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Comment on "Nonadjacent Dependency Processing in Monkeys, Apes, and Humans"

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Abstract: We comment on the technical interpretation of Watson et al (2020)'s study, and caution against their conclusion that the behavioral evidence in their experiments points to non-human animals' ability to learn syntactic dependencies, since their results are also consistent with the learning of phonological dependencies in human languages.

One Sentence Summary: Technical Comment on Watson et al (2020)

Main Text:
Watson et al *(1)* provide some important new findings about animal pattern recognition abilities which are relevant to the understanding of human language. However, they perpetuate a common misconception that we aim to correct here: they identify non-adjacent dependencies (NADs) in language systems with a language's **syntax**. Importantly, 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 NADs. Furthermore, mathematical and computational investigations of language reveal that the NADs in syntax are characteristically different --- they form a superset of the phonological NADs *(2,3)* (see Figure 1). We therefore advocate a more conservative interpretation of Watson et al.'s results.

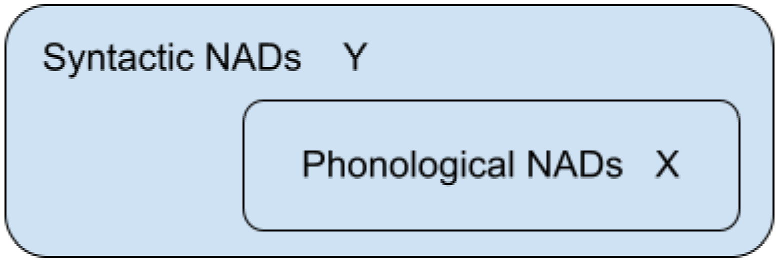

Figure 1: NADs in Human Language. Experiments testing NADs in animals examine patterns of type X. This brief commentary points out that to establish that animals can learn humanlike syntactic dependencies experiments need to find a way to test NADs of type Y.

As we examine the language pattern abilities in non-human 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 Figure 1) as opposed to patterns that are common to both phonology and syntax (X in Figure 1). The observation that syntactic patterns extend the class found in phonology led to the Phonological Continuity Hypothesis *(6)*: auditory pattern recognition in non-human 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 NADs. In this light, Watson et al.'s experiments confirm the results of prior experiments *(7,8,9)*: non-human animals can successfully learn phonological patterns, and as yet present no unambiguous evidence for syntactic pattern learning.

Common examples of phonological NADs include vowel and consonant harmony *(10)*. For example, Finnish vowels are divided into three kinds: front (y,ö,ä), back (u,o,a) and neutral (i,e) *(11)*. Native Finnish words cannot mix front and back vowels, though neutral vowels can freely occur among instances of these harmonizing vowels. As a consequence, we can create vowel-based versions of Watson et al's A-X-B stimuli 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 NADs are not a diagnostic for syntactic patterning.

In contrast to the linear, sequence-based NADs in phonology, human syntax crucially involves recursive, **nested** hierarchical relations *(12)* and syntactic NADs 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 such sentences *(13)* but in some cases the violation of a syntactic NAD 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**.

(Though we note that there are some English dialects which have positive "anymore" with a meaning akin to "nowadays" *(14)*, in which sentences like 2 do occur.) In the case of "not", its scope is the entire predicate (or verb phrase) "working anymore". But 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 Figure 2, the scope of "not" in (4) is "crying" and "anymore" occurs outside its scope, violating the syntactic scopal NAD between "not" and "anymore".

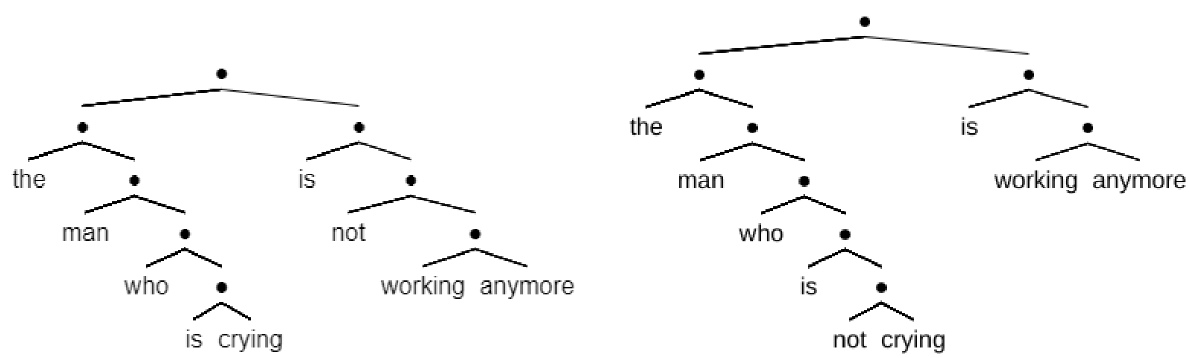

Figure 2: Words like "anymore" need to be within the scope of "not" to receive the intended interpretation. This non-adjacent dependency is satisfied in the left parse tree, where the scope of "not" is "working anymore", but not in the right parse tree, where the scope of "not" is "crying".

One potential explanation for the hierarchical NADs 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 meaningless "jabberwocky" speech is processed in the same way as naturally meaningful speech *(15,16)*.

Animal pattern learning experiments across species examine NADs consistent with human phonology *(1,4,5,6)*. In order to accurately probe whether non-human animals possess the capability to discriminate NADs 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 in fact learn such strictly syntactic NADs would directly challenge the phonological continuity hypothesis, and perhaps provide evidence for the evolutionary primacy of syntax over phonology *(17)*. We appreciate how hard it is to design effective experiments with animals, and agree 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 such experiments when comparing the results with human language patterns. We advocate closer dialogue 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 *(18)*.

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