Investigating task-modulated syntactic prediction with MEG

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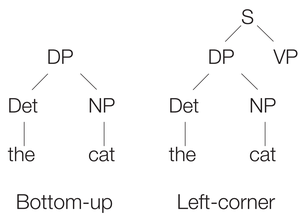
Introduction

- **How do proposed top-down, bottom-up, and left-corner parsing mechanisms differ in the extent to which they employ predictive structure-building?**

  A determiner phrase (DP) as input could lead to the following structures:



- **Which mechanism do humans employ?**

  There is robust behavioral evidence for syntactic prediction, but most is specific to certain complex constructions (e.g. filled gap effects in wh-movement)

- **What is known so far about the neural basis for syntactic prediction?**

  Our recent MEG study (Matchin et al., in prep) showed more neural activity for the first DP in sentences vs. phrase lists, in posterior superior temporal sulcus (pSTS).

  Other recent work (e.g. Bonhage et al., 2015) has also implicated left pSTS and inferior frontal gyrus pars orbitalis (IFG-orb) and triangularis (IFG-tri).

- **Do human comprehenders strategically shift parsing mechanisms in response to contextual demands?**

  In investigating this, our aim is to develop a neural index for predictive structure-building that can be applied much more generally.

Paradigm

We introduce a novel paradigm for comparing neural responses to identical stimuli in contexts that encourage structural prediction of VP to varying degrees.

Sentence blocks: 100% probability of VP

these	wolves	chase	few	ducks
each	assistant	chops	some	carrots

Phrase blocks: 0% probability of VP

these	wolves	several	citizens
each	assistant	every	warrior

Mixed blocks: 50% probability of VP

these	wolves	chase	few	ducks
each	assistant	every	warrior	

Predictions:

- If the blocking successfully modulates parsing strategy, structural prediction of the VP would be indexed as increased neural activity in response to the same initial DP in sentence blocks vs. phrase blocks.
- Mixed blocks explore an open question: whether prediction occurs probabilistically when the need for structure is uncertain.

Task:

- A classic challenge in paradigms contrasting structured and unstructured stimuli is finding a task equally applicable to both conditions.
- Memory probe tasks are often used for this purpose, but we used detection of agreement violations to encourage structural prediction:

*these **wolf** chase few ducks
*these wolves **chases** few ducks
*these wolves chase **few duck**
*each **assistants** every warrior
*each assistant **every warriors**

Methods

- Visual stimulus presentation with 500 ms ISI
- Explicit cues to block type before each run
- Phrase lists created by removing verbs from sentences and randomly rearranging the second DP across trials
- Neural data recorded with 157-channel axial gradiometer KIT MEG system
- Head-shapes digitized for co-registration with structural MRI, available for 14/22 participants, or fsaverage brain
- Low-pass filter at 40 Hz
- ICA used for artifact rejection
- Distributed source solutions calculated with a free orientation of the dipole current
- 0-1000 ms epochs following DP onsets, baseline corrected with preceding 100 ms window for DP1 but not for DP2
- Excluded epochs containing agreement violations or following agreement violations within the trial, as well as false alarms
- Temporal cluster tests conducted in left IFG-tri, IFG-orb, pSTS, and temporal pole ROIs
- Spatiotemporal cluster tests conducted in left temporal/inferior parietal lobes and IFG

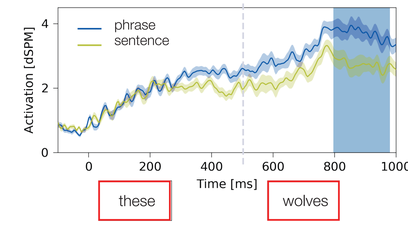
References:

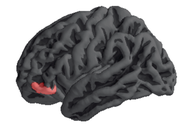
Bonhage, C. E., Mueller, J. L., Friederici, A. D., & Fiebach, C. J. (2015). Combined eye-tracking and fMRI reveals neural basis of linguistic predictions during sentence comprehension. *Cortex*, *68*, 33-47.

Matchin, W., Brodbeck, C.,Hammerly, C., & Lau, E.F. (in prep). The temporal dynamics of structure and content in the language network.

Results

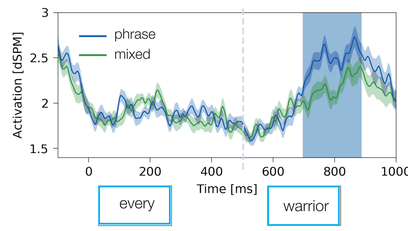
- **First DP:** increased activity for DP1 in phrase block vs. DP1 in sentence block (opposite of expected sentence > phrase), 796-980 ms after onset of DP1, in IFG-orb ROI.

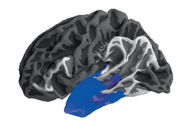




  Mixed block always patterned between sentence and phrase blocks, but could not be differentiated statistically.

- **Second DP:** in phrase trials, increased activity for DP2 in phrase block vs. DP2 in mixed block, 696-888 ms after onset of DP2, in left anterior temporal lobe.





  This indicates a differential response with respect to the probability of DP2 in the trial: 100% in phrase blocks, and 50% in mixed blocks.

Discussion

- This paradigm aimed to identify an index of structural prediction in simple sentences, in order to investigate context-mediated shifts in parsing strategy.
- We did not find a response consistent with predictive structure-building.
- These results are also not consistent with a purely bottom-up parsing strategy, for which expectations related to the block should not change processing during DP1.
- Further refining of the paradigm is necessary and important to clartify these issues.
- Our result also highlights the need for careful accounting of task demands.
  - The agreement violation detection task may have discouraged predictive structure-building because of unreliability of the stimuli.
  - It is possible that agreement processing is in fact unrelated to syntactic structure-building.
  - Finally, the phrase > sentence effect at DP1 may reflect increased attention due to the necessarily higher proportion of agreement violations at that position in the phrase blocks.