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Priming of non-constituents reveals linguistic structure beyond grammar

It is widely believed that language is structured around 'constituents', units that combine hierarchically. Using structural priming, we provide evidence of linguistic structures — non-constituents — that do not fit into such hierarchies, which reveals a blind spot in current theories of language and grammar.

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The question

Humans possess a remarkable ability to put words together into never-before-spoken sentences. How so? A long-standing assumption in the language sciences is that words and phrases combine according to the principles of grammar into ever-larger hierarchical units called constituents. For example, 'the' and 'ball' combine into the noun phrase [the ball], which, in turn, combines with 'kicked' into the verb phrase [kicked [the ball]] and with 'he' into the sentence [he [kicked [the ball]]]. But not all sequences of words form constituents. In fact, the most common three- or four-word sequences in language are often non-constituents[1], such as 'can I have a' or 'it was in the'.

Owing to their nonconformity to grammar, such non-constituents are often overlooked. Yet, they seem to form part of a speaker's knowledge of their language. For instance, people are faster to process non-constituents if they are more frequently encountered[2] (such as 'in the middle of the'). This raises the question of whether there might be linguistic structure beyond grammar — that is, abstract structures that are not hierarchical.

The discovery

One well-established method for probing the mental representation of linguistic structure is 'structural priming': when someone hears, reads or says a specific linguistic structure, they tend to be slightly better at processing the same structure within a certain time window. It is therefore generally assumed that if a structure can be primed, then it is part of a person's knowledge of language — it is mentally represented in some fashion. Indeed, this logic has previously been used to support the existence of constituents[3].

In our study, we tested whether it is also possible to prime non-constituent structures. For this, we used the phrasal decision task, in which participants see a sequence of words and must judge — as quickly and accurately as they can — whether it is possible to use that sequence in an English sentence. Each participant completes many trials, some with possible sequences such as 'wondered if you' and some with impossible sequences such as 'it your for'. Unbeknown to the participants, two consecutive trials would sometimes involve the same non-constituent structure, as with 'knew that she' and 'wondered if you'. The pivotal test was whether the exposure to the structure in the first of these trials led to faster responses in the second trial — a structural priming effect.

Priming led to a 30–40-ms decrease in reaction time (Fig. 1). This provides evidence for the mental representation of abstract sequential structures that are not constituents. A potential concern, however, was whether the results from the phrasal decision task generalize to real-life language use[4]. We therefore performed two additional analyses of previously published data. In one, eye-tracking measurements from CELER (Corpus of Eye Movements in L1 and L2 English Reading) showed that people are faster at reading a newswire sentence if it contains non-constituent structures that they have recently encountered. In the other analysis, transcripts of telephone conversations from the Switchboard corpus showed that speakers are more likely to use a non-constituent structure after hearing their conversation partner use it. These analyses corroborate the existence of non-constituent structures in everyday language use.

The implications

Our findings reveal a blind spot in current theories of language and grammar and challenge the language sciences to account for abstract non-hierarchical structure. More broadly, the results raise the possibility that the human capacity for language might not involve traditional constituent structure at all but instead use the kind of abstract sequential structures evidenced in our study. This is consistent with recent demonstrations of structural priming in large language models such as ChatGPT, which rely on contextual representations rather than constituent structures rooted in grammar[4].

One obvious limitation is that the research was conducted only in English. Languages differ widely in how they build up structure. In Turkish, for example, the sentence 'I heard that they will not be able to meet' is expressed in a single word, *görüşemeyeceklermiş*. We therefore cannot take for granted that speakers of all languages rely on the same kinds of structure. However, the fact that constituent-based structural priming has been observed across many languages — including Turkish[5] — suggests that our results are likely to generalize beyond English.

A key question for future research is what function these non-constituent structures serve. We propose that they act as a kind of 'processing glue', used by speakers and listeners to connect meaningful sequences on the fly — hinting at a new perspective on how words and phrases can be combined.

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EXPERT OPINION

"This is a fascinating paper. The authors argue that the nature of syntactic representations needs to be rethought. I find their analyses of the reading times of naturalistic text and natural production of text corpora most interesting and persuasive. This has the potential to be a major paper of high importance to the community." **Edward Gibson, Massachusetts Institute of Technology, Cambridge, MA, USA.**

FIGURE

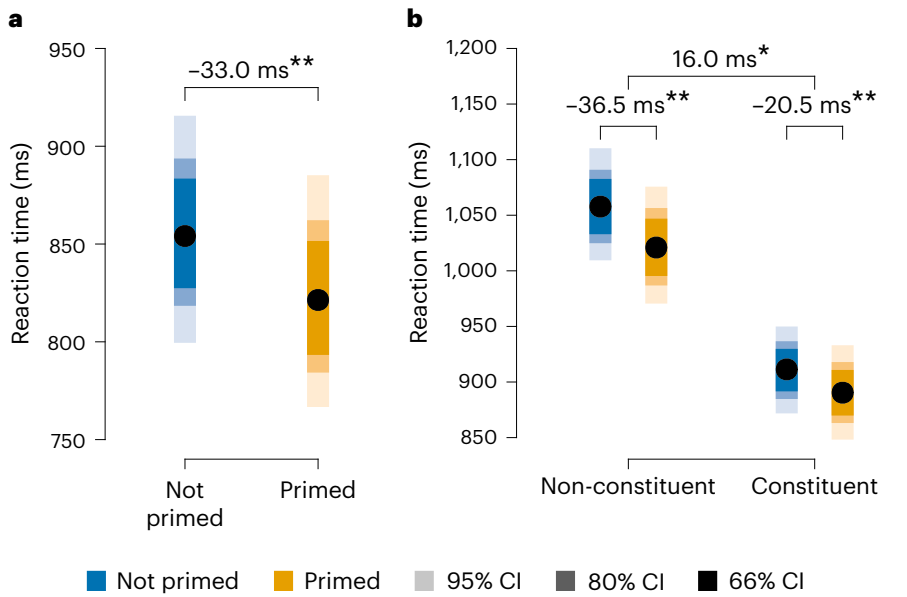


Fig. 1 | Structural priming of constituent and non-constituent sequences. **a**, In a phrasal decision task with non-constituent sequences ($n = 40$), the overall reaction time is lower in trials that were preceded by a structural prime. **b**, In a replication study ($n = 200$) using the same task, the effect on reaction times of non-constituent structural priming is comparable in size to – or possibly larger than – that of constituent structural priming. *Evidence ratio > 5; **Evidence ratio > 10. CI, credible interval. © 2026, Nielsen, Y. A. & Christiansen, M. H.

BEHIND THE PAPER

The project grew out of our discussions about structural priming and whether it could be explained by sequential rather than hierarchical structure. At first, we considered testing structural priming of simple sequential structures such as determiner–adjective–noun. However, this approach would not have allowed us to distinguish between sequential and hierarchical interpretations. We therefore turned our attention to sequences of words that do not fit into traditional hierarchical structures: non-constituents.

The findings were surprising, and early reactions at conferences and talks reflected that — one attendee even asked, "Can't anything be primed at this point?". The constructive criticism we received along the way shaped the project, leading us to replicate and extend our original study in three further experiments and two corpus analyses, to rule out alternative explanations and document the existence of non-constituent structures in naturalistic language use. **Y.A.N. & M.H.C.**

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FROM THE EDITOR

"This work stands out for its compelling challenge to longstanding views of linguistic representation. Through careful experimentation and corpus analyses grounded in naturalistic data, it reveals the structural reality of non-constituent sequences, opening exciting avenues for rethinking how language is mentally represented and processed." **Editorial Team, *Nature Human Behaviour*.**