ‘recurrent’ ABABABA-grammars of the (AB)ⁿ type (MERGE), [AB], [ABAB], [ABABAB]..., for example what we find in the vertical stacking of lexical/vocabulary learning (noting how linear/adjacency supersedes without hierarchy), versus true language-specific (narrow) ‘recursive’ embedded hierarchy of the AⁿBⁿ type (MOVE): [A[A[AB]B]B]...⁹ of what we find in syntax. (For ‘broad vs narrow’ Faculty of Language (FL) distinctions, see Chomsky 1995; Hauser, Chomsky & Fitch 2002; Fitch & Hauser 2004. Also see Friederici et al. 2006; Friederici 2008, 2009). We find that when there are deficits in recursive grammar such as embedded clause interpretations, trace-movement operation, etc. (fn3), several studies suggest that the dysfunctions can be regarded as a main etiological result of a malfunctioning BG. What we can speculate of the evo-devo behind the BG human-like operation parallels that of what we speculate of Broca’s area—viz., that we believe it is both of a late evolutionary emergence in terms of phylogeny (of our mammalian class), and that it is sensitive to ontological critical periods (regarding its latent child onset). (One such clarion call for most developmental linguists of the maturational persuasion is that ‘Broca’s area just hasn’t come online yet’ in the very earliest stages of two-three-word child syntax; this having to do with latent myelination surrounding Broca neural circuitry).
2. The BG plays a critical role not only in movement (both physical as well as mental), but also in sequential actions (Marsden & Obeso 1994) which must take place (e.g., in sequential movement of motor-control mappings onto speech articulation, or stem+affix decomposition

⁸ It was the linguist Alec Marantz some time ago who put me straight on this idea: his analogy that our language-T.V. antennas are always at working scanning, even when there is no possible language signals to be picked up. Also see Moro’s (2020) Lecture on Impossible Languages: (Part 2) ‘the strange case of unspoken language’.

⁹ See Galasso (2023a) paper on ABABABA grammar. For Merge vs Move, see Chomsky 2005, Galasso 2016.

as found in morphosyntax (fix vs speaks) with IPA showing similar final /s/ though with distinctions in stem+affix processing: with final /_s/ in 'fix' being undecomposed/stem, and the final /_s/ in 'speaks' being decomposed e.g., [fiks] vs [[spik]s]... (e.g., Bybee & Slobin 1982; Pinker 1999).

3. The BG also find correlates to the gene known as *FOXP2* (e.g., Vernes et al. 2006, 2007; Shriberg et al. 2006)—this correlate suggests that demonstrable 'specific language impairments' related to movement are in fact associated with deficits in the neural pathways making up the BG. This is easily extended to work carried out by Grodzinsky and his studies related to Broca's Aphasia (BA) dysfunctions in syntactic movement operations, relative clauses and binding (Grodzinsky 2000; Grodzinsky et al. 2008)¹⁰.
4. The Dual Routing Model (also called Dual Mechanism Model/DMM) (Pinker & Prince 1988, 1994; Pinker 1999; Ullman 2001, Galasso 2003) shows how only procedural-knowledge systems seemingly tether to BG—with declarative/working memory tethering to medial Temporal-Lobe (TL) brain structures, (such as the hippocampus, and presumably Wernicke's area (W)), while Front Left Hemisphere (FLH) Broca's (B)/Brodmann's areas 44/45 (B44/45) shows the most connection to BG-related movement. ERP studies perhaps best illuminate these corollaries whereby the N400 signals non-BG connections (and are thus tied to semantics and recurrent ABABABA-grammar) while P600 and LAN signatures tie to recursive-system FLH/B44,45/BG (see Schlesewsky 2009 for review). Single Mechanism Models/SMM (Rumelhart & McClelland 1986)—of the classic sort celebrated by connectionism and even current Artificial Intelligence (AI) models (See Marcus 2001; Galasso 2019 (Note-4) 2019; Marcus & Davis 2019)—cannot tease out such distinctions as they have no ability to shift from recurrent to recursive operating platforms.¹¹
5. According to the above DMM, the processing of regular/recursive morphosyntactic rules (e.g., Number, Tense, Agreement) is supported by FLH/B44,45/BG in contrast with irregular morphology which is sensitive to frequency—with irregular morphologies pertaining to 'ABABABA'-singular-route processing—a form of non-rule/non-symbolic learning associated with recurrent neural networks as found in the TL regions of the brain. This is indeed what we find.
6. On the question of the evolution of BG itself and its unique ability to support language, the consensus in the literature is as follows: (i) That BG situates in a critical subcortical region of the brain which, over its evolution, has become sensitive to inputs/outputs engaged in the diverse spreading of neuronal interactions, (ii) with such complex computations motivating non-linear/sequential time-step releases (of the sort which require hierarchical structured expressions), (iii) and is assumed (I believe rightly) that the increase in (vertical) working-memory space due to this increase in cortical volume spawned these (horizontal) modes of expressions—with flat-language *Recurrent* 'ABABABA-grammars' being attributed to vertical computations (corresponding the Hauser et al's LFb), while *Recursive* 'Basal-Ganglia Grammars' (syntax) being attributed to horizontal computation (corresponding to FLn). Given these assumptions, one can speculate within accepted research norms that not only is 'language special' since the human basal ganglia is special (an LFn version), but that also this insular subcortical mass does share broad evo-devo characteristics with other non-

¹⁰ See Galasso (2023a) paper for discussion.

¹¹ See Galasso 'Squibbing' paper (2023b).

mammalian cortical homologues (an LFB version). There is still no clear evidence that a singular gene (FOXP2) was solely behind this cortical change: it may be the case that cascading events took place, involving a series of other rightly-timed cascading neuro events—e.g., the transcription of multi-genes where protein-modification and neurotransmitter alterations occurred simultaneously, or within a relatively short evolutionary time span).

Conclusion.

The question of whether or not there are selectively dedicated neuro networks specifically designed to promote the capacity of recursive syntax is still an open question. However, some of the recent studies as cited herein suggest that indeed neuronal and substrate structures can and do support move-based operations designed to (potentially) serve recursive hierarchy as uniquely found in human language. We leave it to future evo-devo neurolinguistic research to discover the precise neurological substrates which undergird this BG recursive machine. My best speculation to date is that *pyramidal neurons*, perhaps in conjunction with other peripheral neuronal circuitry, might be the best candidates for recursive grammar, since there is some evidence that such neurons can create the necessary ‘looping effects’ (e.g., repetitive looping <cortex-BG-thalamus-BG-cortex>) which would be required of such recursive implementation. Extending this proposal even further, it has been suggested that the pyramidal neuron itself is a recursive-generating machine—i.e., that syntax is found in the neuron itself (see David Marr below). This would be similar to the wondrous idea that memory itself finds its way embedded inside the circuitry of the cell (Eric Kandel).

Additional Studies (on-line):

Recursive Neuronal Connections & Reverberating Circuits (David Marr):

<http://toritris.weebly.com/>

<http://toritris.weebly.com/recursive-connections.html>

Recursive vs Recurrent neural networks.

<https://ai.plainenglish.io/recursive-neural-networks-rvnn-and-recurrent-neural-networks-rnns-2ff6a067ad01>

Theory of Cortical Function. (David Heeger)

<https://www.pnas.org/doi/epdf/10.1073/pnas.1619788114>

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https://www.researchgate.net/publication/297758854_The_evolution_of_language_and_thought

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