Comment on "Nonadjacent dependency processing in monkeys, apes, and humans"

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We comment on the technical interpretation of the study of Watson *et al.* and caution against their conclusion that the behavioral evidence in their experiments points to nonhuman animals' ability to learn syntactic dependencies, because their results are also consistent with the learning of phonological dependencies in human languages.

Watson *et al.* (*1*) provide some important findings about animal pattern recognition abilities that are relevant to the understanding of human language. However, they perpetuate a common misconception that we aim to correct here: They identify nonadjacent dependencies (Non-ADs) in language systems with a language's syntax. Human languages have separate—but not disjoint—systems governing the combinatorial patterning of sounds within words (phonology) and the combinatorial patterning of words within sentences (syntax), both of which have Non-ADs. Furthermore, mathematical and computational investigations of language reveal that the Non-ADs in syntax are characteristically different—they form a superset of the phonological Non-ADs (see Fig. 1) (*2*, *3*). We therefore advocate a more conservative interpretation of the results of Watson *et al.*

As we examine the language pattern abilities in nonhuman animals (*4*, *5*), it is crucially important that we attend to the combinatorial difference between human phonology and syntax to probe whether the animals are sensitive to strictly syntactic patterns (Y in Fig. 1) as opposed to patterns that are common to both phonology and syntax (X in Fig. 1). The observation that syntactic patterns extend the class found in phonology led to the phonological continuity hypothesis (*6*): Auditory pattern recognition in nonhuman animals shares important characteristics with human phonology, not human syntax, and therefore, the human capacity for language arose by adding additional cognitive or memory capacity to enable the more expressive syntactic Non-ADs. In this light, the experiments

of Watson *et al.* (*7*–*9*) confirm the results of prior experiments: Nonhuman animals can successfully learn phonological patterns and as yet present no unambiguous evidence for syntactic pattern learning.

Common examples of phonological Non-ADs include vowel and consonant harmony (*10*). For example, Finnish vowels are divided into three kinds: front (y, ö, and ä), back (u, o, and a), and neutral (i and e) (*11*). Native Finnish words cannot mix front and back vowels, although neutral vowels can freely occur among instances of these harmonizing vowels. As a consequence, we can create vowel-based versions of the A-X-B stimuli of Watson *et al.* by adding "chameleon" suffixes such as ssa/ssä (meaning "in") to stems in Finnish, for example, P**o**ri-ss**a** "in Pori" versus k**y**li-ss**ä** "in the villages" with **o...a** and **y...ä** filling the A and B roles and **i** (and the intervening consonants) filling the role of X. This demonstrates that A-X-B Non-ADs are not a diagnostic for syntactic patterning.

In contrast to the linear, sequence-based Non-ADs in phonology, human syntax crucially involves recursive, nested hierarchical relations (*12*), and syntactic Non-ADs often rely on the relative scope of the items. A simple case from English is the restriction that words like "anymore" must fall within the scope of a negative item, i.e., "not ... anymore". The most important question is how humans reach a semantic understanding of the meaning of these sentences S4, but in some cases, the violation of a syntactic Non-AD can reduce to a sentence being either "valid" or "invalid," that is, having at least one valid interpretation versus none.

1) Valid: He is **not** working **anymore**.
2) Invalid: He is working **anymore**.

(Although we note that there are some English dialects that have positive "anymore" with a meaning akin to "nowadays" (*13*) in which sentences like S2 do occur.) In the case of "not," its scope is the entire predicate (or verb phrase) "working anymore." However, English also allows sentences to be nested inside sentences, such as sentential modifiers of nouns, and that is where we can see the difference by changing the scope of "not":

3) Valid: The man <u>who is crying</u> is **not** working **anymore**.
4) Invalid: The man <u>who is **not** crying</u> is working **anymore**.

As shown in the parse trees in Fig. 2, the scope of "not" in S4 is "crying" and "anymore" occurs outside its scope, violating the syntactic scopal Non-AD between "not" and "anymore."

One potential explanation for the hierarchical Non-ADs in syntax is that they are tied up with the meaning of sentences, which is an explanation consistent with the absence of meaning for individual sounds within a phonological word. However, such an explanation is not consistent with experimental results, which show that
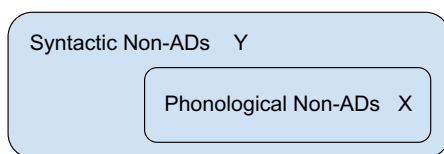

Fig. 1. Non-ADs in human language. Experiments testing Non-ADs in animals examine patterns of type X. This brief commentary points out that to establish that animals can learn human-like syntactic dependencies, experiments need to find a way to test Non-ADs of type Y.

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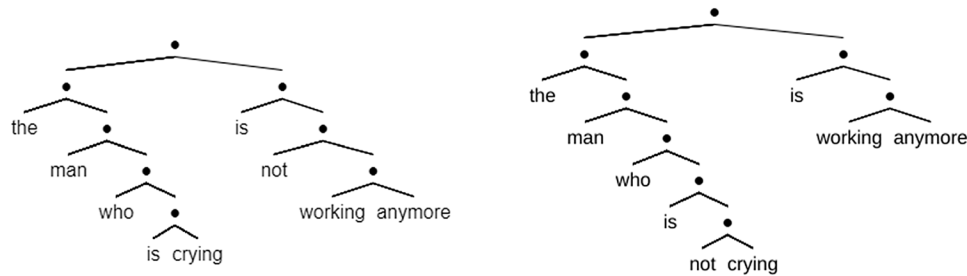†These authors contributed equally to this work.

Fig. 2. Scope in syntactic structures. Words like "anymore" need to be within the scope of "not" to receive the intended interpretation. This nonadjacent dependency is satisfied in the left parse tree, where the scope of "not" is "working anymore," but not in the right parse tree, where the scope of "not" is "crying."

meaningless "jabberwocky" speech is processed in the same way as naturally meaningful speech (*14*, *15*).

Animal pattern learning experiments across species examine Non-ADs consistent with human phonology (*1*, *4–6*). To accurately probe whether nonhuman animals have the capability to discriminate Non-ADs consistent with human syntax, the right experimental contrasts must be drawn, such as those involving hierarchical relations like scope. A robust experimental design showing that animals can learn these strictly syntactic Non-ADs would directly challenge the phonological continuity hypothesis and, perhaps, provide evidence for the evolutionary primacy of syntax over phonology (*16*). We appreciate how hard it is to design effective experiments with animals and agree that it is very important to continue this line of research. However, it is also important for us as a field to acknowledge the challenges and limitations of these experiments when comparing the results with human language patterns. We advocate closer dialog and collaboration between language scientists, cognitive scientists, and computer scientists to design experiments with the appropriate contrasts to ensure experimental inferences about comparative cognition are theoretically sound and analytically robust (*17*).

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