Is Structure Dependence Shaped for Efficient Communication?: A Case Study on Coordination

Kohei Kajikawa [1,2] Yusuke Kubota [2] Yohei Oseki [1]
[1]The University of Tokyo [2]NINJAL

CoNLL 2024@Miami

kohei-kajikawa@g.ecc.u-tokyo.ac.jp

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    - Compositionality [Kir+15]
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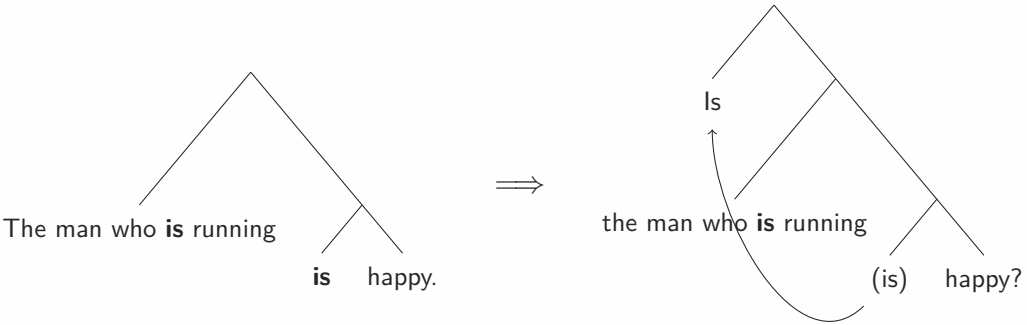
    - **Structure Dependence**? (← this work)

Structure Dependence

- Grammatical operations are applied **structurally** rather than linearly.
- In English yes-no questions,

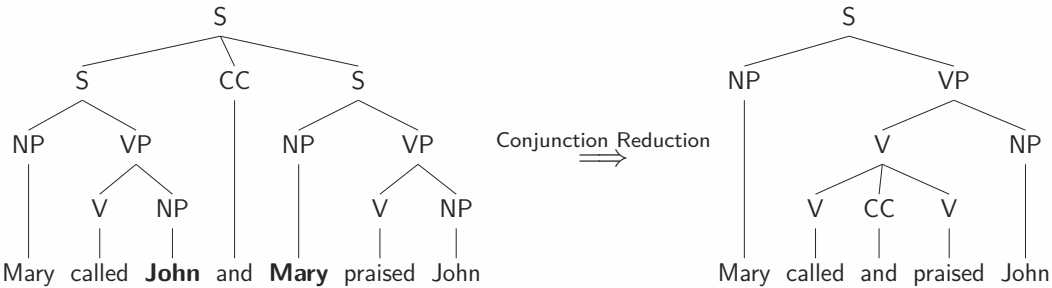
  good rule moves the auxiliary of the *main clause* to the front (structural)

  bad rule moves the *leftmost* auxiliary to the front (linear)



Structure Dependence

- **Coordinate structures** are constructed through a structure-dependent reduction operation, *conjunction reduction* [Cho57; Cho55; Ros67].
  - Which words are reduced is determined by their structural position.



Experiment: Design of 3 types of languages

1. `No-reduction` lg:
   - Mary called John and Mary praised John.
2. `Structure-reduction` lg:
   - Mary called _ and _ praised John.
3. `Linear-reduction` lg:
   - Mary called John and _ praised _.

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- Create the corpora of them using [WC21]'s toy PCFGs.

Estimating Communicative Efficiency

- Following [HJF20], we defined *simplicity* and *informativeness* as *predictability* and *parsability*, respectively.

$$\text{predictability} := -H(\mathcal{U}) = \sum_{u \in \mathcal{U}} p(u) \log p(u) \tag{1}$$

$$\text{parsability} := -H(\mathcal{T}|\mathcal{U}) = \sum_{t \in \mathcal{T}, u \in \mathcal{U}} p(t, u) \log p(t|u) \tag{2}$$

$$\text{communicative efficiency} := \lambda \text{predictability} + (1 - \lambda)\text{parsability} \quad (\lambda \in [0, 1]) \tag{3}$$

  - Predictability is approximated with mean negative *word-by-word surprisal*.
    - represents the ease of processing on average under surprisal theory [Hal01; Lev08].
  - Parsability is approximated with mean *word-by-word logLik of parse*.
    - captures how unambiguously the underlying syntactic structure can be reconstructed.

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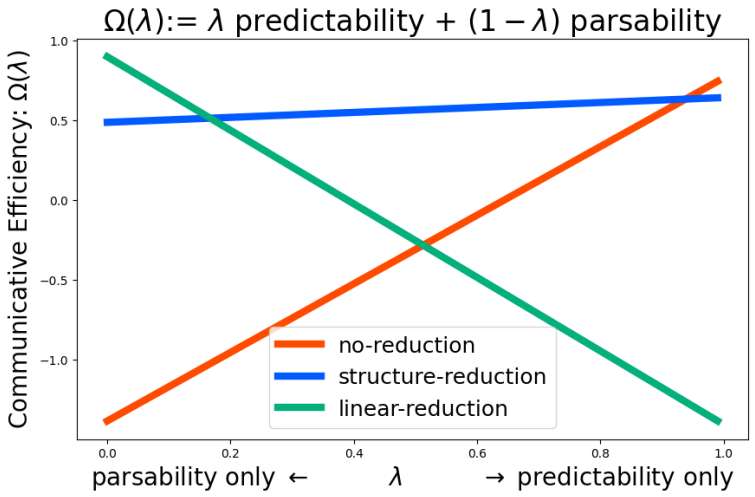
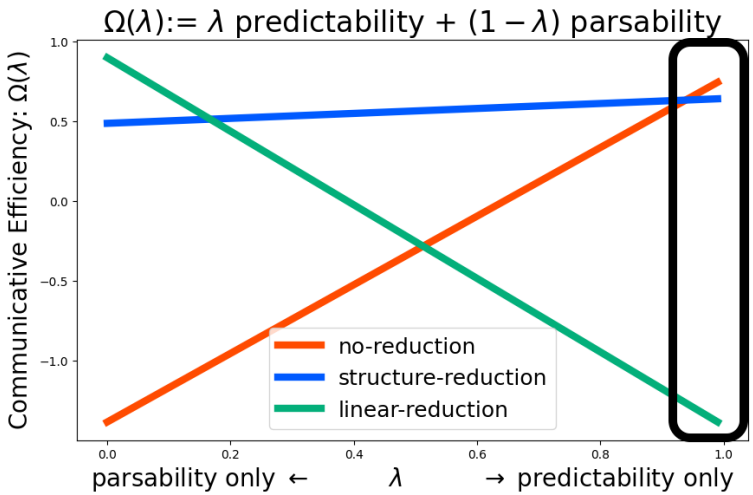
- calculated them with Reccurent Neural Network Grammars (RNNGs; [Dye+16]).

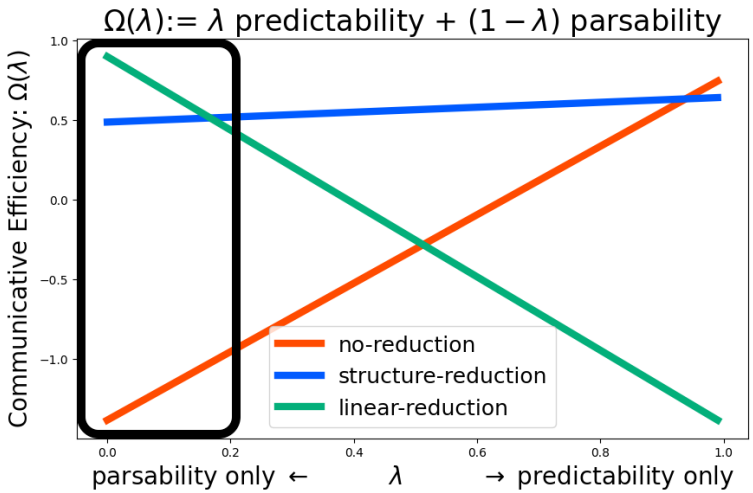
Results



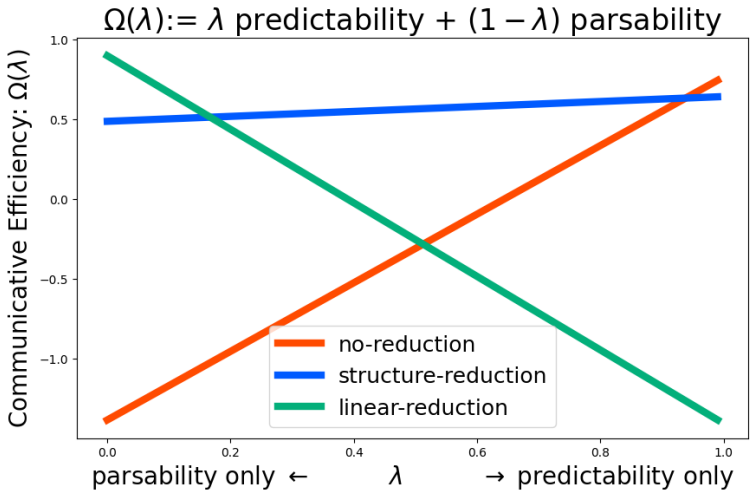
- The `structure-reduction` lgs are the most communicatively efficient under the parameter $\lambda \in [0.18, 0.93]$ for 95% CI.



- When considering only predictability (simplicity), the `no-reduction` lgs take the best score.
  - `No-reduction` lg is the simplest for local string patterns, which makes prediction easier.



- When considering only parsability (informativeness), the `linear-reduction` lgs take the best.
  - `Linear-reduction` lg has shorter overall expressions, resulting in fewer possible parses at each word position.



- Balancing the trade-off between the two, a structure-dependent reduction is the most preferred design for maximizing communicative efficiency.

Implications for Theoretical Linguistics

- A prominent view in the mainstream generative grammar:
  - natural language involves **domain-specific** predispositions and syntactic properties of language—including structure dependence—are best explained from the perspective of 'efficient *computation*' [HCF02; Cho05; Eve+15; BC16].
  - communication is considered an epiphenomenon [Cho02; HCF02].

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  - communication is considered an epiphenomenon [Cho02; HCF02].
- Our results suggest that at least some structure-dependent properties present in natural language (such as coordination) can be explained from the perspective of **domain-general** efficient *communication*.
  - This aligns with the existing body of efficient communication research [Gib+19; FPG24].

Conclusion

- We investigated whether **structure dependence** reflects the optimization for **efficient communication**.
  - focusing on coordinate structures.
- The experiment results suggest that the structure-dependent properties can be reduced to the functional perspective of efficient communication.

Thank you!

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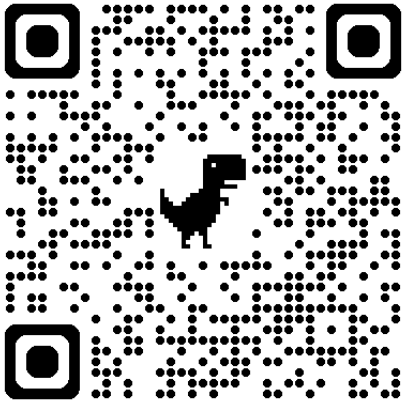

Link to Paper

Acknowledgments

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