Distributional learning of recursive structures: The role of the structural representation

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General background

- The ability for recursion is a crucial part of the language faculty (e.g., Berwick & Chomsky, 2017), **but languages differ regarding the syntactic domains of recursive structures.**

  (1) English: the man's neighbor's book
  (2) German: *das Manns Nachbars Buch (Pérez-Leroux et al., 2022)

- **How to learn whether a structure allows recursive embedding?**

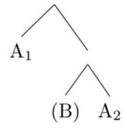
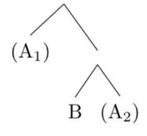
The distributional learning proposal

- **Recursion as substitutability** (Li et al., 2021): A structure is recursive if sufficient words that appear in one position can also be used in the other.
- Corpus studies show **such distributional evidence is available** in the input (Grohe et al., 2021; Li et al., 2021; Yang, 2021, 2022) and artificial language learning experiments confirm **learners can use this evidence to determine which structures allow recursion** (Li & Schuler, 2021).
- But, **some structures that are substitutable in linear position do not allow recursion** (e.g., 'NP_1-V-NP_2' in English '*dogs chase cats chase rats…'). To avoid wrong generalizations, **substitutable elements are proposed to be the head of the structure.**

Do learners form productive generalizations about recursion differently for heads than other constituents?

Methods

- Participants: 50 native English-speaking adults on Prolific (25 in each condition)
- **Two artificial languages identical in linear order (A-B-A) but differing in hierarchical structure (A is head in one, B in other).**
- As in natural languages, heads are obligatory, constituents are optional.

	e.g., 'dog's name'	e.g., 'dogs chase cats'
	A-head language	B-head language
structure		
1-word	A, *B	*A, B
2-word	*AB, BA, AA (A_2 is head)	AB, BA, *AA
1-level embedding	ABA	ABA
2-level embedding	ABABA	*ABABA

Methods

Did participants learn the head? YES

- **Participants in both conditions could tell the difference between grammatical and ungrammatical 2-word strings ($p < 0.001$).**

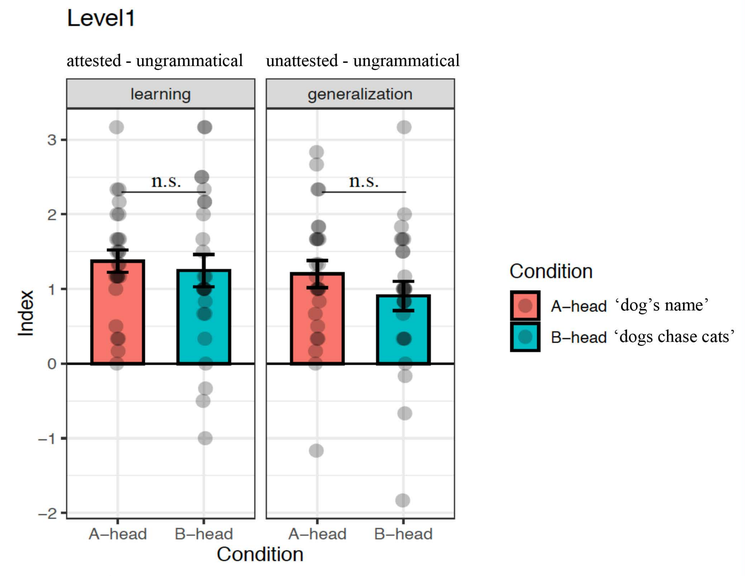
  (e.g., AA was judged as grammatical in A-head, but ungrammatical in B-head)

Main predictions

- **Both languages are substitutable in linear order: all participants should learn that 1-level sentences (ABA) are substitutable.**
- **Only A-head language has evidence of *head* substitutability: participants in A-head language should be more willing to endorse recursive embedding (2-level sentences).**

Results

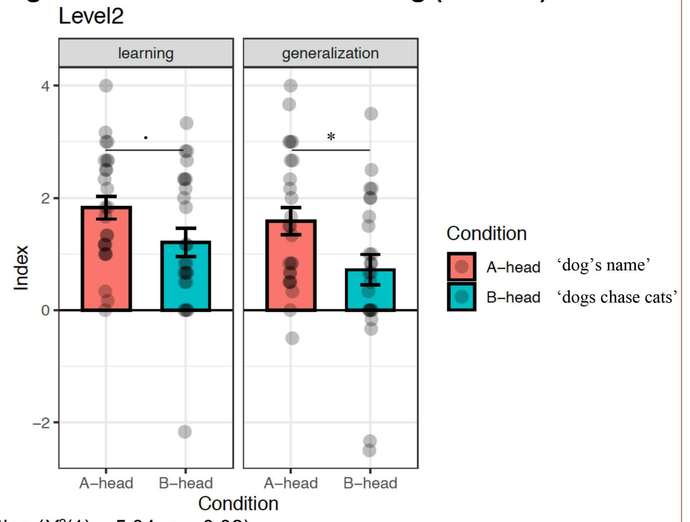
All learned linear substitutability: no difference in learning or generalization on 1-level sentences (ABA).



- Condition ($X^2(1) = 0.71$, $p = 0.40$)
- * Type (learning vs. generalization) ($\chi^2(1) = 9.38$, $p = 0.002$)
- Interaction between Type and Condition ($\chi^2(1) = 1.10$, $p = 0.29$)

Results

Participants exposed to head substitutability (A-head) were more willing to allow recursive embedding (ABABA).



- * Condition ($X^2(1) = 5.04$, $p = 0.02$)
- * Type ($\chi^2(1) = 12.46$, $p < 0.001$)
- Interaction ($\chi^2(1) = 1.66$, $p = 0.20$)

Conclusion

- Participants from A-head condition were more willing to allow recursion for both attested and unattested words.
- By contrast, although participants from B-head condition also learned substitutability at level-1 (e.g., 'NPs are substitutable in NP_1-V-NP_2'), they were unwilling to recursively embed the structure using either attested or unattested words.
- Results suggest learners can integrate knowledge of the syntactic structure to distributionally acquire recursion.

Selected References

Berwick, R., & Chomsky, N. (2017). *Why only us*. **Li**, D., et al. (2021). The distributional learning of recursive structures. *Proc BUCLD45*. **Li**, D., & Schuler, K. (2021). Distributional learning of recursive structures. *Proc CogSci2021*. **Pérez-Leroux**, A., et al. (2022). Structural diversity does not affect the acquisition of recursion: The case of possession in German. *Language Acquisition*. **Yang**, C. (2016). *The price of linguistic productivity.*

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