# The Integration Hypothesis of Human Language Evolution and the Nature of Contemporary Languages

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## Abstract

How human language arose is a mystery in the evolution of *Homo sapiens*. Miyagawa, Berwick, & Okanoya (*Frontiers* 2013) put forward a proposal, which we will call the **Integration Hypothesis** of human language evolution, that holds that human language is composed of two components, E for *expressive*, and L for *lexical*. Each component has an antecedent in nature: E as found, for example, in birdsong, and L in, for example, the alarm calls of monkeys. E and L integrated uniquely in humans to give rise to language. A challenge to the Integration Hypothesis is that while these non-human systems are finite-state in nature, human language is known to require characterization by a non-finite state grammar. Our claim is that E and L, taken separately, are in fact finite-state; when a grammatical process crosses the boundary between E and L, it gives rise to the non-finite state character of human language. We provide empirical evidence for the Integration Hypothesis by showing that certain processes found in contemporary languages that have been characterized as non-finite state in nature can in fact be shown to be finite-state. We also speculate on how human language actually arose in evolution through the lens of the Integration Hypothesis.

## Introduction

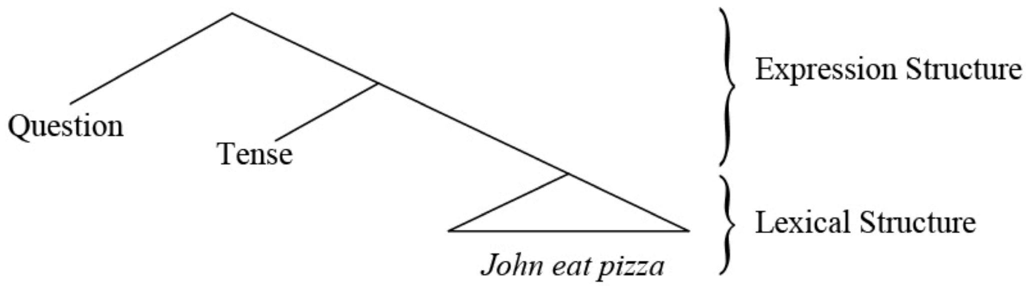
Human language appears to have developed within the past 100,000 years (Tattersall, 2009). While it is extremely challenging to directly confirm any hypothesis of the actual process that led to the emergence of language, it is possible to formulate a theory that is broadly compatible with what we find in contemporary systems among mammals, birds, and humans. Miyagawa, Berwick, & Okanoya (2013) put forward such a theory, which we will call the **Integration Hypothesis** of human language evolution. In this article, we will provide empirical evidence from contemporary languages for crucial components of the Integration Hypothesis. We will also speculate on how human language actually arose in evolution through the lens of the Integration Hypothesis.

We will narrow our focus on the structures found in human language and compare them to other systems such as those found in monkey alarm calls and birdsong. In recent linguistic theory, it is proposed that there is just one rule responsible for structure building, called Merge, which takes two items and combines them into an unordered set (Chomsky, 1995). If Merge is indeed what gives human language its unique character for building structures, it is this operation that largely distinguishes human language from other systems (Hauser et al., 2002;Berwick, 2011). This view of human language leaves open a host of questions including: (i) how did Merge appear?; (ii) why is human language characterizable by a non-finite state grammar (Chomsky, 1956) while other systems of the animal world are finite-state in nature (Berwick et al., 2011)?; and (iii) why do we find processes such as movement and agreement in human language (Chomsky, 1995;Miyagawa, 2010)? The Integration Hypothesis addresses these questions by advancing a conventional Darwinian view: two pre-adapted systems found elsewhere in the animal world were *integrated* in humans to give rise to the unique system that underlies today's languages. One system, which we call Type E for *expressive*, is found, for example, in birdsong (Berwick et al., 2011), which serves to mark mating availability and other 'expressive' functions. The second system, Type L for *lexical*, is found in monkey calls (Seyfarth et al., 1980;Arnold and Zuberbühler, 2006) and honeybee waggle dances (Riley et al., 2005). Types E and L are the two primary forms of communication found in the animal world. Our view that human language syntax arose from pre-existing systems as found in other species is a conventional mode of evolutionary explanation, and so has been advanced by other researchers. For example, Fitch (2011) suggests that the roots of the core computational capacity of human language may be found in the motor control and motor planning. The Integration Hypothesis differs from these accounts in that it is more linguistically detailed and broadly consistent with facts of contemporary languages. At the end of the article, we will speculate on how the E and L systems emerged in humans.

## 2. The Integration Hypothesis of human language evolution (Miyagawa, Berwick, Okanoya 2013)

Every human language sentence is composed of two layers of meaning: a *lexical* structure that contains the lexical meaning (Hale and Keyser, 1993), and *expression* structure that is composed of function elements that give shape to the expression (Chomsky, 1995;Miyagawa, 2010). In the question, *Did John eat pizza?*, the lexical layer is composed of the words *John, eat, pizza*; these words are constant across a variety of expressions. The sentence also contains *did*, which has two functions: it marks tense, and by occurring at the head of the sentence, it also signifies a question. Tense and question are two elements that give form to the expression, making it possible to use it in conversation. The two layers of meaning are commonly represented as follows.

(1) Duality of semantics (Chomsky, 1995;2008;Miyagawa, 2010)




The Integration Hypothesis (Miyagawa et al., 2013) views these two layers as having antecedents in other animal species. The lexical layer is related to those systems that employ isolated uttered units that correlate with real-world references, such as the alarm calls of Vervet monkeys for pythons, eagles, and leopards (Seyfarth et al., 1980; Tomasello and Call, 1997). The expression layer is similar to birdsongs; birdsongs have specific patterns, but they do not contain words, so that birdsongs have syntax without meaning (Berwick et al., 2012), thus it is of the E type. Although parallels between birdsong and human language have often been suggested (Darwin, 1871;Jespersen, 1922;Marler, 1970;Nottebohm, 1975;Doupe and Kuhl, 1999;Okanoya, 2002;Bolhuis et al., 2010;Berwick et al., 2012), we believe that the actual link is between birdsong and the expression structure portion of human language.

(2) Human language and the non-human language-like types

| | | | |
|---|---|---|---|
| LEXICAL STRUCTURE | <—> | BEE DANCES/PRIMATE CALLS | TYPE L |
| EXPRESSION STRUCTURE | <—> | BIRDSONG | TYPE E |

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< Please insert Figure 1 around here>

Figure 1, Bengalese finch song

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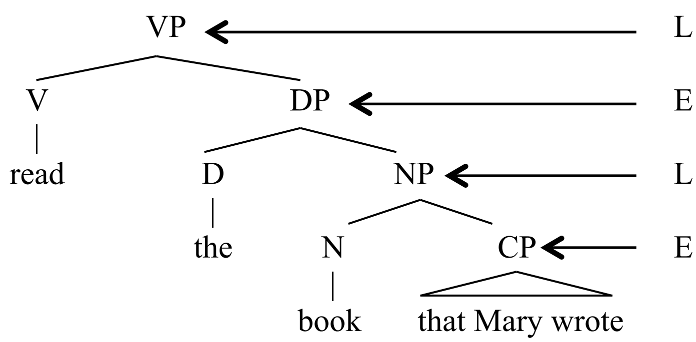
Birdsongs can be complex, as in the example of the Bengalese finch. The Bengalese finch song loops back to various positions in the song, which leads to considerable variation. Nevertheless, all known birdsongs can be described as a *k*-reversible finite state automaton (Berwick et al., 2011), a restricted class of automata that are efficiently learnable from examples. The L type also is a simple finite state system. The Integration Hypothesis conjectures that these two major systems in nature that underlie communication, E and L, integrated uniquely in humans to give rise to language.

Some theories of human language that are not easily compatible with the views proposed here. For example, Lexical-Functional Grammar views words and phrases as having equivalent functions. However, there are the notions of *argument structure* and *expression* *structure* (Bresnan 2001, 9-10) that parallel in general terms the design we are assuming. We in fact adopt the term *expression structure* from LFG. Distributed Morphology (Halle and Marantz 1993, Marantz 1997) denies a division between word formation and phrasal formation. But built into DM is a sharp division that is potentially illuminating for how E and L integrated. According to DM, basic lexical items (*book, cat*, *eat*) lack specification for category. It is only when a category-inducing head is merged (*v, n, a*, etc.) that the structure takes on the familiar category of N, V, A, and so forth (Marantz 1997). Hence, there is a division between structures that don't have any categorical specification, something akin to the L system, and those that have categorical specification and can participate fully in syntactic operations. Whatever the final picture turns out to be, the Integration Hypothesis, looked at from a theory such as DM, would not simply link an E layer with an L layer. Instead, the integration is one of interweaving the two in very fine mesh: E-L-E-L... We in fact see this meshing, or what Boeckx (2006) calls fluctuation, in clausal structure.

(7) E/L hierarchical structure ("D" stands for "Determiner" and is part of the E system for noun phrases)




**3. Three challenges for the Integration Hypothesis from contemporary languages**

We take up three challenges to the Integration Hypothesis from contemporary linguistics: two that ostensibly argue against our proposal that inside E and L we only find finite-state processes; and a third that has to do with the assumption that no two L items can combine directly — any combination requires intervention from E.

The first challenge to the Integration hypothesis that E and L are finite state in nature has to do with the existence of so-called discontiguous word formation. For example, Carden (1983), based on Bar-Hillel and Shamir (1960) and Langendoen (1975;1981), argues that sequences involving the prefix *anti-* and a noun such as *missile* are non-finite state in nature (see also Boeckx, 2006;Narita et al., 2014).

(8) a. [anti-missile]
b. [anti-[anti-missile] missile] missile

The ostensible point is that this formation can involve center embedding, which, if true, would constitute a non-finite state construction. As shown in (8) above, when additional *anti* is attached to the front of the construction, one or more instances of *missile* must occur at the end, giving the impression of center embedding. However, this is not the correct syntactic analysis. When *anti-* combines with a noun such as *missile*, the sequence *anti-missile* is a modifier that would modify a noun with this property, thus, [*anti-missile*]-*missile*, [*anti-missile*]-*defense*. Each successive expansion forms via strict adjacency, as shown by the italicized element below, without the need to posit a center embedding, non-regular grammar.

(9) a. [anti-missile]-*missile*
b. *anti*-[[anti-missile]-missile] (modifier)
c. [anti-[[anti-missile]-missile]]]-*missile* (or, anti-anti-missile-missile-*defense*)

The final construction also led some to claim that when *anti-* is added on the left, two instances of *missile* must occur on the right, which, if true, is a non-regular grammar process. However, as we can see, that is not the correct way to view this construction. *anti-* is attached to [[anti-missile]-missile], forming the modifier *anti*-[[*anti-missile*]-*missile*. To this the additional *missile* is added that is modified by the rest, giving appearance that two instances of *missile* were added.

The second challenge to the finite state nature of E/L is reduplication, often cited as being non-finite state (McCarthy and Prince, 1995;1999;Urbanczyk, 2007). In reduplication a word is reduplicated in its entirety or in part.

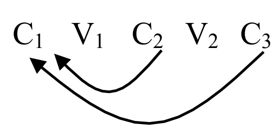
(10) Full reduplication: $\underline{C_1V_1C_2V_2C_3}$ - $C_1V_1C_2V_2C_3$
Partial reduplication: $\underline{C_1V_1}$ - $C_1V_1C_2V_2C_3$.

Following are actual examples of full and partial reduplication (Moravcsik, 1978).

(11) a. kuuna-kuuna 'husbands' (Tohono O'odham plural)
b. tak-takki 'legs' (Agta plural)

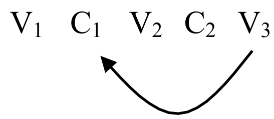
Contrary to the non-finite state approaches common in the literature, Raimy (2000) provides an analysis of reduplication that, in its most basic form, is similar to the 1 finite state automaton we saw for the song of Bengalese finch. He argues that reduplication is a process of looping back:

(12) 1 Finite State Automaton and Reduplication:



There are cases in which a reduplicant may occur to the right of the base: *erasi-rasi* ‘he is sick’ (Siriono continuative, Key, 1965). Here the reduplicant is a copy that begins in the middle of the base and goes to the end. Right-handed reduplicants always have this property of starting in the middle of the base and copy to the end (Marantz, 1982).

(13) “Suffix” Reduplication:




This copying process is a product of a 1 finite state automaton in which the loop back is to the middle of the string.

The third challenge concerns the assumption that the members of L do not directly combine with each other: *L-L. There are compound words such as *tea:cup, brain:power*, that appear to be L-L combinations. However, there is evidence that some E element does occur between the two L’s. In German, when two words combine to form a compound, typically an element (/n/ or schwa) is inserted between the two words, as in *Blume*-N-*wiese* ‘flower meadow’ (Aronoff and Fuhrhop, 2002); this “linking” element has no apparent function, so we can reasonably assume this sequence to be L-E-L. In English, we find a similar linking element in the form of /s/ in: *craft*s*man*, *mark*s*man*, *spoke*s*man* (Marchand, 1969). This /s/ has no function other than to link the two L’s. These linking elements suggest that there is a slot between the two L’s in compound words where we predict an E element to occur. In the case of *teacup*, where there is no overt linker, we surmise that a phonologically null element occurs in that position. As a reviewer notes, languages such as Chinese, where sentences appear to be simple noun-verb-noun sequences, the idea that there are expression items intervening between L items becomes a challenge. Sybesma (2007) argues that there are tests to detect the occurrence of tense in Chinese, hence T head, despite the fact that it is not pronounced.

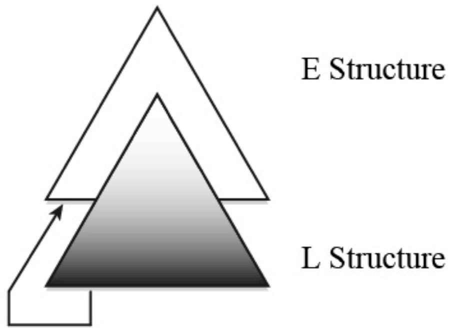
## 4. Movement as a non-finite state process

An operation that is pervasive in human language is movement.

(14) What did you eat ___?

Here the question word *what* is the object of *eat*, yet it has evidently been displaced from this position of thematic interpretation after the verb to where it is actually pronounced, at the head of the sentence. This is clearly a non-finite state operation. When we look at a typical syntactic movement, it is from the L structure to the E structure: *what* begins in the L position of object, then moves to the E position of Question (e.g., Chomsky, 2001;2008;Miyagawa, 2010).

(15) Movement




Agreement is another process that crosses E and L (Miyagawa et al., 2013). Movement and agreement are processes that, by connecting E and L, tie the two structures together. Hence, while we find finite state grammar processes inside E and L, thus reflecting their antecedents in the non-human animal world, non-finite state procedure is introduced to link the two structures together. That is, it is only in crossing from one structure to another that something other than a finite state operation is required.

Theories that do not posit movement nevertheless have operations that cross E and L. For example, Head-driven Phrase Structure Grammar (HPSG) constructs 'pointers' between "what" at the head of sentences to the position after "eat", via the propagation of information from "what" to this thematic argument point. Although there is no explicit 'movement,' the effect is the same (Sag, I., Bender, E., Wasow, T. 2003). Similarly, LFG reconstructs such pairings by means of information structure pairings that cross E-L boundaries, using a base context-free grammar that is composed from two finite-state systems in just the manner suggested above. To be sure, given the wide range of current syntactic theories, in other cases it is simply not possible to mimic the E-L account – an unsurprising outcome, since such theories are often incompatible with each other, as noted by Jackendoff (2010).

**5. Speculation on the integration of E and L**

Given the evolutionary proximity between humans and other primates, the lexical structure in human language can plausibly be traced to non-human primates and their alarm calls and similar L systems. However, the same cannot be said of expression structure and birdsong. The ancestors of present-day birds and mammals split 300 million years ago (Benton, 1990), an evolutionary divide of 600 million years that suggests convergent evolution – independent evolution of E systems in birds and humans, rather than descent from a common ancestor that possessed this trait. Further, even within the *Aves* lineage, vocal learning in songbirds has been independently evolved; for example, there are closely related bird species, such as Ruby Throated hummingbird and Anna's hummingbird, where the former possesses vocal learning but the latter does not – a concrete example of convergent evolution. The other evolutionary possibility is that E systems were present in the common ancestors of humans and non-human primates, or even the rest of the mammalian lineage, in which case humans would have E in virtue of common descent, although the E system would not necessarily be expressed as part of a communication system.

It is known that some behavioral patterns of non-human mammals can be described by finite-state grammars. Syrian golden hamsters (*Mesocricetus auratus*) collect and store food away, and this food-hoarding behavior consists of variable action sequences, which are reported to obey finite-state grammars (Hilton Jones, C. & Pinel, J.P.J, 1990, Behavioral Brain Research). Another example of finite-state action grammar in non-human mammals is the facial grooming and taste-elicited ingestive/aversive actions of rats (Berridge, K.C., Fentress, J.C., & Parr, H. 1987, Behavioral Brain Research). The neural circuits involved in this behavioral grammar in rats have been elucidated (Cromwell, H.C. & Berridge, H.C., 1996, Journal of Neuroscience; Aldridge, J.W. & Berridge, K.C. 1998, Journal of Neuroscience).

However, the finite-state nature of rodents' action sequences does not, in itself, make them Type-E systems, typically seen in birdsong. Individual action units in rodents' behavior cited above are relatively independent of each other, while song elements in birdsong are produced rapidly in succession, creating a sustained pattern when seen as a whole. Each of those individual action units of rodents also has a functional meaning, while individual song elements of birds are meaningless. That is, functional interpretation is possible only when birdsong is seen holistically.

The two requirements for an E system are:

(16) E System
  (i) It creates a sustained pattern;
  (ii) It holistically expresses an internal state of the singer.

E systems may in fact be present to a limited extent in the behavior of non-human primates, for example, in their singing, as first suggested by Darwin (1871). Most non-human primates do not sing, but there is an exception: gibbons (Hylobatidae) (Marshall and Marshall, 1976;Haimoff, 1984). They sing long, complex songs that can last 10 to 30 minutes or even longer. They sing solo songs as well as duets with the opposite sex. It has been suggested that the gibbon song, as a whole, has functions such as territory advertisement, mate attraction, the strengthening of pair and family bonds (Brockelman and Srikosamatara, 1984;Raemaekers et al., 1984;Mitani, 1985;Geissmann and Orgeldinger, 2000). This is analogous to birdsong, a Type E system, which holistically expresses the singer's internal state, but not with meanings based on lexical units.

Some of gibbon's songs are stereotypical, especially in females, but others are highly variable. A song consists of a series of notes, uttered in succession. There are several note types, and in most gibbon species, male songs can be flexible in the order of notes (Raemaekers et al., 1984;Haimoff, 1985;Mitani, 1988). For example, the male song of the Javan silvery gibbon (*Hylobates moloch*) contains 14 distinct note types, which can be assembled into a song in various orders (Geissmann et al., 2005). The transition from one note type to another appears to be probabilistic, allowing one to calculate transition probabilities among note types for a given individual (see Figure 7 of Geissmann et al., 2005). For example, starting from note B3, the song can repeat B3 or go to note C, and then go back to B3 again or move on to note B2, and so forth, at certain probabilities. There is, however, no reported evidence that the gibbon song contains hierarchy in the sense of human syntax. The gibbon song, characterized by probabilistic transitions among different note types but lacking internal syntactic hierarchy, may be analogous in its grammatical structure to certain birdsongs, such as those of Bengalese finches.

Hence, non-human primates, our close relatives, may have the latent potential to vocalize continuously in a finite state fashion to convey a holistic message. What prevents most of them from doing so is not entirely clear, but singing and speech-like vocalizations require complex, precisely timed coordination of various articulation apparatuses. Just generating a sound is not enough; in human speech, sounds generated by the vocal cord are further modulated rhythmically by various orofacial movements. "Lip-smacking", or rapid opening and closing of the mouth and lips, seen in the gelada, a non-human primate, seems to share features of periodicity or rhythm with these orofacial movements of humans' (Ghazanfar et al., 2012). It has recently been reported that geladas not only lip-smack rhythmically but can also vocalize while lip-smacking (Bergman, 2013). It may be that some of the capacities that are natural in humans, such as the production of precisely timed, rhythmic orofacial movements, are not present in non-human primate species. If so, attempts should be made to find E-like systems in non-vocal domains in these animals.

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