

Does Broca's play by the rules?

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Languages may all share and be constrained by a universal grammar. A new study shows that Broca's area (long thought to participate in grammatical aspects of language) becomes increasingly active as participants acquire rules from a foreign language, but not as they acquire comparable rules that are inconsistent with real languages. Could Broca's area be a neural substrate for universal grammar?

The capacity to acquire language is a uniquely human trait. The influential linguist Noam Chomsky has long argued that this capacity depends on an innate 'universal grammar' (UG) that constrains the form that human languages can take. For example, Chomsky proposed that the grammars of human language consist of recursively or hierarchically defined relations rather than linear relations¹; a simple yes/no question (*Could Sandy win?*), for instance, is formed by extracting the hierarchically highest auxiliary verb from the corresponding declarative sentence (*Sandy could win*) rather than the first auxiliary verb in the linear order of the sentence. Hence the question corresponding to *The man who was running is bald* is *Is the man who was running bald?*, rather than *Was the man who running is bald?* (Fig. 1). This subtle observation reflects an important fact about what people know about their language, including even pre-school aged children² who have relatively little practice with such constructions. On Chomsky's view, a child's ability to learn the right generalization about forming English questions is a direct reflection of the biology of UG, which constrains the mind to be able to acquire certain types of grammatical rules, and not others.

In an intriguing article in this issue, Musso *et al.*³ present new neuroimaging results that may provide insight into the neural underpinnings of such a universal

grammar. German-speaking adults learned a small vocabulary in a foreign language (Italian or Japanese). Participants were then explicitly taught UG-consistent rules (for example, dropping subject pronouns in Italian, *Io mangio una pizza* → *Mangio una pizza*), and UG-inconsistent manipulations of the foreign languages (for example, forming negation in pseudo-Japanese by inserting *nai* after the third word of the sentence, *Maria wa piza o taberu* → *Maria wa piza nai o taberu*). Subsequently, participants were asked to judge whether novel test sentences followed or violated those sets of rules. Methodologically, this design represents a considerable advance over many earlier studies that looked only at artificial languages⁴ or 'jabberwocky' sentences that are made up of a familiar grammar with novel open-class lexical items⁵ (for example, *The plover was being rished*). Musso *et al.*'s study may thus be the first to directly contrast UG-consistent and UG-inconsistent rules. By using real linguistic materials and testing users' ability to manipulate linguistic items according to real rules of natural language, Musso *et al.* offer an unusually direct investigation of the hypothesis that language acquisition is constrained by UG.

Subjects learned UG-consistent and UG-inconsistent rules equally accurately (perhaps due to a ceiling effect), and both

real and pseudo-linguistic rules initially activated Broca's area to a similar degree, although subjects were faster with the real language rules. Most intriguingly, a specific subdivision in Broca's area, the pars triangularis (Brodmann's area 45), became more active over time as participants became adept with the real rules but less active over time during comparable presentations of

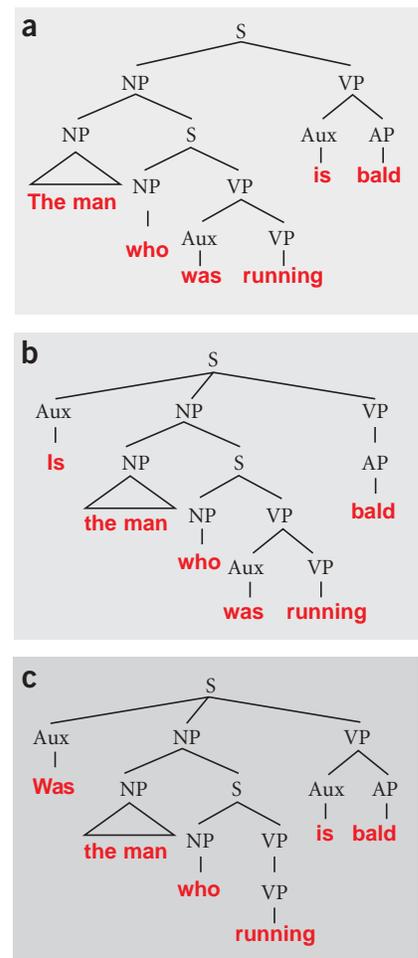


Figure 1 The grammars of human languages consist of hierarchically defined relations (illustrated here with three examples of a simple sentence) suggesting that an innate 'universal grammar' may constrain the form that human languages can take. For example, simple questions are formed by extracting the hierarchically highest auxiliary verb (**b**) from the corresponding declarative sentence (**a**) rather than simply the first auxiliary verb in the linear order of the sentence (**c**).

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their pseudo-linguistic counterparts—apparently reflecting a neural sensitivity to the distinction between UG-consistent and UG-inconsistent grammatical operations.

As Musso *et al.* note, such results are broadly compatible with the Chomskian view that a universal grammar or ‘language acquisition device’ is critical for language acquisition: one possible interpretation of these results is that Broca’s area may initially be recruited in the ‘unreal’ rule task by the apparent linguistic nature of the stimuli, but as increased exposure reveals that the experimental ‘rule’ does not specify the type of hierarchical relation found in natural language, Broca’s area disengages. In contrast, learning genuine linguistic materials elicits increased engagement of Broca’s areas.

Before settling on this interpretation, however, further controls are necessary to rule out a variety of less exciting alternatives. For example, would more complex grammatical sentences^{6,7} (or sentences that place greater memory demands) engage Broca’s area more over time than other less complex, but equally grammatical, sentences? Would learning hierarchical operations applied to non-linguistic materials (such as musical tones) elicit similar results? Before one can take the extent to which Broca’s area engages (or disengages) with proficiency and time as an index of UG—as opposed to an index of complexity, memory or language-independent recursion—follow-up studies must show that changes in the engagement of Broca’s area over time truly track a UG/non-UG distinction, rather than alternative factors.

An additional question concerns the differences between first (native) language acquisition and adult second language acquisition. Taken at face value, the current results appear to show that Broca’s area is involved not just in language processing (long known from studies of aphasia) but also in language acquisition—in the actual process of acquiring language. (Although language acquisition and language processing must make use of some of the same resources, they might also use distinct or partly distinct neural substrates, much as the acquisition and production of birdsongs seem to do.) Given the difficulties adults have in acquiring second languages, especially in comparison to their younger counterparts, it will be interesting to see whether similar results are obtained in children.

Perhaps the most important question is whether the results of Musso and her colleagues genuinely reflect language acquisi-

tion, rather than (say) the acquisition of conscious rules in a recursive version of a language game like Pig Latin. Especially given that subjects were told the rules in explicit form (in contrast to children who extract the rules of language without explicit instruction), it will be important to see to what extent the language faculty is truly engaged. Although the materials patently have the form of genuine linguistic content, the current methods test at most whether subjects could detect the grammaticality of relatively isolated sentences, rather than, for example, whether subjects correctly understood their meanings.

If the increasing engagement of Broca’s area over time truly can be taken as an index of UG, it could be used as a tool to compare competing conceptions of language. For example, whereas Chomsky described the formation of yes/no questions (Fig. 1) in terms of a transformation that ‘moves’ the main auxiliary verb to the front of a sentence, other linguists have developed competing accounts in which structures are generated directly, without appeal to any inversion operation (in which case the current task would less directly reflect the underlying linguistic operations)^{8,9}. Although the current data cannot distinguish between these differing conceptions, similar techniques might contribute to evaluating competing hypotheses.

Either way, the methods and results reported here might also have important implications for our understanding of Broca’s area. In an earlier era, researchers thought that Broca’s area was the seat of grammar and little else. More recent studies have shown that the cluster of grammatical impairments known as Broca’s aphasia are not necessarily tied to Broca’s area: lesions in other parts of the brain can lead to grammatical impairments, and not every lesion in Broca’s area leads to grammatical deficit¹⁰. Furthermore, other recent studies have shown Broca’s area to be active in domains as diverse as music perception¹¹ and motoric imitation¹².

One possibility, consistent with current results, is that different subdivisions within Broca’s area may specialize in different domains. The pattern of differential engagement in this study is confined to the anterior subdivision of Broca’s area, the pars triangularis (Brodmann’s area 45), and does not extend to the more posterior division, pars opercularis (BA 44). The current activation of pars triangularis is thus consistent with results of prior studies of syn-

tactic processing¹³. This anterior (BA 45) localization is in contrast to studies of Jabberwocky sentences, musical syntax and imitation of actions, which tend to activate the posterior pars opercularis subdivision (BA 44) of Broca’s area^{5,11,12}, suggesting that different subdivisions may specialize in different content areas (for example, language versus music).

Alternatively, different brain regions may specialize in different types of computations—such as detecting properties of structure, interpreting hierarchical structures, or recognizing dependencies between repeated or related elements—independently of particular content domains. On this view, regions of the brain like Broca’s area may genuinely participate in a wide range of tasks, with specialized function emerging from unique configurations of domain-general mechanisms; the results of Musso *et al.* might then reflect a domain-general mechanism for supporting recursion, rather than a UG-specific neural substrate (for instance). Rather than there being a single, localizable ‘language module’, our faculty for language might consist of a small number of uniquely human neural substrates working in tandem with a wide range of other evolutionarily conserved mechanisms^{14,15}. The present results remind us that whether or not the majority of the neural substrates for language are specialized solely for language, they are likely to be a repository of rich and interesting constraints on what a language can be.

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