Appendix S: Aspects of Language [1]

James T. Fulton

Language is a protocol used in conjunction with two physical entities, a generator of signals and an interpreter of signals to transfer ideas via a communications channel (a media). The protocol has an intrinsic component plus the ability to be shaped and expanded.

> One cannot discuss language until he/she has read at least a few of the books by the current lingust, John McWhorter[2]. John has a lively way of putting language, and the maturation of languages, in perspective.

> Kids can learn any language, fast and perfectly–obvious when immigrant's children grow up sounding indistinguishable fro the American peers. The skill atrophies in adults, however. There are occasional exceptions, those who master a new language with barely a trace of an accent and fine idiomatic command in their thirties. However, they are just that–exceptions, blessed with inborn talent and a leaning towards persistence. Generally, an adult cannot learn a new language to the point of sounding native.
> John McWhorter (2011) pg 23

> Any discussion of language involves a group of immigrants speaking about a specific language at a specific time.

S.1 Introduction

The current best estimates are that human language arose on the order of 150,000 years ago. No similar estimates have been offered for the beginning of language in other species. The speculation about how human language came on the scene is entirely speculative and frequently falls back on the concept of one or more genetic mutations. This speculation is in spite of a total lack of any understanding of how a mutation could cause an operational change in the performance of a species.

Discussing language is difficult because so many of the terms used (including the definition of language itself) differ so significantly between the vernacular, books written for the popular press and books and articles written for the academic community. There is also the grossly different perspectives taken by the physiology related investigations and the psychology related investigations. A 2002 paper by Hauser, Chomsky & Fitch appears to grasp most of those problems as it discusses the faculty of language from multiple perspectives[3]. "One aim of this essay is to promote a stronger connection between biology and linguistics by identifying points of contact and agreement between the fields. Although this interdisciplinary marriage was inaugurated more than 50 years ago, it has not yet been fully consummated." The paper is only ten pages of typeset material but quite comprehensive with carefully designed figures. Its semantics become less precise when addressing the computational-intentional system and the putative I-language defined below; probably because they only address the conceptual aspects of that system from a linguist's perspective.

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[1]Released: 18 January 2014

[2]McWhorter, J. (2011) What Language Is (and what it isn't and what it could be) NY: Gotham Books With a list of his books on the facing page to the frontpiece

[3]Hauser, M. Chomsky, N. & Fitch, W. (2002) The faculty of language: What is it, who has it, and how did it evolve *Science* vol 298, pp 1569-1579

Excerpts from

PROCESSES IN BIOLOGICAL HEARING:

including,

ELECTROCHEMISTRY OF THE NEURON

This material is excerpted from the full β-version of the text. The final printed version will be more concise due to further editing and economical constraints. A Table of Contents and an index are at the end of this paper.

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2 Biological Hearing

Several key subjects are introduced early in the Hauser et al. paper:

• The “language” of DNA is different from the “language of intraspecies and interspecies communications.
• “It is important to distinguish between questions concerning language as a communicative system and questions concerning the computations underlying this system, such as those involving recursion.”
• A distinction between FLB (the Faculty of Language in a Broad sense) and FLN (the Faculty of Language in a Narrow sense).
• Their concentration on “language” used quite differently (specifically) to refer to an internal component of the mind/brain (sometimes called “internal language” or “I-language”).
• Their assertion that FLB includes FLN plus at least two other organism-internal systems which they define as “sensory-motor” and “conceptual-intentional.”
• Their association with the ability to utilize recursion as a key element in FLN.

• Their assertion that, the recursive feature within FLN constitutes a key distinction between the human language capability and the communications capability of lower species.
• They introduce the term “discrete infinity” to mean a infinite capacity to combine discrete words in an indeterminate variety of sentences of potentially infinite length.
• They also address the fact that whereas the human can theoretically create infinite length sentences through recursion, there are many internal physiological constraints on the length of such sentences (page 1571).

Even with the degree of care taken in this review to choose their words carefully, they occasionally veer into the use of “language” to only refer to “‘a system of sound-meaning connections’ that has been recognized for thousands of years.” They also appear to use the term word as the minimal unit of verbal communication rather than a word element, a morpheme. The morpheme has a discrete value in information theory and in semantics.

> While they note their concept of discrete infinity is largely the same as that of the mathematicians in conjunction with the number line, the analogy is both rationale but running counter to their main argument. The concept of infinity finds its natural home in the Calculus where it is used conceptually but seldom in actual practice. Applications of the concept of infinity are usually avoided except in very advanced Calculus. Instead, only a much briefer range of variables is used, much as a lower number of recursions are used in usable language.

To the extent their concept of human language is distinct from other animal communications, based entirely on the introduction of recursion into their FLN, the proposition is understandable but may lack substance in mamy investigators minds.

The Conclusion to their paper is very carefully prepared and suggests an additional series of experiments, including those related to their hypotheses #1, #2 and #3, can be defined to demonstrate refutation (falsification) or confirmation.

Allen has performed a wide variety of empirical studies on the relationships between articulation and intelligibility, particularly with respect to vowels versus consonants[4].

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[4]Allen, J. (2005) Articulation and Intelligibility. London: Morgan & Claypool

Patel has provided a book discussing many aspects of music and language[5]. It contains many useful graphics. When looking at brain scans obtained using computer aided tomography (CAT), the convention of the radiologist is to show the left side of the brain on the right side of the figure (as if the plane of the reconstruction was viewed from below).

S.1.1 The fundamental communications system

Whatever language is, it must be compatible with the basic elements of the associated communications system. The elements of a communications system have been well developed in the field of information theory since at least the time of Shannon[6]. **Figure S.1.1-1** provides a framework for discussing language. It attempts to show the basic situation relative to a discussion of language. The theme of this work is that language is a protocol used in conjunction with two physical elements shown within the shaded box to communicate over a communications system. The two other physical elements, signal projection and signal reception, are closely tied to the character of the communications channel (media). The boxes on the left can be considered the hardware and the boxes on the right variants of the software used in the "system."

An initial extension of the communications mechanism involved the introduction of an alternate channel supported by several media, cave walls, stele, tablets and writing paper. With the implementation of modern technology additional media have been employed calling for new media specific protocols as suggested by the dashed inset

[5]Patel, A. (2008) Music, Language and the Brain. London: Oxford Univ Press
[6]Shannon, C. (1948) A mathematical theory of communication, *Bell System Tech J* vol 27, pp: 379-423 and 623–656

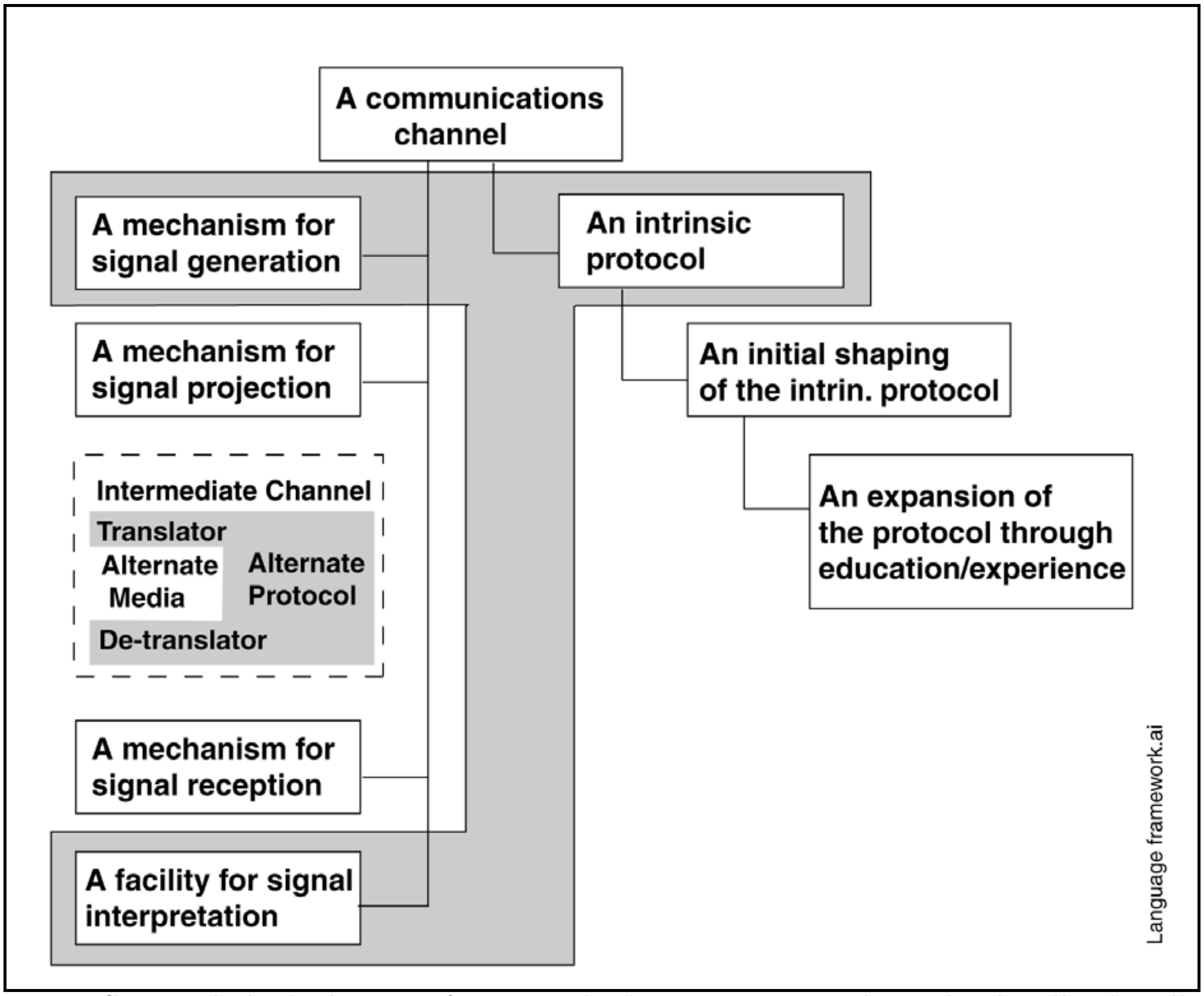

Figure S.1.1-1 The basic elements of a communications system. It can be used to describe virtually any system whether animal or man-made in character. All of the elements on the left must be present before the system can be used. The elements on the right can be implemented progressively. The three boxes within the shaded area must be compatible before operation of the system can be attempted. The intrinsic protocol is analogous to the "boot" routine of a modern desk top computer system. The dashed box contains an additional capability where an intermediate channel is introduced between the projector and the receiver to expand the range of the channel. See text.

The basic diagram can be used to discuss any mode of communications, from the distribution of pheromones among conspecifics of a species to the distribution of HDTV through a satellite relay system. The critical condition on the operation of a communications system is the compatibility between the three boxes within the shaded area. The physical elements of the system must be able to generate and interpret signals according to the intrinsic protocol. In addition, the mechanisms for projection of the signal and reception of the signal at a distance must be optimized for the specified communications channel.

In the case of human speech, the distance over which Homo sapien could project and receive signals was limited to the dimensions of a Grecian amphitheater until about 5000 years ago. At that time a major innovation was introduced, writing. The introduction of this new communications channel (or medium) called for the introduction of several new boxes into the block diagram based on the adoption of this medium. These are shown within the dashed box on the left. A scribe and a reader were introduced between the signal projection source and the signal receiver.

> The scribe translated the projected signal into a written form (a transcription) that could be used to traverse an extended distance and to traverse time. A reader was then used to reproduce the original prjected message for the recipient. This overall process was improved substantially during the Middle Ages through education, allowing the auto translation of a message onto paper (writing) by the originator and its unobstructed auto interpretation (reading) by the recipient. During the 18th and 19th 19th Centuries additional translation mechanisms were developed that overcame the time delays intrinsic with the transport of written media over significant distances, beginning with the semaphore and then the electrical telegraph.

With respect to the intrinsic protocol implemented by man during the 19th Century and associated with the telegraph;

> The intrinsic protocol can be as simple as a series of dots to indicate the letters of the alphabet or the more useful Morse Code protocol using a combination of dots and dashes. The intrinsic system capability only defined the presence or absence of a signal within the channel, and that is how it was used. Morse introduced the initial shaping of the intrinsic protocol to include the presence of signals of different duration (dots and dashes) This protocol was later expanded to address numbers and eventually special signals patterns designed to alert the teletype operators. No mechanism for signal generation was present in the original Morse Code. That mechanism was provided by a human source.

> Within a generation, the capability of the mechanisms providing signal projection and signal reception were improved to provide a new dimension, a finite frequency range beyond the presence and absence of a signal. This allowed the use of a more complex protocol based on the already present capability of the signal generator (vocalization) and signal interpretation (audition). New media were soon developed that required additional protocols compatible with those media (phonographs, wire recordings, tape recordings, CD recordings, the MPEG protocols for conserving space on the new media, etc.

The introduction of alternate media and protocols associated with that media led to the expansion of the concept of language; to the point the label was no longer constrained to human language. The word language became a root for the codes employed in connection with a variety of media (analog and digital electrical codes in telephony, a variety of categories of computer language, and potentially the language of other biological species. The introduction of alternate media also led to the cascading of communications channels in recent times (think of end-to-end communications employing facsimile transmission and e-mail as intermediate media of communications between the signal generator and the signal interpreter.

S.1.2 The acoustic range of human vocalization

Figure S.1.2-1 reproduced from Coulmas is a very useful description of human speech based on Peterson & Barney (1952). It shows the natural logarithm of the frequency of the first formant (F1) and the second formant (F2) used to form the common vowels for three classes of humans. Nearey (1978) provided a similar plot using logarithmic scales which show a more common shape only displaced among the subject classes.

S.1.3 The symbol set of human language

A set of phonetic symbols has evolved to describe the sounds (phonemes) of human language. It is maintained by the International Phonetic Association[7]. The complete set is very large and includes a number of extensions to support individual minor languages supported by an individual culture. A group of phonemes (typically consonants and vowels) are used to describe the morphemes used within a given cultural language (natural language as defined by Gregg[8]).

This subject will not be explored here.

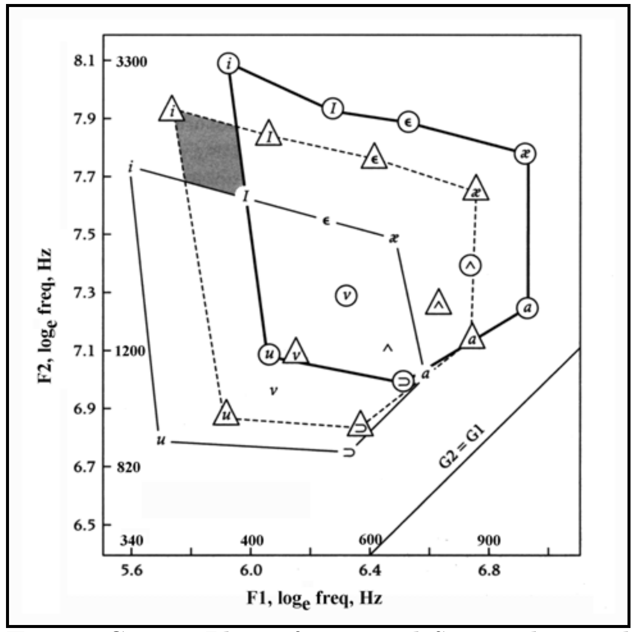

Figure S.1.2-1 Plots of averaged first and second formant frequency combinations that specify the vowels of English for men, women and adolescents. Scales are natural logarithm of frequency in cycles per second, with selected frequencies also shown. From Coulmas, 1989.

S.1.4 The role of writing in language

The role of writing is profound but relatively subtle with respect to language. Coulmas has also explored this subject[9]. Writing is an extraordinary cultural invention. It creates the ability to record the history of human activity beyond leaving behind physical artifacts. Coulmas lists four major functions of writing;

- The mnemonic function; supporting individual and group memory in the short term.
- The distancing function; expanding the communication range in distance between humans.
- The reifying function; expanding the communications range in time between humans.
- The social control function; regulating social behavior by standardized governmental decrees.

Writing has inexorably advanced from pictorial icons (hieroglyphics) to a graphic alphabet recording the communications express (almost) purely phonetically according to a protocol that will be defined below as language. The phonetic expression is decisive in language development.

S.1.5 Why other higher primates cannot speak

There has been considerable discussion concerning why other mammalian species cannot speak effectively. Brief discussions generally focus on the position of the larynx within the throat. The more important criteria is suggested in the sketches provided in Lieberman[10]. **Figure S.1.5-1** shows his sketches of the "supralaryngeal vocal tract" (SVT) of an adult male chimpanzee and an adult human. It is unfortunate that only sketches appear to be available in the literature even though cineradiography of the structures are known to be available[11]. The captions for these

[7] http://en.wikipedia.org/wiki/Phonetic_symbols_in_Unicode
[8] Gregg, J. (2013) Are Dolphins Really Smart? NY: Oxford Univ. Press page 132
[9] Coulmas, F. (1989) The Writing Systems of the World. Oxford, UK: Basil Blackwell
[10] Lieberman, P. (2000) Human Language and Our Reptilian Brain. Cambridge, MA: Harvard Univ Press
[11] Nearey, T. (1979) Phonetic Features for Vowels. Bloomington IN: Indiana Univ Linguistics Club *also* (1978) Vowel space normalization in synthetic stimuli *J Acoust Soc Am* Volume 63, Issue S1, pp. S5-S5

sketches miss the critical point. While focusing on the difference in length of the oral cavity and the position of the larynx within the pharynx, Lieberman fails to focus on the key positions of the epiglottis and velum. In primates, the epiglottis is high in the pharynx and directs virtually all air flow from the lungs into the nasal cavities, blocking it from passing into the oral cavity. As noted in Lieberman's text, this condition allows the chimpanzee to breath while ingesting food (that can pass (out of plane) around the "wind pipe" into the esophagus. Lieberman does note that the human baby shares this configuration with other primates in order to avoid choking on food passing down through the larynx into the lungs. Lieberman has presented another book for the popular press describing this subject in more detail[12].

Cineradiographic recordings of the SVT show how the pharynx portion varies in length during the course of syllable formation.

This feature can be explored with respect to other species. In the dolphins, the paths to the lungs and to the stomach are entirely separate. Thus, there is no connection between the lungs and the mouth. In the primates and baby humans, the path to the mouth from the lungs is restricted, particularly when the larynx is in the raised position. The epiglottis is the primary control of air flow into the nasal and oral cavities. In older humans, the path from the lungs to the mouth is the major air passage during speech. The control of the air path is by the velum and not the epiglottis.

Lieberman cites Negus[13] as describing the chimpanzee configuration as the standard plan for the SVT.

Human have evolved specifically to accommodate speech. The chimpanzee has evolved to accommodate simultaneous eating and breathing without significant consideration to the production of sound, particularly sound influenced by the detailed shape of the oral cavity. The dolphins have evolved to allow even greater separation of the eating and breathing function, which probably supports their enhanced active acoustic system.

[12]Lieberman, P. (1998) Eve Spoke. NY: W. W. Norton
[13]Negus, V. (1949) The Comparative Anatomy and the Physiology of the Larynx. NY: Hafner

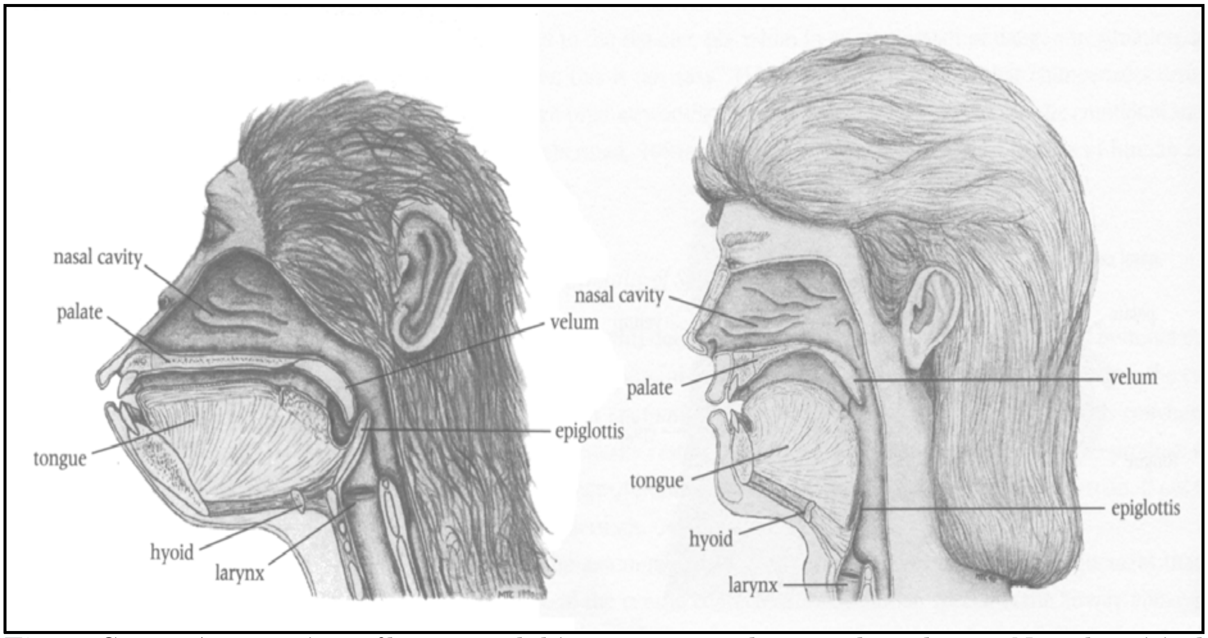

Figure S.1.5-1 A comparison of human and chimpanzee supralaryngeal vocal tract. Note the critical position of the epiglottis relative to the velum in the two sketches. From Lieberman, 2000.

Lieberman & Crelin have studied the SVT of the La Chapelle-aux-Saints Neanderthal fossil[14]. They concluded that this specimen's SVT resembled that of infant homo sapiens and the Neanderthal was incapable of producing the vowels [i], [u], or [a].

S.1.6 Why *Cetaceans* can "speak"

Hauser, Chomsky and Finch have presented a hypothesis #1 that includes an "empirical problem" relating to their faculty of language–broad (FLB) and related to the sensory-motor system of a species. These concepts and labels are discussed more fully below. They discuss this empirical problem in the context of homologous morphological structures among animals and the constraints imposed by vocal tract anatomy.

To create speech, an animal need not exhibit a homolog of the human vocal apparatus, it must only employ an analog that can accomplish the same end product, a multiplicity of morphemes that can be assembled into words and sentences expressing ideas. The *Cetaceans* meet the analog requirement while adopting an entirely different vocal apparatus. The dolphins are the most carefully studied of the *Cetacean* family. They exhibit a highly developed vocal apparatus associated with their lungs, trachea and nasal passages instead of, and separate from, their alimentary canal and mouth (see Appendix L). The frequency range of the dolphin vocal and auditory systems extend nominally from a few thousand cycles per second to 150 kHz. It does not overlap significantly (using a logarithmic scale) with the human auditory range.

It is not always appreciated among both the psychological community and the broader audience that *Cetaceans* do not generate any sounds using their mouth, teeth and alimentary canal (which are totally isolated from their trachea and lungs).

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[14]Lieberman, P. Crelin, E. & Klatt, D. (1972) Phonetic ability and related anatomy of the newborn , adult human, Neanderthal man, and the chimpanzee *Am Anthropol* vol 74, pp 287-307

From the perspective of a *Cetacean*, as well as the "Martian" visitor invoked by Hauser et al. if he should encounter a *Cetacean* before encountering a *Homo sapien*, the pneumatic system of the Homo sapien is remarkably poor mechanism (given its commingling of functions with the alimentary canal and its limited acoustic frequency range) for generating complex communications employing a versatile language protocol.

The potential, probability of, and characteristics of dolphin speech are addressed in Appendix U of this work. . http://neuronresearch.net/dolphin/pdf/Dolphin_language.pdf

S.1.6.1 The dolphin vocal repertoire

Dolphins are widely known for their diverse repertoire of sounds and their ability to mimic other sources of sound. Neonates are known to reproduce their mothers name shortly after birth and before adopting their own distinct name within a few hours. Dolphins are known to repeat the names of other dolphins in their pod and to become much more vociferous when swimming together in a pod. When they voice the name of a fellow dolphin, it is not clear whether this is a form of greeting or whether it is used on the creation of a recursive message.

When a pod of dolphins enters the home waters of another pod, the sounds generated take on a different character, suggesting they are involved in attempting to rationalize two distinct dialects.

When dolphins are swimming alone but believe other dolphins maybe (are) in the vicinity, they will repeatedly announce their name, much as aircraft due to establish their presence to other aircraft and ground controllers.

Without a significant attack by humans on the messages and signals of dolphins aimed at discovering the meaning of their abstract sounds, it is not possible to determine whether they are or are not using protocols that qualify as language. Any such attack must recognize the broad frequency spectrum of the vocal and hearing modalities of dolphins. It must also be performed by a dedicated crytanalyst with considerable experience in the culture of the target species along with a detailed knowledge of morphology used by that species. No comprehensive cryptanalysis designed to discover the language(s) of dolphins have been undertaken to date. Appendix U of this work does review the attempts to identify the morphemes of dolphin calls.

> "The Enigma code of World War II was broken at least partly due to the rigidity of the German military in using a prescribed valediction at the end of every message." This was a serious error in crypto security.
>
> Until the elements of the protocols used by Cetaceans in their communications are discovered, it is impossible to determine whether their signaling is capable of limitless concrete and abstract meaning as required by Gregg (page 132) for a "natural language."

S.2 The null hypothesis for the precise definition of language

After examining a variety of features and elements involved in language and communications, this paper will approach asymptotically a definition of language as a protocol used in intra-species, and potentially inter-species, communications that is not restricted to audition. It will accept the condition that, within the auditory sector of human language, a recursive feature (of limited degree) can be readily incorporated into both the signal generation capability and the information extraction capability supporting the human language protocol. Each instance of a recursive feature can be considered terminated by a semicolon within a written transcript of the communication. This semicolon analog is of value during information extraction within stage 4 and the presentation of the resulting information to the cognitive engines of stage 5 of the neural system.

This null hypothesis differs from that of Hauser et al. but suggests a parallel between this hypothesis and their faculty of language–broad case (FLB). The null hypothesis is also compatible with the FLB when it incorporates the recursive computational capability thereby becoming the faculty of language–narrow case (FLN) they associate with Homo sapiens.

This null hypothesis recognizes the degree of recursion used in human language is significantly limited by the pneumatic characteristics of the human anatomy and the capacity limits of the short term memory provided in the human neural system.

S.2.1 What is the character of the neural schematic used in language?

Figure S.2.1-1, which is an expansion of [**Figures 4.6.3-1** and **12.5.1-1**] developed earlier, includes additional detail related to the afferent paths of stage 4, information extraction and efferent paths of stage 6, command generation (subsequent to instruction generation within stage 5). Major features to note before entertaining detailed discussion related to language include;

• Both the afferent and efferent paths are massively parallel while serving different modalities at the detail level.

• There is a large scale reflex pathway through the cerebellum.

• There is a large scale reflex pathway through the striatum/pallidum

• The efferent paths associated with vision are addressed elsewhere[15].

• The afferent paths associated with all of the sensory inputs merge in the associative areas of stage 4, information extraction.

• Stage 5, cognition, accesses the results of information extraction from the (largely conceptual at this time) saliency map.

• Stage 5, cognition, creates instruction both ab initio and in response to the information presented by the saliency map.

• Stage 5 instructions are expanded into operating commands to the motor/glandular system in two major steps. High level commands are created within the premotor cortex and its affiliated areas with a greater number of lower level commands created in conjunction with the cerebellum for each identifiable change in the motor and glandular systems.

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[15] Fulton, J. (2004) Processes in Biological Vision. Section 15.2.5

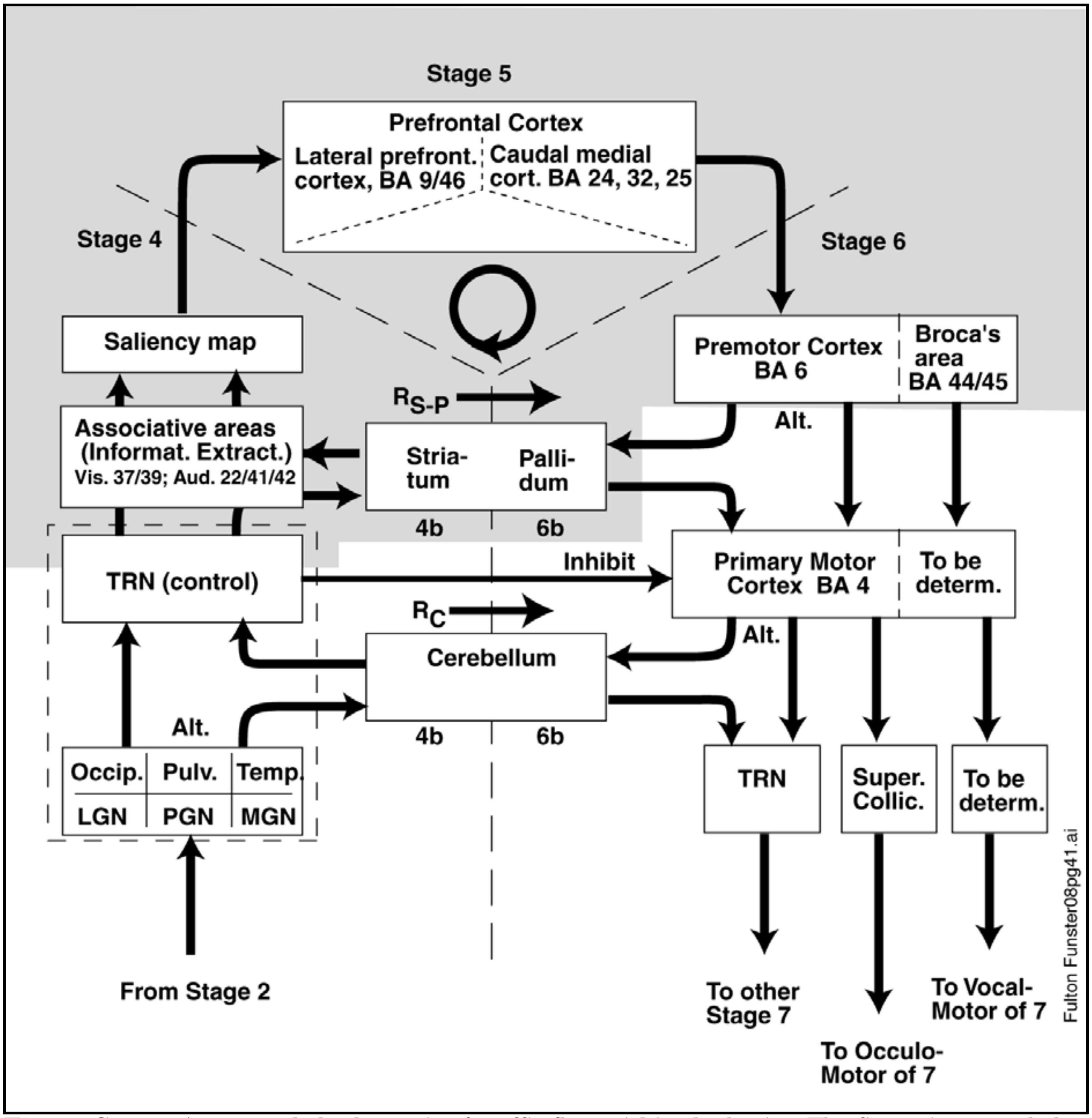

Figure S.2.1-1 An expanded schematic of traffic flow within the brain. The figure is expanded to focus on the relevance of areas labeled by Wernicke and by Broca. It is also useful in defining the sensory-motor and conceptual-intentional areas defined by Huaser, Chomsky & Finch. The shaded area and the rotating loop shown describe an immensely complicated area of interconnection that probably encompasses the mind, the source of consciousness and the origin of the general form of the protocol of language. See text.

As noted, the associative areas of stage 4 are extensive and include those dedicated to vision (Brodmann's areas 37 & 39), hearing (areas 22, 41 & 42) etc. For several decades, the areas dedicated to hearing have been labeled Wernicke's area. More recently the terminology has been expanded to identify Wernicke's hearing area from Wernicke's vision area. These areas are in the main path leading to stage 5 cognition. As such any diseases in these areas can cause significant problems for cognition within stage 5 and the appropriate instruction development.

It is reasonable to consider Broca's area as a partitioned area within the premotor cortex due to its position adjacent to Brodmann's area 6. Pending further review of the literature, no label has been assigned to the neural engines of the primary motor cortex associated mainly with vocal activity. Similarly, any major neural engines associated with the diencephalon and dedicated to vocalization have not been identified.

As in the earlier figure, the afferent path on the lower left consists of a group of engines and projection neurons forming the receiving elements of the parallel sensory structures. The efferent path on the lower right consists of a group of engines and projection neurons forming the signal projection elements of the parallel motor structures. The engines and pathways shown at the top constitute the hardware of the general purpose "computational system" described by Hauser et al. as well as this work.

> A caution is in order; the circuits of the neural system, including stage 4, information extraction, and stage 5, cognition, appear to be optimal for pattern matching rather than "computation."
>
> As noted in **Section S.4.1**, the human neural system appears to be incapable of transcendental calculations, such as performing a Fourier transform or evaluating a correlation function, using computational techniques. It is able to perform rudimentary calculations of these types by employing spatial rearrangements among the neurons delivering signals in parallel to the engines of these stages.

This hardware also houses a large variety of protocols supporting both the declaratory and non-declaratory operations of stage 5 cognition.

There is another dimension of the neural system. The limbic system occupies this out-of-plane dimension. It plays a significant role in the overall operation of the neural system but it will not be addressed in this document.

S.2.1.1 Where does the fundamental framework of the protocol arise?

The above schematic defines the most likely neural engines and their gross interconnections responsible for both the extraction of the information associated with signals using the language protocol and the generation of signals related to the language protocol. However, it can not do justice to the complexity of the interconnections within the brain in the areas associated with the terminal portions of stage 4, the engines of stage 5 and the initial areas of stage 6. The shaded area involves immensely complicated inter-engine connections at the detailed level. These interconnections support an equally immense feedback loop or loops (and loops within loops) suggested by the rotating loop in the center of the shaded area that also includes engines of the limbic system that are not shown.

The interconnection of these engines have only been described conceptually in the literature of physiology and histology[16]. The complexity of this area may account for the development of consciousness itself. It may also account for the recursive capability discussed here; and it may account for the more critical framework (that requires the recursive capability) used in the generation of the initial signals that ultimately support the external language protocol.

S.2.1.2 Important failures of language interpretation & production

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[16] Noback, C. (1967) The Human Nervous System. NY: McGraw-Hill pp 212-213.

This section is destined to expand exponentially once the framework developed here has been formalized.

From the schematic, it is reasonable to expect diseases of Wernicke's areas can be expected to interfere with the operation of the conceptual-intentional areas of Hauser et al., those paths other than those marked R_C or $R_{S.P}$. The high level reflex paths, R_C and $R_{S.P}$ provide alternate pathways through the brain often employed when a person suffering from either Wernicke's syndrome or Broca's syndrome are asked to sing from music they are already familiar with or recite text they are allowed to read as part of the recital. These actions employ engines of the sensory-motor areas, but not the significant employment of the conceptual-intentional areas of Hauser et al., i.e., the engines of stage 5.

S.2.2 How does language differ from communications?

The perennial question must be addressed here, what is language? Is it a grammar, a lexicon, a communications channel or a protocol used to establish communications between two or more organisms? If it is a protocol, does it support chemical communications among a wide variety of species, does it support physical signaling among a wide range of animals, does it only support such physical signaling among vertebrates, or is it limited strictly to communications among mammals, or even more strictly to homo sapiens (by the putative exclusive inclusion of a recursive computational capability within the engines of stage 5 and 6 of the neural system of that species)?

Gregg differentiates between a language and a natural language ("like English or Chinese") and defines a natural language as;

> "An arbitrary set of learned symbols (usually vocal) shared by a group, consisting of discrete elements that are combined following the rules of a grammar system to represent limitless concrete and abstract meaning."

He places considerable weight on the adjective, limitless, in his subsequent discussions. On page 135, he "shoehorns" into his discussion of whether dolphins employ language or communications what he defines as the "Ten Essential Ingredients of (Natural) Language." As noted in **Section S.1.6.1**, it is literally impossible to determine whether the dolphin signals constitute a language by any definition without learning the characteristics of their signaling. At present, the dolphin messages can be considered encrypted as far as human analysts are concerned.

Gregg has omitted a discussion of whether the sensory/motor traits of a species are pertinent to language (thereby avoiding the homolog versus analog property discussed in this paper).

The Hauser et al. paper uses the heading for one section, "Defining the Target: Two senses of the faculty of language." The section opens with the caveat,

> "The word 'language' has highly divergent meanings in different contexts and disciplines.
> • In informal usage, a language is understood as a culturally specific communication system (English, Navajo, etc.).
> • In the varieties of modern linguistics that concern us here, the term 'language' is used quite differently to refer to an internal component of the mind/brain (sometimes called 'internal language' or 'I-language').
> • We assume that this is the primary object of interest for the study of the evolution and function of the language faculty.
> • However, this biologically and individually grounded usage still leaves much open to interpretation (and misunderstanding)."

After a bit of discussion about the inadequacies of the above quotation, they focus on their distinction between a "faculty of language–broad sense" (FLB) as distinguished from a faculty of language–narrow sense"(FLN). Their figure 2 is useful pedagogically in bringing everyone to a common arena for discussion but is not specific enough for the question at hand. As an example, this investigator prefers to consider written records (shown within an outer circle) as not language but a transcription of the morphemes of language in order to extend the distance a language can operate within. The FLB form when limited to external auditory signals is shown at the bottom of the outer circle. The three other labels, FLB, are associated with other restrictive labels, conceptual-intentional, sensory-motor and other. Within an inner circle, only the label FLN with the additional restriction of recursion, is shown (along with a variety of graphic symbols and arbitrary individual words). A variety of other labels appear more or less arbitrarily placed around the outer circle.

Their figure, along with the schematic introduce above, engenders several additional points of discussion.

• Is “language” a faculty for interspecies communication or does it have a broader usage?
• Are there multiple forms of language used for intra communications within an organism?
• Is there only one I-language or are there several, one within the stage 5 cognitive engines and associated with reading the information associated with the afferent saliency map as well as issuing efferent instructions, one employed to distribute high level commands and one employed to distribute low level commands within the neural system?
• Does the capability to incorporate recursion into a communications system transform the communications system into a language?. If so, what is the degree of recursion that must be met in the minimal case–in the average case–in the limiting case?

Their definition of FLB requires an organism to employ both a sensory-motor and a conceptual-intentional “systems” and to include the recursive computational capability of the FLN. Thus there definition of a language under this heading does not involve interspecies communication, only the internal capability to prepare signals that, when implemented by the motor system, would form the basis (code) of language within this interspecies communications channel.

In parallel, they define FLN as, “the abstract linguistic computational system alone, independent of the other systems with which it interacts and interfaces. FLN is a component of FLB, and the mechanisms underlying it are some subset of those underlying FLB.” Alternately, the sensory-motor and conceptual-intentional “systems” can be considered the hardware (neural engines of stage 5 and/or 6) that supports the software (recursive routines) among many other routines required to support communications.

> **If these interpretations are reasonable, then the difference between language among humans and intra-species communications among other species is reduced to the degree of recursion these species can each employ within their communications channels.**

S.2.3 How does language arise in the young?

One of the major arguments in favor of a fundamental protocol of language embedded in the neural system is the realization that newborns within a very short interval will begin using “baby talk” or “babbling.” This phenomenon is shared with birds, with dolphins[17] and undoubtedly with other species. The argument is often offered that the mother generally shapes this apparently amorphous baby talk, based on the inherent protocol of that species, into the lexicon and semantic preferences of the local species. The recordings of Kassewitz et al. appear to clearly demonstrate this shaping within a few hours of birth among the dolphins. Presumably it occurs over a similar interval in birds.

The intrinsic protocol of the human species is not limited to shaping and expansion within the atonal domain, it is equally compatible with shaping into a tonal language and into music as a language in its own right.

[17]Kassewitz, J. Weber, M. Fulton, J. & Lingenfelser, R. (2007) A Preliminary Analysis of the First Hour of Sound after Birth Produced by a Dolphin Calf (Tursiops truncatus) *Available from this author*.

S.2.4 How narrow can the definition of language be drawn?

The linguistic community has long struggled with the question of whether animals other than Homo sapien use language. The Chomsky team, as typified by the paper of Hauser, Chomsky and Finch, have argued that only humans employ language and all other species merely communicate. In recent times, they have based this distinction on the capability of humans to employ the mechanism of recursion within their communicating capability, emphasizing the order of the recursion can approach infinity. However, as a practical matter, the physiology and memory capacity of the human currently limit the order of the recursion associated with a given message (whether spoken or transcribed into a different medium) to less than about four.

With a limited order of recursion in practice, the use of recursion as the defining feature separating human language from animal communications appears fragile. Especially in the absence of substantial ***evidence*** that recursion does not occur in animal communications.

In the absence of evidence that recursion is not used in animal communications, it appears the protocol constituting language in the FLB sense must be accepted as available to all animals (or at least mammalian) species. This leaves human language as an extension of the broader FLB protocol that includes recursion as a feature (FLN as an extension of the FLB shared by many species and many communications channels).

S.2.4.1 Comparative physiology related to language

- - - -

When exploring the comparative physiology of animals from a linguist's perspective, only preliminary conceptual conclusions can be drawn. As an example, Hauser et al. appear to consider the potential language capability of *Cetacean* only from the perspective of homologs (rather than analogs) and do not address the use of different media for communications purposes; water and air are distinctly different media for the propagation of acoustic energy..

In addressing their conceptual-intentional system, Hauser et al. annotate five key features of a language based on studies of various monkeys;

1. Individuals produce acoustically distinctive calls in response to functionally important contexts, including the detection of predators and the discovery of food.
2. The acoustic morphology of the signal, although arbitrary in terms of its association with a particular context, is sufficient to enable listeners to respond appropriately without requiring any other contextual information.
3. The number of such signals in the repertoire is small, restricted to objects and events experienced in the present, with no evidence of creative production of new sounds for new situations.
4. The acoustic morphology of the calls is fixed, appearing early in development, with experience only playing a role in refining the range of objects or events that elicit such calls.
5. There is no evidence that calling is intentional in the sense of taking into account what other individual believe or want.

From the perspective of the previously introduced Martian, the five points appear to describe the communications systems used by humans as well as selected animals quite clearly. With the exception of point five, they appear to describe the characteristics of the FLB of many animals following the initial shaping and limited expansion of the protocol. Point five is difficult to interpret without the authors providing additional interpretation. As commonly noted in other forums, the lack of evidence of any mechanism is not equivalent to the evidence of a lack of such mechanism. This principle is particularly important in the joint arena of comparative physiology and communications where so little investigation has been documented relative to so many species.

S.2.4.2 The character of the neural codes used within the CNS?

Hauser et al. do not address the character of the neural codes used to communicate within the central nervous system of animals. They only note (page 1570) the use of the conceptual term, internal language, "I-language," as a component of the mind/brain used among a varieties of modern linguistics. Such a definition is not precise enough, or sufficiently subdivided to address the actual communications facilities within an animal.

> While the signaling within the peripheral neural system (PNS), and much of the CNS relies upon bit serial/word serial signaling, it is very likely that the CNS also employs a more sophisticated form of bit parallel/word serial signaling that greatly speeds the processing of information within the CNS and greatly simplifies the process of comparing similar records. In the context of this overall work, bit serial/word serial coding is used almost exclusively between engines of the PNS and the inputs to the stage 4 engines. The outputs of the stage 4 engines (including the saliency mar), virtually all of the stage 5 engines, and the initial circuits of the stage 6 engines processing instructions from stage 5 involve the faster bit parallel/word serial protocol.

The two different signaling methodologies used within the neural system suggest the term I-language needs expansion to incorporate two distinct internal neural languages, a bit serial based protocol I_{BS} and a bit parallel based protocol I_{BP} .

Hauser et al. recognize the narrowness of their definition of I-language, but from a different perspective, "Thus, this conception is too broad to be of much use. We therefore delineate two more restricted conceptions of the faculty of language, one broader and more inclusive, the other more restricted and narrow" where they define their two faculties, the faculty of language–broad (FLB) and faculty of language–narrow (FLN).

Figure S.2.6-1 interprets the semantics of Hauser et al. in order to aid the discussion in this area. There descriptions related to FLB and FLN are brief. As in the earlier figures in this appendix, the upper two boxes under the general title are dominated by the software (protocols) controlling the linguistic capability and the lower boxes focus on the hardware of the capability. Hauser et al. only addressed a duplex communications channel restricted to one media, speech in air. They defined the elements of a faculty of language using the right protocol (FLB) or left protocol (FLN) and essentially the same engine implementations in both cases.

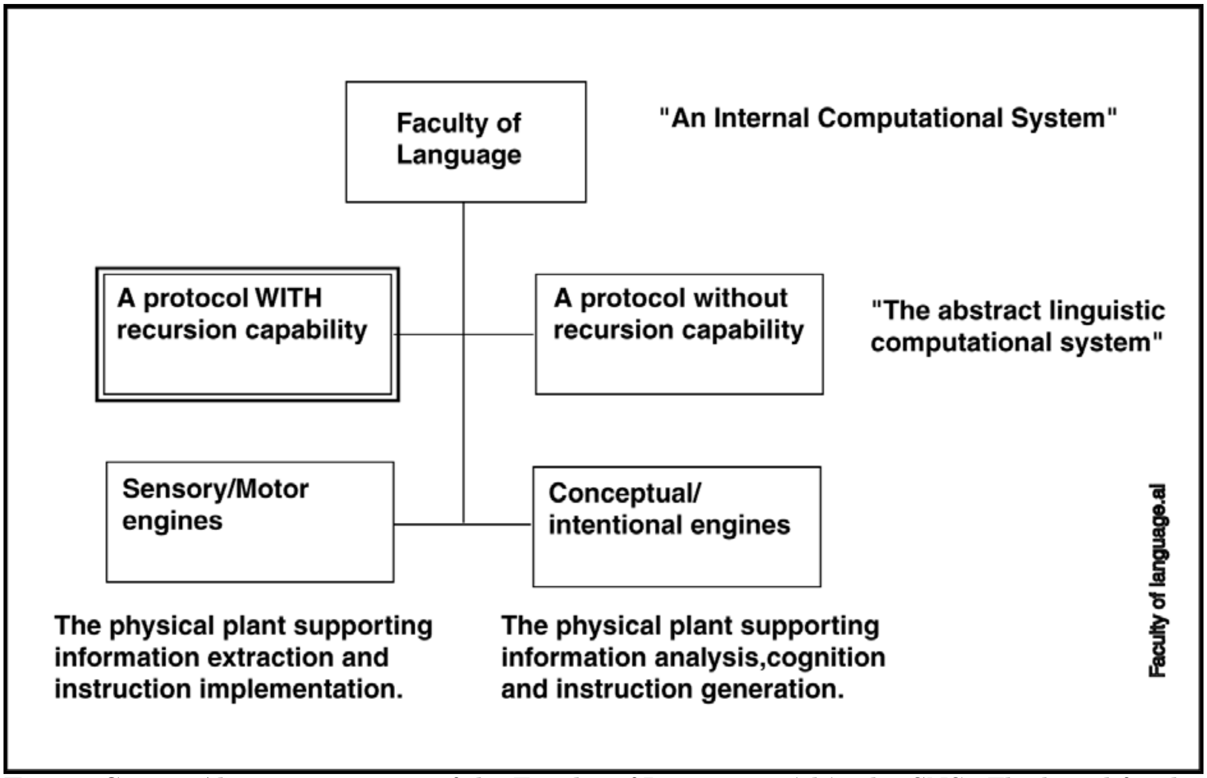

Figure S.2.6-1 Alternate concepts of the Faculty of Language within the CNS. The broad faculty (FLB) of Hauser et al. employs the protocol at upper right. The narrow faculty (FLN) employs the protocol at upper left. The quotations are from Hauser et al. See text.

They took a particularly homocentric position when they assert, "We take as uncontroversial the existence of some biological capacity of humans that allows us (and not for example, chimpanzees) to readily master any human language without explicit instruction." To date, no human has exhibited the capacity that allows us to readily master any putative non-human language (with or) without explicit instruction.

The only unique feature of the human language protocol that was identified by Hauser et al. was the inclusion of a recursive capability within that protocol. "At a minimum, then, FLN includes the capacity of recursion (page 1571)."

> The degree of the recursive protocol can be illustrated by a sentence of the following form assuming a first person speaker;
>
> Ralph said that, John said that Bill said that "he was going to the football game on Saturday."
>
> In this example the sentence exhibits recursion of the third degree relative to the original speaker.

As noted earlier, recursion to greater than the third degree is only found in pedagogical material. The human faculty is not well designed to handle higher levels of recursion and certainly not the concept of discrete infinity (the use of an infinite level of recursion involving discrete words) or limitless concrete or abstract meaning as defined by Gregg. This is clearly illustrated in Gregg's example (page 147 from Akmajian et al[18].;

"The rat that the cat **that the dog bit** chased ate the cheese"

Three verbs in a row (bit chased ate) is beyond the expanded protocol for reading by even highly educated humans. The suggestion of "limitless" numbers of such articles in a row or other forms of "discrete-infinity" in natural language is mind boggling. As shown in Chapter 19 of "Processes in Biological Vision" such complex grammar will upset the reading process and throw the "conceptual/intentional" system of the brain back into the analytical mode. The reading process will encounter a "familiarity default." As a minimum, this transition will cause the eyes to revert back to the start of the sentence and address each syllable individually in order to support more detailed information extraction within the engines of stage 4.

S.2.5 Evidence does not limit language to Homo sapiens

Much of the linguistic community takes the position that only humans enjoy the facility of language with all other species limited to communications. Hauser, Chomsky & Finch assert that only humans enjoy the faculty of language because of the unique feature of recursion imbedded in their protocol supporting vocalization and hearing. On page, 1572, under the title of comparative approach to language evolution, they address the question of evidence for their assertion. "Logically, the human uniqueness claim must be based on data indicating an absence of the trait in nonhuman animals and, to be taken seriously, requires a substantial body of relevant comparative data. More concretely, if the language evolution researcher wishes to mak the claim that a trait evolved uniquely in humans for the function of language processing, data indicating that no other animal has this particular trais are required." There subsequent discussion aimed at demonstrating the uniqueness of language to humans is verbose, loosely drawn and unconvincing!

Their focus on homology rather than analogy is unnecessarily restrictive (in eliminating *Cetaceans* from consideration for example). Their focus on recursion as an exclusive human feature is not demonstrated. The degree of recursion used in human speech is far below their suggested discrete-infinity proposal. Thus, their reliance upon the recursive feature to relegate animal communications to a lower level than human language is unwarranted.

S.3 Ab initio speech production versus recitation from text

The mechanisms of speech production vary significantly between ab initio production conscious executive instruction and the recitation of text or musical transcripts. The former involves (instruction) signal paths from stage 5 cognitive engines to the vocal motor area (Broca's area, Brodmann's area 44 and 45`) where commands are prepared for propagation to the muscles of the oral cavity and lips. Recitation involves signal paths arriving at Wernicke's area (Brodmann's area 41 and 42) from either circuits associated with the visual modality or potentially from the circuits of the auditory modality if speech is being reproduced based on hearing (a variant of mimicry). These signals are passed on to Broca's area in instruction form after information extraction in or before Wernicke's area. They are passed over a nerve bundle known as the *arcuate fasciculus* (fasciculus = bundle of nerves).

The arcuate fasciculus is frequently described as "a white matter tract linking areas in the temporal lobe involved in interpreting speech with areas in the frontal lobe that control motor movements. Its role in language was established years ago. With the advent of diffusion tensor imaging (DTI) type MRI, the details relating to this pathway is becoming better documented. It appears to be a more complex pathway with yet to be defined branches corresponding to the

[18]Akmajian, A. Demers, R. Farmer, A. et al. (2010) Linguistics: An Introduction to Language and Communications. Cambridge, MA: MIT Press page 211

interconnections defined by Noback[19] for the pyramidal system of the brain. Catani & Mesulam have recently provided a historical perspective on the arcuate fasciculus[20], including potential paths through the external capsule (thalamic reticular nucleus or TRN). "Wernicke thought that the temporal and frontal language areas were mutually interconnected by fibres passing through the external capsule and relaying in the cortex of the insula." More details are awaited from the ongoing DTI investigations.

S.3.3 Disorders in speech vocalization

Dysphasia is a disorder resulting in poor diction, pronunciation or other problems associated with learning disorders.

Aphasia is found in two forms; Broca's aphasia, generally defined by an inability to complete sentences in a timely manner and Wernicke's aphasia generally defined by an inability to compose and deliver meaningful sentences (generally associated with an inability or reduced ability to understand spoken words).

Broca's aphasia is frequently observed in connection with other premotor or motor disorders due to the adjacency of Broca's area (Brodmann's area 44 and 45) and the other engines of the premotor cortex (Brodmann's area 6). The facial portions of the motor homunculus appearing on the precentral gyrus are adjacent to or form Broca's area. These motor disorders are described as ataxia. Broca's aphasia and ataxia have been associated with inadequate reserves of vitamin B1 (thiamine) to maintain homeostasis within the subject's system. The primary role of Vitamin B1 within the body is believed to be to convert carbohydrates (primarily stored fat) into glucose.

S.4 The working hypothesis of language

Language is a protocol used in conjunction with a communications channel primarily among members of the same species (conspecifics) for the exchange of ideas. The protocol arises initially in a general form within the neural engines and algorithmic routines of the pyramid system of the central nervous system. It is reduced to one of potentially multiple structured forms within a social setting (normally shaped primarily by the mother).

Corollary 1: The protocol of language is not limited to a specific communications channel. However, its most highly developed implementation appears to involve the pairing of vocalization and audition in speech

Corollary 2: The intrinsic protocol of spoken language does not specify the order of semantic features within a language. The order is defined during the shaping process after birth.

Corollary 3: The spoken language of *Homo sapiens* has developed a recursive mode that appears to arise in its general form within the pyramid system and is used to a limited degree (normally degree 0 to 1, seldom degree 2 to 3 and rarely degrees above 4). The presence of recursion is undocumented in other species and can be taken as a hallmark of *Homo sapiens* at this time.

Corollary 4: The spoken language of *Homo sapiens* takes on many culturally specific protocols (and dialects within defined specific protocols) in order to support involvement of the members of the species in larger communities.

Corollary 5: A written form of a spoken language is literally a transcript of a message transmitted using that protocol (and not a language in itself) whether actually spoken or transcribed *ab initio*.

---

[19]Noback, C. (1967) The Human Nervous System. NY: McGraw-Hill pp 212-213

[20]Catania, M. & Mesulamb, M. (2008) The arcuate fasciculus and the disconnection theme in language and aphasia: History and current state *Cortex* vol 44(8), pp 953-961

S.4.1 What is the character of the intrinsic protocol as expressed within the prefrontal cortex

There is virtually nothing in the literature that would describe the signal encoding employed within the prefrontal cortex for any purpose.

From a theoretical perspective, it is likely the signaling employed within stage 5 may consitst of a bit parallel/word serial format. Such a format, the same as now used by all man-made general purpose computers, would allow stage 5 to acheive information transfer rates far higher than the transfer rates used within the stage 3 circuits supporting the peripheral neural system and some initial engines of stage 4. The challenge is identifying the parallel stage 3 neurons associated with a given signaling channel and recording signals from all of them simultaneously.

There remains no viable data showing the prefrontal lobe of the brain (like other regions) can perform any form of transcendental computation (such as taking a Fourier Transform or computing a correlation function) except through spatial transformations associated with the neurons of a nerve changing their physical arrangement between their source and target engines. On the other hand, the brain appears to employ unsurpassed pattern matching capabilities after it has been trained to recognize such a pattern(s).

The vast majority of the computational modeling of the PFC remains at the conceptual stage rather than at the actual circuit modeling stage.

It is becoming common to employ multiple probe recording protocols and present the data as rastergrams. There has been no way to determine what part of a signal (generally a two dimensional image) is associated with a given signal channel. The records generally show a burst of signals within the rastergram all beginning more or less at a given time suggesting when the signals reached the output of the neural engine being probed. Lacking confirmation that the individual neurons are related to each other and that the pulse pattern occurring at a given time within the rastergram applies to some piece of information leads to a lack of interpretability with regard to the signals.

Investigators assertions that they have located a "Julie Harris" neuron are generally not statistically supportable (Section xxx).

Curtis & D'Esposito give an overview of the nature of signaling as of 2003 and provide a description of the work remaining to be done in this area[21].

> "Understanding PFC functions is likely to hinge on our ability to resolve the nature of stored representations in addition to the types of operations performed on such representations necessary for guiding behavior. Representations are symbolic codes for information stored either transiently or permanently in neuronal networks. Operations are processes or computations performed on representations. Models of working memory and models of PFC function vary substantially in the relative importance given to representations and operations." "Some models attribute storage functions or representations to posterior cortical areas (e.g. premotor, parietal, and temporal cortex) and reserve the collection of 'executive' operations for the PFC. The distinction between representations and operations can be made clear in the vernacular of our cognitive models, but as we shall see, it might prove extremely difficult to distinguish between them with our current indirect (e.g. fMRI) and even direct measures (e.g. unit recordings) of neuronal activity."
>
> "Box 3. Questions for future research
> • What is the nature of the code reflected in sustained delay period activity in the PFC?

[21]Curtis, C. & D'Esposito, M. (2003)

Does it reflect the storage of internal mnemonic representations? Or does it reflect control processes that select or focus attention on relevant representations stored elsewhere?
• Sustained activity has been reported in several cortical areas, the prefrontal, premotor, parietal, and temporal cortices. Can we develop experimental assays to distinguish between the information carried by these persistent signals in these various cortical regions?"

S.8 Recent MEG activity relating audition to articulation

Tian& Poeppel have recently presented a paper showing magnetic encephelography (MEG) of the human brain with relative magnetic intensities and some time delay information[22]. Their model is totally dependent on an efference copy of the planned motor activity. An efference copy is not supported in the hypothesis of this work.

Tian & Poeppel investigated the auditory and articulation modalities in their psychology laboratory by starting with articulation activity as the initial function (their figure 1). "We focus here on the role of the motor system in the construction of perceptual experience in mental imagery. We propose a motor-based mechanism that is an alternative (additional) mechanism to Kosslyn's memory-attention-based account (Kosslyn, 1994, 2005; Kosslyn et al.,1994): planned action is simulated in motor systems to internally derive the representation of perceptual changes that would be caused by the actual action (perceptual associations)." Their figure 1 appears difficult to accept based on a more detailed knowledge of the operation of the neural system. The terminology used is not that of the conventional neuro-scientist of the current day. However, the MEG results in their figure 2, **Figure S.5.1-1**, are worthy of careful review.

Their figure 3 shows a resemblance to the signaling loop presented in this work (**Section xxx**) but with different semantics.

It is not clear where their modeling fits into the overall understanding of the neural system. "We conclude that the simulation-estimation mechanism provides a novel conceptual and practical perspective that allows for new types of research on predictive functions and sensory-motor integration, as well as stimulating some new insights into several neural disorders. Typically, mental imagery has been studied in cognitive psychology and cognitive neuroscience, while the concepts of internal forward models (and sensory-motor integration) are the focus of motor control research from an engineering perspective.

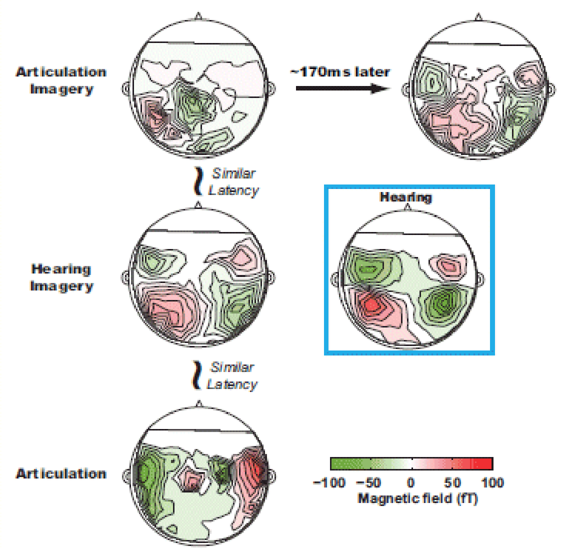

FIGURE 2 | Results from Tian and Poeppel (2010). The sequential estimation during articulation imagery revealed by MEG recordings. All plots are MEG topographies (response patterns) when participants actually speak (lower row), imagine hearing (middle row), and imagine speaking (top row). The activity patterns in the first column are temporally aligned with the onset of articulation movement. At a similar latency, bilateral frontal, bilateral temporal, and left lateralized parietal activity patterns are observed in articulation, hearing imagery, and articulation imagery conditions. In articulation imagery, about 150–170 ms later after the parietal activity, bilateral temporal activity is also observed. All the bilateral temporal activity patterns in *hearing imagery* and *articulation imagery* resemble the topography of the auditory response during actual hearing (highlighted in a blue box, response pattern when participants listen to the same auditory stimuli as in other conditions).

Figure S.5.1-1 MEG results involving articulation and audition ADD.

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[22]Tian, X. & Poeppel, D. (2012) Mental imagery of speech: linking motor and perceptual systems through internal simulation and estimation *Frontiers in Human Neurosci* vol 6(314), pp-152-162

Our atypical pairing of internal models as an additional source for mental imagery yields, in our view, some provocative new angles on mental imagery in both basic research and applied contexts."

S.9 The information content of speech

Some languages always sound more rapid than other to me. My assumption is the rate is higher because the information content of each syllable is less and the human is typically capable of transferring oral information at a nominally fixed rate of information transfer.

Pellegrino et al. have provided information on this subject[23], **Figure S.6.1-1**

LANGUAGE	INFORMATION DENSITY ID_L	SYLLABIC RATE (#syl/sec)	INFORMATION RATE
English	0.91 (± 0.04)	6.19 (± 0.16)	1.08 (± 0.08)
French	0.74 (± 0.04)	7.18 (± 0.12)	0.99 (± 0.09)
German	0.79 (± 0.03)	5.97 (± 0.19)	0.90 (± 0.07)
Italian	0.72 (± 0.04)	6.99 (± 0.23)	0.96 (± 0.10)
Japanese	0.49 (± 0.02)	7.84 (± 0.09)	0.74 (± 0.06)
Mandarin	0.94 (± 0.04)	5.18 (± 0.15)	0.94 (± 0.08)
Spanish	0.63 (± 0.02)	7.82 (± 0.16)	0.98 (± 0.07)
Vietnamese	1 (reference)	5.22 (± 0.08)	1 (reference)

Figure S.6.1-1 Information density and rate in language. Cross-language comparison of information density, syllabic rate, and information rate (mean values and 95% confidence intervals). From Pellegrino et al., 2011.

Note the grouping of the information rate for these languages around a nearly constant value of 1.00 xxx per second.

[23]Pellegrino, F. et al. (2011) xxx *Language* xxx

Appendix S: Table of Contents

Appendix S: Aspects of Language 1
S.1 Introduction 1
S.1.1 The fundamental communications system 3
S.1.2 The acoustic range of human vocalization 5
S.1.3 The symbol set of human language 6
S.1.4 The role of writing in language 6
S.1.5 Why other higher primates cannot speak 6
S.1.6 Why *Cetaceans* can "speak" 8
S.1.6.1 The dolphin vocal repertoire 9
S.2 The null hypothesis for the precise definition of language 9
S.2.1 What is the character of the neural schematic used in language? 10
S.2.1.1 Where does the fundamental framework of the protocol arise? 12
S.2.1.2 Important failures of language interpretation & production . . . 12
S.2.2 How does language differ from communications? 13
S.2.3 How does language arise in the young? 14
S.2.4 How narrow can the definition of language be drawn? 15
S.2.4.1 Comparative physiology related to language 15
S.2.4.2 The character of the neural codes used within the CNS? 15
S.2.5 Evidence does not limit language to Homo sapiens 18
S.3 Ab initio speech production versus recitation from text 18
S.3.3 Disorders in speech vocalization 19
S.4 The working hypothesis of language 19
S.4.1 What is the character of the intrinsic protocol as expressed within the prefrontal cortex 20
S.8 Recent MEG activity relating audition to articulation 21
S.9 The information content of speech 23

Chapter 4 List of Figures 1/18/14

Figure S.1.1-1 The basic elements of a communications system 4
Figure S.1.2-1 Plots of averaged first and second formant frequency combinations 5
Figure S.1.5-1 A comparison of human and chimpanzee supralaryngeal vocal tract 8
Figure S.2.1-1 An expanded schematic of traffic flow within the brain 10
Figure S.2.6-1 Alternate concepts of the Faculty of Language within the CNS 17
Figure S.5.1-1 MEG results involving articulation and audition ADD 21

(Active) SUBJECT INDEX (using advanced indexing option)

95% 23
analytical mode 18
area 41 18
area 6 . . . . 12, 19
attention 21
bit serial 16
Broca’s area 12, 18, 19
cerebellum 10
computation 12, 20
computational 1, 9, 12-14, 20
conscious executive 18
consciousness 10, 12
diencephalon 12
DNA 2
Dolphin 8, 9, 13, 14
epiglottis 7, 8
executive 18
fasciculus 18, 19
fMRI 20
Fourier transform 12, 20
homologs 15
homunculus 19
limbic system 12
MEG 21
MRI 18
pallidum 10
reading 5, 14, 18
saliency map 10, 14
stage 3 20
stage 4 . . . . 9-12, 16, 18, 20
stage 5 . . . . 9, 10, 12-14, 16, 18, 20
stage 6 . . . . 10, 12, 16
striatum 10
syndrome 13
temporal lobe 18
thalamic reticular nucleus 19
translation 5
Wernicke 10, 19
Wernicke’s area 12, 18
white matter 18
Wikipedia 6
word serial 16, 20
working memory 20
xxx 20, 21, 23