

Tuesday • November 9, 2021

Neural Networks and Grammar



NO, you cannot understand the meaning of a text without explicitly evaluating its linguistic constituents and defining grammar rules!



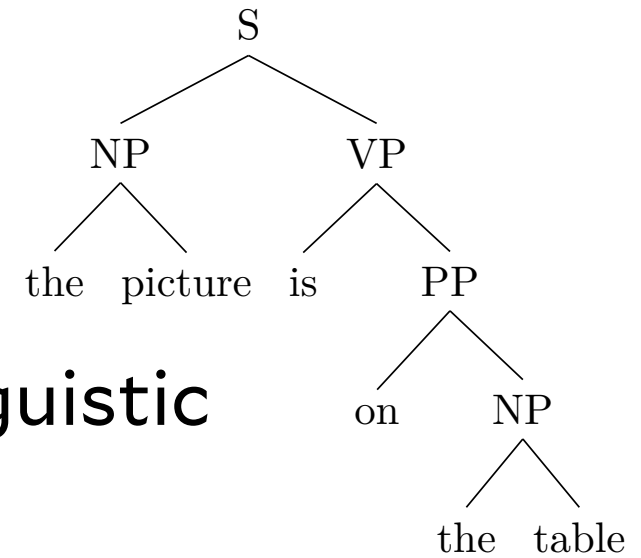
haha gpus go brrrrrrrrr



Yale

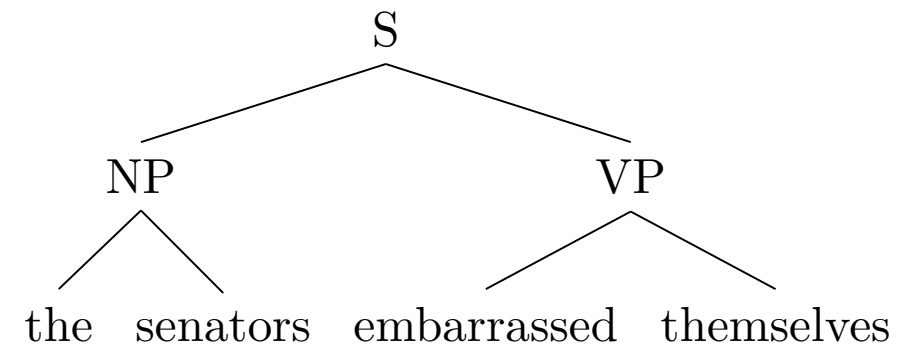
LING 380/780
Neural Network Models of Linguistic Structure

Knowledge of Language



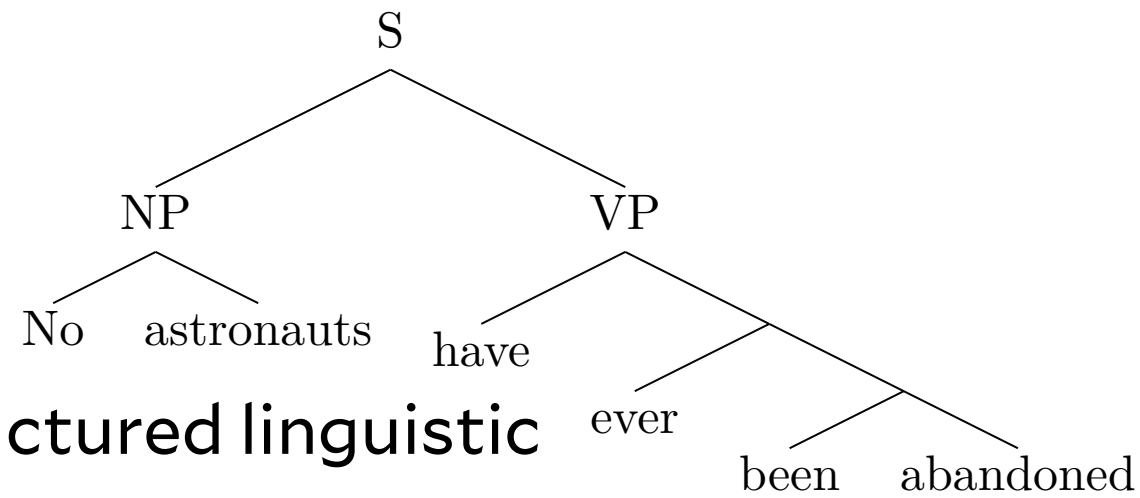
- Linguistics posits hierarchically structured linguistic representations
 - Agreement:
 - The picture is/*are on the table
 - The picture of the mountains is/*are
 - The picture that I took during one of my vacations to the mountains is/*are

Knowledge of Language



- Linguistics posits hierarchically structured linguistic representations
 - Anaphora:
 - The senators embarrassed themselves/*herself
 - The senators near Nancy embarrassed themselves/*herself
 - The senators who were visiting Nancy wearing ugly jackets embarrassed themselves/*herself

Knowledge of Language



- Linguistics posits hierarchically structured linguistic representations
 - Negative polarity licensing:
 - No/*some astronauts have ever been abandoned on the ISS
 - No/*some astronauts who fulfilled their mission have ever been abandoned on the ISS
 - The astronauts who fulfilled *no/*some missions have ever been abandoned.

Knowledge of Language

- How do such representations and the generalizations over them arise?
 - Learning: primary linguistic data guides the learner
 - Inductive Bias (UG): innate constraints shape the hypotheses

Arguments for UG

- Evidence underdetermines knowledge (Gavagai!)
 - Agreement:
 - the books near the flowers are ...

Arguments for UG

- Evidence underdetermines knowledge (Gavagai!)
 - Wh-movement (Chomsky 1977)
 - **Questions:** What book has Mary written ____?
 - **Relative clauses:** the book that Mary has written ____ is on the table.
 - **Tough movement:** That book was tough to write ____.
 - Properties:
 - **Filler ↔ Gap**
 - **Unbounded:** What book did Alfred say that Mary has written ____?

Arguments for UG

- Constraints on movement (island effects)
 - What book did Alfred say that Mary wrote ____?
 - **Wh-island:**
 - *What book did Alfred say why Mary wrote ____?
 - *The book that Alfred said why Mary wrote ____

Arguments for UG

- Constraints on movement (island effects)
 - What book did librarian put ____ on the shelf?
 - **Adjunct island:**
 - *What book did the patron get mad [because the librarian placed ____ on the shelf]?
 - **Complex NP island:**
 - *What book did you read a review [that criticized ____]?

Detecting Linguistic Knowledge

- Can't find abstract structures in weight matrices, but we can't do that in brains either.
- Evaluate on the basis of patterns of behavior.
 - Sentence production
 - Acceptability judgments
 - Patterns of processing
- How do we instantiate these in a NN?

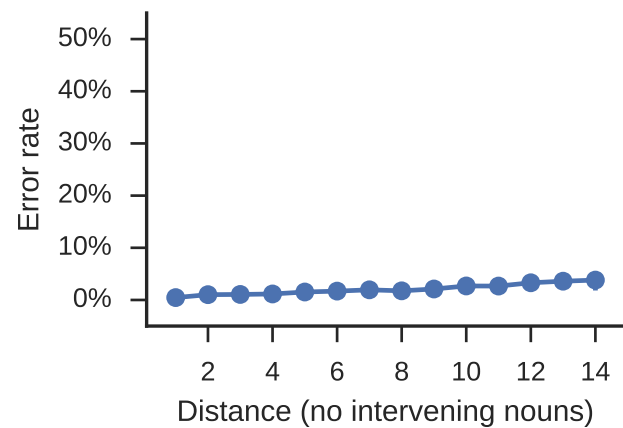
Linzen, Dupoux and Goldberg (2016)

- Question: Do NNs show knowledge of hierarchically-governed subject-verb (number) agreement?
- Argument:
 - LSTMs perform well in prediction and language modeling tasks involving challenging cases of number agreement
 - They have (some) knowledge of hierarchical structure

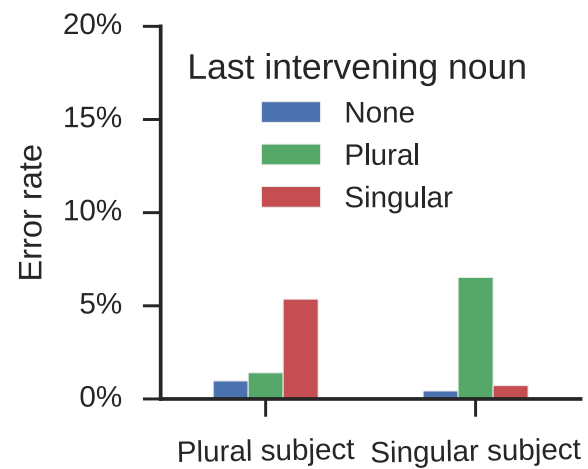
Experiments

- **Number prediction:** train LSTM to predict sing vs. plural using examples of present tense verbs (and their preambles) from Wikipedia
 - The only championship banners that are currently displayed within the building **[PLUR]**
 - 50-dimensional hidden state
 - compare to baseline model that sees only nouns

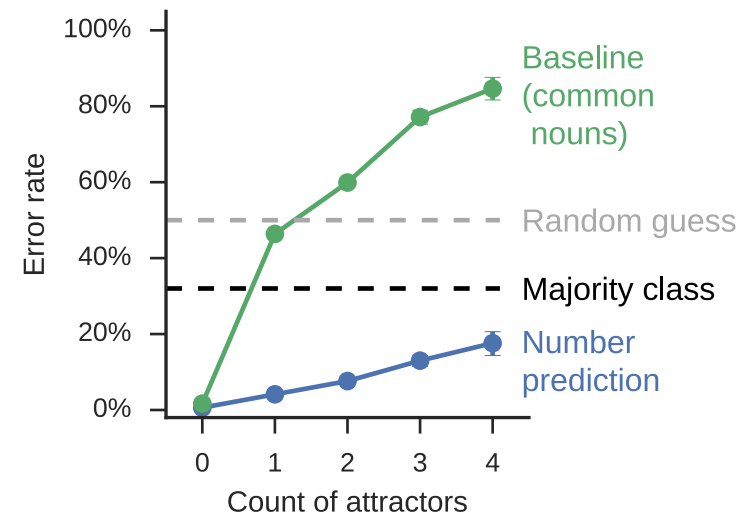
(a)



(b)



(c)



Intervention effects

- Bock and Miller (1991):
 - the label on the bottles
 - the label that I put on the bottles

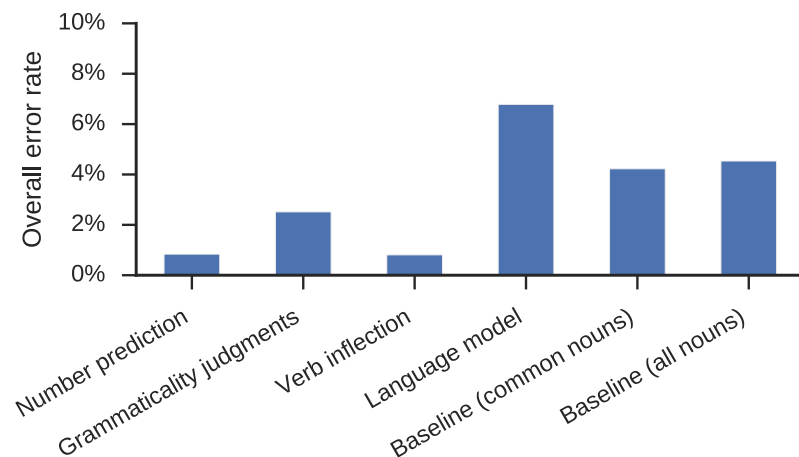
Other tasks

- Inflection:
 - the key to the cabinets + BE : is
 - the keys to the cabinets + BE: are
- Grammaticality
 - the key to the cabinets are: *
 - the key to the cabinet is: OK
- Language modeling

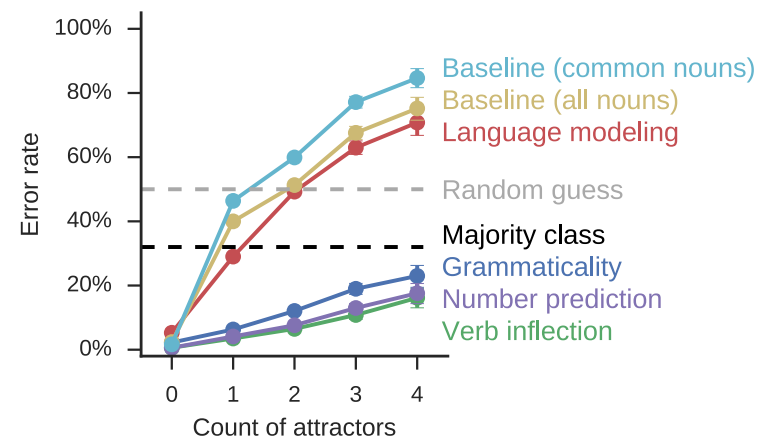
Acceptability Judgments as Language Modeling

- the books *is/are
- Absolute:
 - $p(\text{the books is}) < \theta$
 - $p(\text{the books are}) > \theta$
- Conditional:
 - $p(\text{is} \mid \text{the books}) < \theta$
 - $p(\text{are} \mid \text{the books}) > \theta$
- Relative
 - $p(\text{is} \mid \text{the books}) < p(\text{are} \mid \text{the books})$

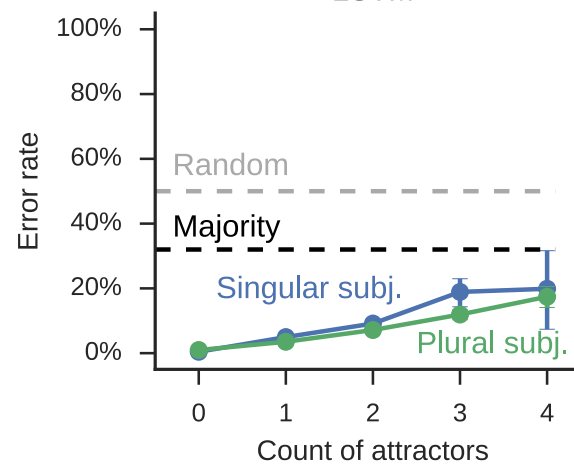
(a)



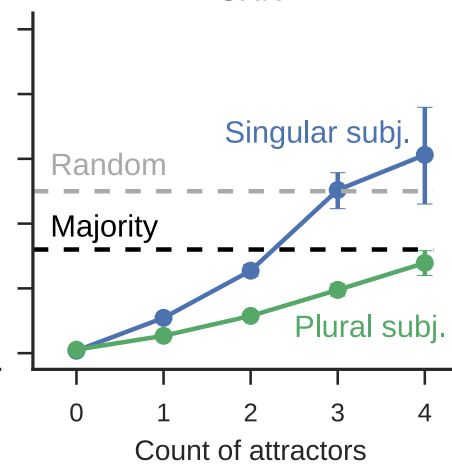
(b)



LSTM



SRN



Conclusions

- Networks show evidence of structurally mediated agreement.
- Sensitivity to intervention (but not distance) like people
- LSTMs perform better than SRNs.
- Could this be semantic rather structural association?
(Gulordova et al. 2018)

Other linguistic phenomena (Marvin and Linzen 2018)

	RNN	Multitask	<i>n</i> -gram	Humans	# sents
SUBJECT-VERB AGREEMENT:					
Simple	0.94	1.00	0.79	0.96	280
In a sentential complement	0.99	0.93	0.79	0.93	3360
Short VP coordination	0.90	0.90	0.51	0.94	1680
Long VP coordination	0.61	0.81	0.50	0.82	800
Across a prepositional phrase	0.57	0.69	0.50	0.85	44800
Across a subject relative clause	0.56	0.74	0.50	0.88	22400
Across an object relative clause	0.50	0.57	0.50	0.85	44800
Across an object relative (no <i>that</i>)	0.52	0.52	0.50	0.82	44800
In an object relative clause	0.84	0.89	0.50	0.78	44800
In an object relative (no <i>that</i>)	0.71	0.81	0.50	0.79	44800
REFLEXIVE ANAPHORA:					
Simple	0.83	0.86	0.50	0.96	560
In a sentential complement	0.86	0.83	0.50	0.91	6720
Across a relative clause	0.55	0.56	0.50	0.87	44800
NEGATIVE POLARITY ITEMS:					
Simple	0.40	0.48	0.06	0.98	792
Across a relative clause	0.41	0.73	0.60	0.81	31680