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Lexico-semantics obscures lexical syntax

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Introduction

A recently emerging generalization about language and the brain is that brain regions implicated in language that show syntax-related activations (e.g., increased activation for more complex sentence structures) also tend to show word-related activations, such as increased activation for reading real words (e.g., *poet*) relative to pseudowords (e.g., *tevill*). Fedorenko et al. (2020) generalize as follows: "...syntactic/combinatorial processing is not separable from lexico-semantic processing at the level of brain regions-or even voxel subsets-within the language network". Based on this generalization, Fedorenko et al. have made the conclusion..." that a cognitive architecture whereby *syntactic processing is not separable from the processing of individual word meanings* is most likely," arguing against "syntax-centric" views of language as promulgated by Chomsky and others. However, the notion of "lexico-semantics", a commonly used concept in the field of neurolinguistics, obscures the fact that words are both syntactic and semantic entities. Because of this, any functional neuroimaging experiment that manipulates lexicality will almost assuredly tax both syntactic and semantic resources and is therefore inadequate for isolating conceptual-semantic processing in the brain in addition to syntax. Unlike these sorts of neuroimaging studies, robust lesion data show clear functional-anatomical dissociations within the language network. Finally, a "syntax-centric" view of language is perfectly compatible with the state of the art in neurobiology because of the multiple potential mappings between linguistic theory and neurobiology beyond the level of individual brain regions. The present work presents a critique of Fedorenko et al. (2020) as a way to explore these more general issues.

Words and Rules

> *The way language works, then, is that each person's brain contains a lexicon of words and the concepts they stand for (a mental dictionary) and a set of rules that combine the words to convey relationships among concepts (a mental grammar) (Pinker, 1995).*

Pinker's work had a major impact in popularizing the ideas of Chomsky and mainstream generative grammar (MGG). Like Chomsky, Pinker forcibly argued for the concept of an innate linguistic module of the human brain that allows us to learn language. However, his work included some simplifications that have become ensconced in cognitive science. A major one was "Words and Rules" (Pinker, 1999; Pinker and Ullman, 2002): the idea that language is fundamentally two diametrically opposed systems, a database of form-meaning pairs (the lexicon) and a rule-based, combinatorial system (syntax), each rooted in distinct underlying brain systems (Figure 1, left). Pinker combined the traditional Saussurean notion of human language as fundamentally a system of arbitrary form-meaning pairs with the focus of generative grammar on combinatorial syntactic operations.

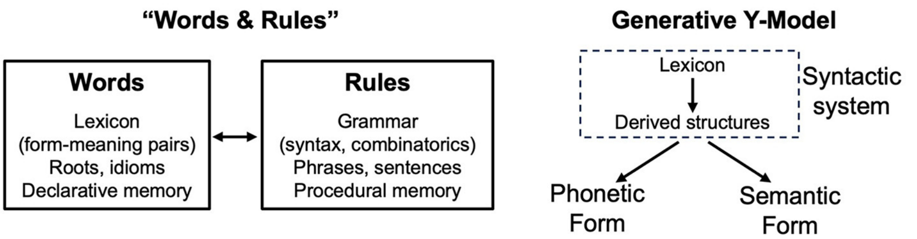

FIGURE 1
LEFT: the Words and Rules theory of Pinker (1999), adapted from Pinker and Ullman (2002). Separate cognitive systems are posited, each with distinct memory mechanisms, one containing a lexicon of form-meaning pairs (words) and one involved in combining lexical elements to create complex structures and semantic relations (rules). **RIGHT:** the Y-model posited in mainstream generative grammar (e.g., Chomsky, 1965, 1981, 1995b). A syntactic module, which combines lexical elements into complex structures, is then interpreted by two separate modules, one for phonetic form (how an expression is pronounced) and one for semantic form (the meaning of an utterance). In the Y-model, there is only an indirect and loose connection between the lexicon and meaning, whereas in the Words and Rules model, the lexicon is a repository of form-meaning pairs.

While many have taken the Words and Rules theory of Pinker to accurately summarize the MGG approach, these approaches are actually fundamentally incompatible (see also Embick and Marantz, 2005). The first models of MGG did not even contain a lexicon (Chomsky, 1955, 1957). Later models understood words as *syntactic* objects, inputs to syntactic computation, only later acquiring phonological and semantic expression (the inverted Y-model; Chomsky, 1965, 1981, 1995b) (Figure 1, right). Even further, Chomsky (1995a) proposed the theory of bare phrase structure, in which the labels of phrasal projections are not traditional syntactic categories like nouns and verbs but are rather derived from the lexical items themselves. For example, instead of verb phrases, there are "eat phrases"; instead of noun phrases, there are "cat phrases"; and so on. Some researchers have pointed to compelling evidence that words do not bear a direct mapping to meaning as Saussure claimed (Pietroski, 2018; Preminger, 2021), referring to phenomenon such as polysemy, in which the meaning of the same lexical item, for example, "book," is determined by syntactic context (e.g., *the book's pages were torn*—a physical object, *the book has challenged millions of readers to reexamine their views*—an abstract collection of words).

I do not claim that this approach is incontrovertibly correct. However, almost every modern (psycho)linguistic approach acknowledges that words have syntax, a point not raised or addressed by Fedorenko et al. (2020). The most popular alternative approach to MGG, the construction grammar/usage-based approach (Jackendoff, 2002; Goldberg, 2003), while advocating for a clearly distinct approach to language, does not abolish the distinction between syntax and semantics but, rather, articulates that words and constructions are *pairs* of syntactic form and meaning. In addition, popular psycholinguistic models of word production involve two stages: the first stage involves going from meaning to the lemma, which includes the syntactic representation of a concept; the second stage includes going from the lemma to the phonological form (Kempen and Huijbers, 1983; Levelt, 1989; Dell and O'Seaghdha, 1992; Levelt et al., 1999).[1] The idea that word retrieval involves access to syntactic information, even in the context of single-word production, is mostly uncontroversial in this literature. Thus, the idea of a coherent lexico-semantic system entirely distinct from and diametrically opposed to syntax is, in many ways, an aberration, yet it appears to have had a substantial impact on cognitive neuroscience.[2]

Functional differentiation in the language network

Fedorenko et al.'s claims about the neurobiological implementation of language are unusually strong and are based on the problematic notion of "lexico-semantics" reviewed earlier. First, Fedorenko et al. (2020) argue against the idea of a purely syntactic system in the brain because several previous studies "found that any language-responsive brain region or electrode that shows sensitivity to syntactic structure... is at least as sensitive, and often more sensitive, to meanings of individual words." This is simply the observation that regions implicated in syntax activate more to real words than pseudowords;[3,4] there is no evidence that these activations only reflect *meaning*. A syntactic system in the brain should activate more to real words relative to pseudowords, reflecting access to syntactic elements as reviewed earlier. Thus, the "lexico-semantic" activations reported in these experiments are ambiguous between lexical-syntactic and lexical-semantic processing.

Then, Fedorenko et al. (2020) performed a series of three additional functional magnetic resonance imaging experiments

1 Some have critiqued the notion of lemmas (Krauska, 2023). However, the alternative view of speech production articulated by these authors also involves two steps with an intermediate syntactic layer.

2 Many researchers use the term *lexico-semantic* to refer to a conglomeration of lexical and conceptual processing that excludes syntax. However, there is an alternative, viable usage of *lexico-semantic* that refers to monadic concepts.

3 The term *non-word* should be supplanted by *pseudo-word*. It acknowledges the complexities of the potential higher level linguistic processing that occurs when people process them (Vitevitch and Luce, 1999).

4 In many of these experiments, the word lists include morphologically complex forms and morphosyntactic features such as past tense. Thus, syntax is often present in the putatively "lexico-semantic" conditions.

designed to separately target "lexico-semantic" and syntactic processing, following similar experimental designs in previous research (Dapretto and Bookheimer, 1999; Kuperberg et al., 2000, 2003; Friederici, 2003; Noppeney and Price, 2004; Menenti et al., 2011; Segaert et al., 2012). This article provides example stimuli from the critical, putatively "lexico-semantic" conditions in Fedorenko et al. (2020). In these experiments, the initial sentence or clause is followed up by a second sentence or clause that contrasts with the initial one:

> Experiment 1: "Although his ears were damaged... the man could still cook" (meaning violation)
> Experiment 2: "The protestor quoted the leader -> The striker cited the chief" (different words)
> Experiment 3: "The scientist flattered David -> The scientist misled David" (non-synonym)

All three of these experiments conflate syntax and semantics within the "lexico-semantic" condition. In Experiment 1, the meaning violation is also a violation of the expected word, which is a syntactic, as well as a semantic, element. In addition, it is quite possible that violations of meaning are accompanied by syntactic revision processes in order to attempt to reinterpret the sentence. In Experiment 2, different words are different syntactic elements, as well as different meanings. In Experiment 3, the manipulation involves changing the final word, which is again both a syntactic and a semantic element. It is, therefore, no surprise that brain areas thought to be potentially selective to syntax (such as the inferior frontal lobe and posterior temporal lobe as postulated by many authors; Hagoort, 2005; Tyler and Marslen-Wilson, 2008; Bornkessel-Schlesewsky and Schlesewsky, 2013; Friederici, 2017; Matchin and Hickok, 2020) show activations to both the "lexico-semantic" and syntactic conditions because the"lexico-semantic" conditions always involve a "hidden" syntactic manipulation. That is, these experiments always manipulate words, which are intrinsically syntactic as well as semantic, which is a consensus position in linguistic theory as reviewed earlier.

Researchers using similar experimental conditions in brain imaging research have reported dissociations of syntactic and semantic processing (Dapretto and Bookheimer, 1999; Kuperberg et al., 2000, 2003; Friederici, 2003; Noppeney and Price, 2004; Menenti et al., 2011; Segaert et al., 2012), which seem to be discrepant with the results reported by Fedorenko et al. (2020). However, these previous authors reported whole-brain activation maps, whereas Fedorenko et al. do not. It is possible that the subtle spatial dissociations reported by previous authors would be replicated in the Fedorenko et al. experiments if whole-brain analyses had been reported.[5] Regardless, it is more important that these previous authors operated under the same mistaken assumption as Fedorenko et al.: that "lexico-semantic" manipulations do not tax syntax. The fact that Fedorenko et al. do not (appear to) replicate the syntax–semantics dissociations reported by previous authors is more likely due to the fact that these original experimental designs were flawed to begin with.

5 In many papers, Fedorenko et al. do not report whole-brain analyses. However, they are critical supplements to region of interest analyses, potentially revealing hidden patterns in the data and allowing for better comparability across studies.

Future functional neuroimaging studies investigating the syntax–semantics distinction should account for the dual semantic and syntactic nature of the lexicon by eschewing the conventional notion of "lexical-semantics" itself. Instead, researchers should develop more careful experiments that independently vary the richness of conceptual-semantic content and lexical-syntactic complexity or separately model these components during sentence comprehension (see Pylkkänen, 2019, 2020 for reviews; Hale et al., 2022).

Syntax in the brain: multiple viable instantiations

Fedorenko et al. (2020) focus on the idea of a syntactic system in the brain that should *not* be activated by lexical manipulations, a prediction that does not follow from "syntax-centric" theories of MGG (e.g., Chomsky, 1965, 1981, 1995b). However, they do report a significant preference for the syntactic condition in the posterior temporal lobe for Experiment 2 when using a localizer more sensitive to syntax. It is not a coincidence that the posterior temporal lobe has been strongly implicated in syntax by recent authors (Bornkessel-Schlesewsky and Schlesewsky, 2013; Pylkkänen, 2019; Matchin and Hickok, 2020). Recent lesion-symptom mapping literature supports a strong association between syntactic comprehension deficits and damage to posterior temporal-parietal areas (Pillay et al., 2017; Rogalsky et al., 2018; Matchin et al., 2022a,b), a similar pattern that is also emerging for paragrammatic speech production deficits (Yagata et al., 2017; Matchin et al., 2020). Residual functional activation in the posterior temporal lobe after accounting for lesion effects appears to be uniquely associated with aphasia recovery (Schneck, 2022; Wilson et al., 2022). Given that lesion-symptom mapping provides a much stronger causal inference than functional neuroimaging (Rorden and Karnath, 2004), such data need to be addressed together.

Finally, while I find the evidence for a hierarchical, abstract syntactic system in the posterior temporal lobe to be highly compelling, a variety of multiple perspectives on this issue are possible. First, even if no brain region is selective for syntax, specific network configurations could be (Schnitzler and Gross, 2005; Buzsaki, 2006; Anderson, 2016; Farahani et al., 2019). Furthermore, linguistic theories do not make predictions about how much cortical surface area would be needed to process syntax and semantics or whether there must be large cortical areas dedicated to processing syntax at all (Poeppel and Embick, 2005; Embick and Poeppel, 2015). The ideas of Chomsky regarding the uniqueness and expressive power of syntax are perfectly compatible with a "slight rewiring of the brain" (Chomsky, 2005) of an evolutionarily recent hominin ancestor, augmenting a sea of brain mechanisms that resulted in the modern human language faculty (Berwick and Chomsky, 2016), regardless of whether there is clear evidence of a large swath of syntax-selective cortex.

Author contributions

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Conflict of interest

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