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What's special about human language? The contents of the "narrow language faculty" revisited

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Abstract

In this review we re-evaluate the recursion-only hypothesis, advocated by Fitch, Hauser and Chomsky (Hauser, Chomsky & Fitch, 2002; Fitch, Hauser & Chomsky, 2005). According to the recursion-only hypothesis, the property that distinguishes human language from animal communication systems is recursion, which refers to the potentially infinite embedding of one linguistic representation within another of the same type. This hypothesis predicts (1) that non-human primates and other animals lack the ability to learn recursive grammar, and (2) that recursive grammar is the sole cognitive mechanism that is unique to human language. We first review animal studies of recursive grammar, before turning to the claim that recursion is a property of all human languages. Finally, we discuss other views on what abilities may be unique to human language.

Observers of human and animal communication systems seek to understand the cognitive mechanisms and processes that underlie their respective abilities. The research effort is motivated by a desire to understand how and why human language abilities differ from both our hominid ancestors and from other living hominid species, such as chimpanzees (*pan troglodytes*) and mountain gorillas (*gorilla gorilla berengei*). The research question is often framed as a contrast between *continuity* -- the idea that human language abilities are refinements of abilities that are present in a reduced form in other species -- and *discontinuity* -- the idea that human language abilities are qualitatively different and represent a clean break from other species.

The Narrow Language Faculty Hypothesis

How do human communication abilities differ from those of other animals? One possibility is that aspects of grammatical representation and processing represent the key characteristic that discriminates between humans and other kinds of animals. This approach fits squarely within the discontinuity tradition. Fitch, Hauser, and Chomsky (Hauser, Chomsky & Fitch, 2002; Fitch, Hauser & Chomsky, 2005), in particular, divide human language abilities into *narrow* and *broad language faculties*. The broad language faculty includes perceptual and cognitive abilities that are required for language production and comprehension, but that are shared with other perceptual and cognitive processes (such as reasoning and decision-making) or are shared with non-human animals. The narrow language faculty, by contrast, includes those cognitive abilities that are used for language production and comprehension, are not used for any other perceptual or cognitive tasks, and are not shared with non-human animals. Grammar and syntax are described as the key components of the narrow language

faculty. More specifically, these theorists advocate *recursion* as being the vital component of grammar that differentiates human language from other forms of cognition, including communication systems in other animals (Hauser et al., 2002; Fitch et al., 2005). Recursion is defined as the ability to embed a representation of a given type within another representation of the same type to an infinite depth.ⁱ (Although other definitions of recursion are available in the literature, this seems to be the characteristic to which Hauser and colleagues refer.)

These theorists also claim that recursion is the property of grammars that differentiates between *finite-state grammars* and *phrase-structure grammars*.ⁱⁱ Finite state grammars and phrase-structure-grammars are representational and processing systems that allow an individual to combine symbols into extended strings. However, some linguists argue that only grammars that include recursion are truly generative. That is, only such grammars permit embedded structures and the existence of long-distance dependencies. In this formulation, while a finite-state grammar can produce strings of alternating symbols such as, ABAB, or BABA, a phrase-structure grammar is necessary in order to generate strings such as AAABBB or $A_1A_2A_3A_4B_4B_3B_2B_1$, in which each A-element is paired with a corresponding B-element, and the two paired A and B elements may be separated in the string by intervening elements. In short, phrase-structure grammars allow the embedding of representational units within larger, hierarchically organized structures.ⁱⁱⁱ (It is such embedding that allows the construction of natural language strings such as *The senator that the reporter that I like interviewed denied the accusations.*)

Fitch and colleagues' claim that recursion is the sole occupant of the narrow language faculty is based on a review of the non-human communication literature. As they note (Fitch, Hauser, & Chomsky, 2005, p. 203), "Despite decades of search, no animal communication system known shows evidence of ...recursion. Nor do studies of trained apes, dolphins, and parrots. The perceptual data currently available indicate that monkeys cannot even process hierarchical phrase structure, much less recursion. There is no unambiguous demonstration of recursion in other human cognitive domains, with the only clear exceptions (mathematical formulas, computer programming languages) being clearly dependent on language."

The chief goal of this review is to reconsider the central claims advocated by Fitch, Hauser, and Chomsky. The first of these is that non-human primates (and other animals) lack the ability to acquire phrase-structure grammars. The second is that recursion is uniquely tied to human language and is not present in other animal communication systems. A third claim is implicit in the second; namely, that recursion will be found wherever human language is found. If any of these claims is refuted, that would call into question the description of human language as consisting of a narrow language faculty that has recursion as its sole occupant, and a separately configured broad language faculty that includes other kinds of cognitive abilities, some of which are shared by other systems and other animals. Thus, we take seriously Fitch and colleagues' description of the broad and narrow language faculties as a theory of human language abilities which can be subjected to empirical evaluation. As

ⁱAlthough infinite embeddings are hypothetically possible, multiple embeddings in natural language are rare and even single embeddings can be very difficult to process, as in *The lawyer that the banker phoned needed a favor*. Prominent psycholinguistic accounts attribute practical limitations on embeddings to working memory restrictions (e.g., Gibson, 1998), the availability of alternate forms (Gennari & MacDonald, 2009), or other cognitive factors (MacWhinney & Pleh, 1988).

ⁱⁱNote that not all linguists believe that phrase-structure grammar is the appropriate means for describing non-scrambling languages, such as English (e.g., Sag et al., 2003; Traxler & Pickering, 1996). Further, many linguists argue that phrase-structure representations do not apply at all to scrambling languages. They advocate instead for a representational system based on dependency relations (see Evans & Levinson, 2009, for a description of some alternative representational frameworks and a recent review of the available linguistic evidence.)

ⁱⁱⁱThe fact that such strings are un-parseable in practice does not mean that they are ungrammatical.

they noted (Fitch et al., 2005, p. 182) "The contents of FLN are to be empirically determined." Further, (pp. 182–183), "We do not define FLN as recursion by theoretical fiat (note, we say "a key component"), which would contradict the aims of our paper, but offer this as a plausible, falsifiable hypothesis worthy of empirical exploration." As part of this evaluation, we will re-examine the body of animal studies that have been claimed to support recursion as a unique feature of human language, as this evidence plays a critical role in supporting Fitch and colleagues' account. As they noted (Fitch et al., 2005, p. 203), "... current data justify our placing syntactic recursion in FLN. This assignment would clearly be threatened by a claim of similar recursion in birdsong or the discovery that chimps can process recursive strings, or *various other empirical findings* (emphases ours) - all signs of a strong, falsifiable hypothesis." We interpret "various other empirical findings" as encompassing a cross-linguistic evaluation of recursion as a universal property of human languages.

Grammar Learning in Animals

To decide whether aspects of phrase-structure grammar constitute the narrow language faculty (as defined by Fitch and colleagues), one would need to investigate whether the ability to represent hierarchical relations between discrete representational elements is present in species other than humans. The most likely candidates to possess such abilities would be other primates. Researchers have therefore applied exposure-test research methods to studies of non-human primates to address the question of whether they can acquire phrase structure grammars. Evidence that other non-human primates can acquire phrase structure grammar would falsify the claim that only humans can process hierarchically organized phrase-structure representations, which would in turn invalidate Hauser and colleagues' claims about what makes human language unique.

To find out whether primates can learn a phrase structure grammar, researchers have used an experimental paradigm in which meaningless sounds, typically syllables, are strung together in different kinds of sequences (Fitch & Hauser, 2002). Some of these sequences can be generated by finite-state grammars; other sequences, however, can only be generated by a phrase-structure grammar. To date, cotton-top tamarins (*Saguinus oedipus*), birds, and humans have been tested on their ability to learn sequences generated by a phrase-structure grammar.

To determine whether tamarins can learn complex sequences of syllables, researchers first exposed them to a 20-minute recording of syllable sequences of different types. The syllable sequences were generated either by a finite state grammar (ABAB) or a phrase-structure grammar ($A_1A_2A_3B_3B_2B_1$). The morning after the 20-minute exposure session, tamarins heard two-minute excerpts from the previous days' recording to refresh their memories and were then tested.

It is important to note here that, in all of the relevant tamarin research to date, all of the "A" and "B" syllables were further differentiated by gender of the speaker. As critics have since pointed out, this makes it possible for an animal to distinguish between the two types of sequences by attending to the number of male-female transitions (1 or multiple) (Perruchet & Ray, 2005; Hochmann, Azadpour & Mehler, 2008).

The test phase involved novel sequences of syllables that were either consistent with the training grammar or consistent with another, non-trained grammar. The sequences were played over a speaker in the animal's enclosure, with stimulus onset occurring only when the tamarins were looking away from the speaker. The critical measure was whether the tamarin oriented toward the speaker. If the tamarins were habituated to the stimulus, because they recognized the sequence as being familiar, then they should orient to the test sequence for

only a short period of time. If instead they recognized the sequence as being novel, then they would orient towards the source of the stimulus for a longer period of time. The results of the experiment suggested that the tamarins (9 of 10 animals) acquired the finite state grammar. Animals that were trained on the finite state sequences spent 70% more time oriented towards the source when the test sequences violated the finite-state grammar. By contrast, animals that were trained on the phrase-structure sequences did not spend more time oriented towards the source when the test sequences violated the phrase-structure grammar. Hauser and colleagues concluded that tamarins were capable of acquiring the finite-state grammar, but not the phrase-structure grammar (Fitch & Hauser, 2004; Hauser et al., 2005).

These results contrast with the outcomes of very similar studies conducted on a variety of bird species. For instance, Gentner et al. (2006), studied European starlings (*Sternus vulgaris*) to determine whether they could discriminate between strings generated by a context-free phrase-structure grammar and strings generated by a finite-state grammar. The sequences consisted of "warbles" or "rattles." There were eight different "warbles" and eight different "rattles." Eleven starlings were trained to peck for a food reward if they heard a series of sounds that matched a grammar upon which they had been trained. If they pecked incorrectly, they were given a time out, during which time they were not rewarded with food. The starlings' ability to recognize the trained pattern was estimated using a d' score (which is a measure that takes into account response bias and false alarms, and so returns an accurate estimate of discrimination ability). A sub-set of the starlings, 4 "fast learners," required 9,400 training trials to attain maximum accuracy. Other birds required up to 56,000 trials. Two birds never managed to discriminate between the different kinds of strings. These results were interpreted as indicating that starlings have some ability to "accurately recognize acoustic patterns defined by a recursive self-embedding context-free grammar" (Genter et al., 2006, p. 1204). If these results were taken at face value, they would show that starlings can compute recursive relationships between constituents in auditory strings. This would call into question Fitch and colleagues' claim that a "narrow" human language faculty consists of recursion, because the ability to recognize recursive strings and differentiate them from similar "ungrammatical" strings would have been shown to occur in a non-human species.

However, critics of the starling research have noted that birds could pass the discrimination test without actually computing the embeddings or keeping track of long-distance dependencies (Van Heijningen, 2009; see also Corballis, 2007). For example, zebra finches were exposed to similar AAABBB ("phrase-structure") or ABAB ("finite-state") strings, but were additionally tested with other strings that were consistent with only a sub-component of the training strings. These sub-component strings might begin with AA but continue with BBB, rendering them inconsistent with the phrase-structure grammar because one of the B elements lacks a corresponding A element. The zebra finches treated these "ungrammatical" strings as though they were grammatical.

The finches appeared to have internalized a rule specifying that "if it begins with two 'A's, peck; if it does not begin with two 'A's, withhold pecking." Every finch appeared to have its own idiosyncratic strategy which allowed it to respond appropriately to the strings, but no finch actually acquired a phrase-structure like rule. Instead, their behavior was driven by much simpler heuristics. Further, the finches who successfully discriminated AAABBB and ABAB strings were not able to discriminate new strings that used different auditory tokens, such as CCCDDD versus CDCD—other than one exceptional finch, who did generalize the "two same" rule to the new strings. These results call into question the conclusion that European starlings can recognize recursive strings, as the discrimination performance of

those birds may well have been the product of simple heuristics, rather than the acquisition of a phrase-structure grammar rule involving recursion.

The bird work raises a set of larger issues in the comparative approach to grammar and language. First, it is intriguing that birds could "pass" the test for acquiring the phrase-structure grammar sequences but ostensibly much more intelligent animals (cotton-top tamarins) that are more closely related to humans could not.^{iv} Birds relied on a simple counting strategy or heuristic (such as paying attention to AA or BB bigrams) in order to respond appropriately during the test period (Corballis, 2007; Van Heijningen et al, 2007). Presumably, cotton-top tamarins have the cognitive ability to pass the test using a similar strategy. Indeed, Hauser and colleagues themselves comment on the arithmetical abilities of the cotton-top tamarin in their 2004 *Science* article. As they note (p. 379), "Earlier work with the species (cotton-top tamarins) demonstrates that these animals are perfectly capable of storing and recalling at least three separate stimuli and comparing them with subsequent strings (see also Nieder et al., 2002; Jordan et al., 2006, 2008)." Perhaps the critical difference between the bird and primate studies relates to the number of test trials that the animals completed or the operant rewards that accompanied accurate performance in the bird studies. Had the tamarins completed more test trials, perhaps they would eventually have developed the heuristic that birds adopted (even the fastest bird learners required 9000 test trials). However, assuming that the reported results (Fitch & Hauser, 2004) are accurate, this possibility is less likely, because the tamarins were able to pass the finite-state grammar test based on the same number of trials as the phrase-structure grammar test.

The second issue is that the "AAABBB" test for acquiring phrase-structure grammar may not be a valid test of phrase-structure-grammar learning. First, humans, who we know are capable of learning phrase structure grammars, fail some versions of the "AAABBB" test. In a study by Perruchet and Ray (2005; see also Hochmann et al., 2008), humans' (*homo sapiens*) ability to acquire phrase structure sequences under two conditions was tested. In one condition, nonsense syllables were all spoken by the same voice (male or female). In another condition, half of nonsense syllables ("A") were spoken by a male, while the other half ("B") were spoken by a female (as in the non-human primate study discussed above). When the syllables were differentiated by gender of speaker (see above), participants successfully discriminated between grammatical and ungrammatical sequences, based on the phrase-structure grammar pattern. But when all of the syllables were spoken by the same voice, most of the participants were unable to learn the underlying grammar. These results suggest that when humans do pass the "AAABBB" test, they most likely do so by applying a simple heuristic, as did the zebra finches. In fact, human participants in a similar study who were able to correctly reject ungrammatical sequences were the exact participants who subsequently reported a strategy of syllable counting (Hochmann et al., 2008). Thus, human performance on A^nB^n artificial grammar tasks is not based on acquiring the abstract grammar. Instead, their performance seems to be driven by a simple heuristic. As Hochmann and colleagues (2008, p. 1031) note, "Transitional probabilities between categories or rhythmic regularities, rather than grammar extraction, guided behavior in these experiments."

To determine whether non-human primates can learn recursive grammatical structures, better tests will have to be developed. We propose that a better test of the ability to learn recursive grammar must improve upon the A^nB^n paradigm (used in Hauser et al., 2002; etc) in at least two ways. First, an appropriate test would be one for which correct responses can be unambiguously attributed to participants' learning the recursive rule. For example, successful performance should depend on learning that certain *A* elements are paired with

^{iv}Some of Hauser's other published research on tamarins has been retracted.

certain *B* elements, rather than learning that a certain number of *A* elements predicts a certain number of *B* elements. Second, a better test also must be one that humans can consistently pass (again, showing evidence of element-pairing). Such a paradigm should be applied to both humans and non-human primates, ideally chimpanzees and bonobos, which are more closely related to humans than cotton-top tamarins, the only non-human primate species that has been tested thus far.

The Contents of the Narrow Language Faculty

If we accept the description of human language as consisting of a unique core (*Narrow Language Faculty* (FLN) in Fitch and colleagues' terms) and a peripheral suite of cognitive abilities (*Broad Language Faculty* (FLB)), then of the contents of each must be described. According to Fitch and colleagues, the sole occupant of FLN is recursion, defined as the ability to embed a constituent of a given type within another constituent of the same type. This formulation can be falsified if other language abilities are found to be unique to humans, in which case the contents of the FLN would necessarily include more than just recursion. The formulation can also be falsified if evidence is found of a human language that does not make use of recursion (assuming that universal language properties will be manifest in some observable form in all human languages).

Evidence against recursion as a universal human language characteristic might be found in *Pirahã*, a language spoken by approximately 300 hunter-gatherers in the Amazon River basin in Brazil. This language has been documented almost exclusively by the linguist Daniel Everett, who spent approximately three decades living with the Pirahã. According to Everett, Pirahã lacks any form of syntactic recursion. An English sentence such as "Give me the nails Dan bought," contains a recursive element, "Dan bought the nails" -- as in "Give me the (nails)_{filler} that Dan bought _{gap} (the nails)_{filler}." A Pirahã speaker would express that same thought in the following way: "Give me the nails. Dan bought those very nails. They are the same" (Everett, 2010). Even "mild" forms of recursion, such as conjoined noun phrases, are not attested in Pirahã (E. Gibson, 2010, personal communication).

Assuming Everett is correct about Pirahã, the existence of a language that does not have recursion would appear to falsify a strong version of the "narrow language faculty" claim. If recursion is the sole occupant of the narrow language faculty, and if we assume that the contents of the narrow language faculty will influence overt language behavior, the absence of recursion in the overt form of any human language would provide evidence that recursion is not present in the mental processes that generate the overt form.^v Fitch and colleagues (2005) respond by claiming a clear distinction between overt behavior and underlying mental abilities. They suggested (p. 203) that, "A Pirahã child raised in a Portuguese, English or Chinese environment will master those languages with the same ease as his or her mother's tongue, just as the same child could learn the recursive embedding principle of parentheses in mathematics, or a computer programming language with recursive structure." In other words, recursion is present in the narrow language faculty in Pirahã speakers; it is simply not expressed in the overt form of the language. They note further that, (p. 203), "The putative absence of obvious recursion in one of these languages is no more relevant to the human ability to master recursion than the existence of three-vowel languages calls into doubt the human ability to master a five- or ten-vowel language...In the face of the huge

^vOne could argue that the absence of recursion in the overt form of Pirahã does not rule out an underlying ability to compute recursive linguistic forms. The logic is that any system that can compute recursion is also capable of computing non-recursive forms. While this is certainly logically correct, de-coupling observable behavior from underlying computation in this way is problematic. Here is an analogy: If I turn my television on, and a picture appears on the screen, I can assume that there is a picture tube or other device inside that is projecting the picture. However, if I turn my television on and no picture appears, I can not assume that my specific television has a picture-projecting device inside, even if all other televisions do.

number of human languages that have clausal embedding, the existence of one that does not would in no way alter the explanatory landscape...our language faculty provides us with a toolkit for building languages, but not all languages use all the tools." The chief concern about this move is that it introduces a wedge between observable behavior and underlying computations, which in turn makes it difficult or impossible to predict what language characteristics will actually be observed when theoretical claims are subjected to empirical evaluation. We might also ask, if recursion is the sole occupant of the narrow language faculty, does that not place it in a class apart from other items in the "tool kit"? If it is the sole occupant, the unique and universal component of the human language faculty, why should we not expect it to be present wherever we look?

Like Fitch and colleagues (2005), Bickerton (2010) suggests that Pirahã infants would have no trouble acquiring a language that entails recursive structures. He explains the absence of recursion in the overt form of Pirahã as reflecting "a special and extreme case of acquisitional delay" (p. 220). It is not entirely clear what Bickerton means by "acquisitional delay." He may simply be reiterating the competence-performance distinction that has been used elsewhere to buffer linguistic theories of the structure of language from potentially contrary observations of overt behavior. However, he may be implying that cognition among the Pirahã has, for unspecified reasons, lagged behind the rest of the language-using world. If Bickerton intends the former claim, it has the previously described effect of rendering the recursion hypothesis difficult to test. If he intends the latter, this claim is not supported by empirical observations.

Other theorists have provided different explanations for why Pirahã lacks recursion. For example, Coolidge and colleagues (2010), accept the possibility that the absence of recursion in the overt form of Pirahã reflects the absence of recursive representations in the grammar of Pirahã. This move successfully unifies observable behavior with underlying cognition. However, Coolidge and colleagues attribute the absence of recursion to aspects of the broad language faculty. Specifically, they claim that Pirahã speakers lack the working memory capacity necessary to compute recursion. They note that the absence of recursion in Pirahã "could be consistent with other explanations, such as an underlying neurophysiological deficiency, like limited working memory capacity."^{vi} (They also endorse Bickerton's "severe acquisitional delay" explanation as an alternative.)^{vii}

There are a number of problems with this line of reasoning, not the least of which is that Coolidge and colleagues offer no evidence about the working memory capacity of Pirahã speakers. There is evidence that visual short term memory is the same in English speaking and Pirahã speaking populations (Frank et al., 2008). Other short-term memory tasks, in particular, some forms of delayed-match-to-sample tasks, do appear to be undertaken differently by Pirahã speakers, because their language lacks number terms (such as *five*, *seven*, *twenty-two*, etc.). However, cognitive theorists long ago adopted a distinction between short term memory (as indexed by tasks such as digit span) and working memory (as indexed by tasks such as *operation span* and *sentence span*) (Baddeley & Hitch, 1974; Just & Carpenter, 1980; Waters & Caplan, 1996).^{viii}

^{vi}The WIRES opinion article does not have page numbers. The quote can be found on the fourth page of the article, in the second column.

^{vii}Coolidge and colleagues also suggest that the precise reasons why Pirahã lacks recursion do not matter. That is, the evidence from Pirahã is simply irrelevant to the discussion of human language ability in general and the universality of recursion in particular.

^{viii}Even in English, there is not a simple relationship between working memory capacity (as it is normally measured) and grammatical processing ability (as it is normally measured) (Traxler et al., 2002, 2005, in press; see also MacDonald & Christiansen, 2002; Waters & Caplan, 1996).

Everett, by contrast, explains the absence of recursion in Pirahã as reflecting cultural values. He describes Pirahã speakers as culturally committed to literal interpretations and representations. For example, they do not have any creation mythology. They have spiritual beliefs, but these are informed by direct interactions with the physical world, and strong beliefs about the direct perception of spiritual events. Everett explains the absence of recursion in Pirahã by suggesting that the culture only allows direct statements of fact and does not permit presuppositions. These cultural factors influence and constrain the grammatical properties of the language. One example is the "one assertion per utterance" rule. This rule conforms to the Pirahã cultural value of expressing only ideas for which one has direct evidence. In recursive forms, such as "Give me the nails Dan bought," the idea "Dan bought the nails" is implied or pre-supposed but not directly asserted. One way to eliminate pre-supposed elements from a language is to bar recursive structures.^{ix}

Everett's analysis of Pirahã suggests that one can have a human language without recursion, which would nullify the central claim of the recursion-only hypothesis: that recursion is the sole occupant of the narrow language faculty. But what about the flip-side of the argument: Is it possible that other language abilities are unique to humans? That is, could the bulls-eye of what is unique to human language include things other than recursion? Pinker and Jackendoff nominate speech processing, phonology, conceptual structure, the number and range of words that humans know, and aspects of grammar such as case-marking as additional occupants of the narrow language faculty (Pinker & Jackendoff, 2005; Jackendoff & Pinker, 2005).

Appealing to conceptual structure as differentiating human language abilities from other species may be problematic. Pinker himself (1994) strongly differentiates non-linguistic cognition (*mentalese*) and linguistic computations. The notion that aspects of mentalese represent unique components of human language abilities would seem to contradict this earlier formulation.^x That leaves aspects of grammar besides recursion, case-marking in particular, as the possible sole occupant of the narrow language faculty. However, languages like English and Chinese have almost no overt case marking, and such case marking as English has is rapidly dying out (e.g., *who* vs. *whom*; ?"Me and her went to the store" is acceptable in some dialects of English). It would not be at all surprising if one or more of the approximately 6,000 living human languages lacked case marking of any kind. Thus, although Pinker and Jackendoff claim that case marking is an occupant of the bulls-eye, it remains to be seen whether case marking is universally attested in human language. Furthermore, in line with the FLN/FLB framing of the debate, we would need to know whether non-human animals are incapable of learning a case-marking system.

Does Language Learning Require Innate Syntactic Universals?

The discussion of the narrow versus broad language faculties and the potential special role or recursion ties to a larger discussion about the nature of grammatical representation and language acquisition in humans. Nativist theory has had a longstanding attachment to syntactic universals and innate representations as the keystone of human language acquisition. However, belief in innate, syntactic universals is not itself universal amongst

^{ix}Some linguists (e.g., Nevins et al., 2009), argue that Pirahã really does have recursion. This conclusion is based on a linguistic analysis under which some verbatim forms that appear to be non-recursive really are reflecting underlying recursive forms. The problem with this approach is that, like the competence-performance distinction, it asks us to ignore the evidence that we can actually see. It could be the case that non-recursive expressions are produced by an underlying recursive grammar plus some mental process that converts embedded or recursive forms into linear forms prior to production. However, this account loses a parsimony fight with an account that says "recursion does not appear in the observed forms because it is not present in the representations and processes that produce those forms."

^xIn fact, the idea of conceptual processes being distinct from linguistic computation has good empirical support, and is incorporated into predominant theories of language production and comprehension (Levitt, 1989; Traxler, 2012).

linguists or psycholinguists. Recent research on children's grammatical development suggests that grammar may be acquired on a frame-by-frame basis, as opposed to being acquired via parameter setting. Recent advances in mathematical modeling indicate that it is possible to acquire vocabulary and grammar without pre-existing, innate grammatical categories (Abbot-Smith et al., 2010; Bannard, et al., 2009; Casenhiser & Goldberg, 2005; Chan et al., 2010; Kirjavainen et al., 2009; Lieven et al., 1997; Kid et al., 2010; Lany et al., 2007; Marchman et al., 1991; McClure et al., 2006; Tomasello, 2000; Waterfall et al., 2010). Further, *unsupervised learning* models show that grammatical categories can be induced from samples of child-directed speech without external feedback (Waterfall et al., 2010). Similar results have been obtained from self-organizing interactive computational systems that are embedded in autonomous agents (Steels, 2003). These alternative approaches to language acquisition do not require recursion, or any other syntactic form or process, to be present in a language user. Hence, the existence of a human language that lacks recursion does not challenge any of their core assumptions. Minimally, they provide examples of development of sophisticated linguistic behavior that do not depend on the prior implementation of innate syntactic representations. The extent to which these non-innate accounts capture human linguistic development is an area of intense ongoing scrutiny.

Conclusion

Birds, but not primates, have been shown to pass the standard test for phrase-structure grammar acquisition. This may reflect limitations in the test itself and in the published research, rather than reflecting a clean split between the computational abilities of humans and non-human primates. We propose that more stringent tests be applied before strong conclusions are drawn. Further, it may make sense to expand the discussion of human language abilities and acquisition beyond recursion. This broader discussion may include the question of whether we need to postulate innate syntactic universals as a precursor for language acquisition.

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