A different kind of success: Frequent frames identify useful grammatical categories in American Sign Language

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Contents

- Why do we model early language learning
- Grammatical categorization and how it relates to language processing & predictability
- Frequent Frames as a strategy for grammatical categorization
- Using American Sign Language as a case study
- Measurement of utility, based on predictability: computational measure perplexity
- Results, Implications, & Future work

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What do you know (if you are a baby)?

- Why do we care about what a baby knows about language?
- Babies are really good at learning language, almost all of them do it without explicit instruction
  - And yet, they are generally terrible at calculus

What do you know (if you are a baby)?

- So how do young children learn language?
  - ?????

Let's use
computational modeling!

=

What are you learning (if you are a baby)?

- The target knowledge for an early learner probably shouldn't look like adult level knowledge
  - Might not know all nouns
  - Maybe you know dog and kitty are the same kind of thing but you don't know dog and idea are (even though both are nouns)

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Grammatical Categorization

- A language skill we need to have but is not explicitly taught is grammatical categorization
- What is grammatical categorization?
  - Abstracting words into groups
  - Examples:
    - Noun: Puppy
    - Verb: Running
    - Adjective: Cute

Grammatical Categorization

- Why is it helpful to group dog and kitty together?
- If you know how groups of words behave, easier to predict your language

  - If I know how nouns behave, I can tell that "dax" is a noun here
    - "I like that dax"
  - This make language easier to process!
    - Formalized in surprisal theory of sentence processing (Levy 2008)

Grammatical Categorization

- How are grammatical categories helpful for predicting sentences?
- Consider the sentence: "I like nice penguins"

Grammatical Categorization

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Pronoun

↓

I

Grammatical Categorization

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Pronoun → Verb

I like

Grammatical Categorization

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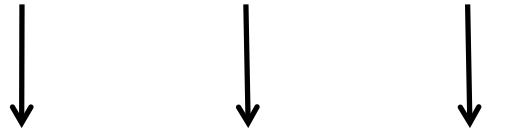
Pronoun → Verb → Adjective



I like nice

Grammatical Categorization

- How are grammatical categories helpful for predicting sentences?
- Consider the sentence: "I like nice penguins"

Pronoun → Verb → Adjective → Noun

↓	↓	↓	↓
I	like	nice	penguins

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Frequent Frames

- Frequent Frames (FFs) is a computationally inexpensive strategy for the beginning stages of grammatical categorization.
- Basic intuition:
  - Frequently occurring frames tend to identify words that behave similarly in sentences

- Relies on local framing units
  - Words or morphemes

What are Frequent Frames?

Example with words as frames:

For a sequence of words XYZ, X__Z is the frame, and Y is the thing identified.

If the corpus has sequences "I LOVE YOU" and "I HATE YOU"

I__YOU puts LOVE and HATE together into the same category, in this case, verbs.

What are Frequent Frames?

Example with morphemes as frames:

For a sequence of words XYZ, X__Z is the frame, and Y is the thing identified.

If the corpus has sequences "I AM KICKING" and "I AM JUMPING"

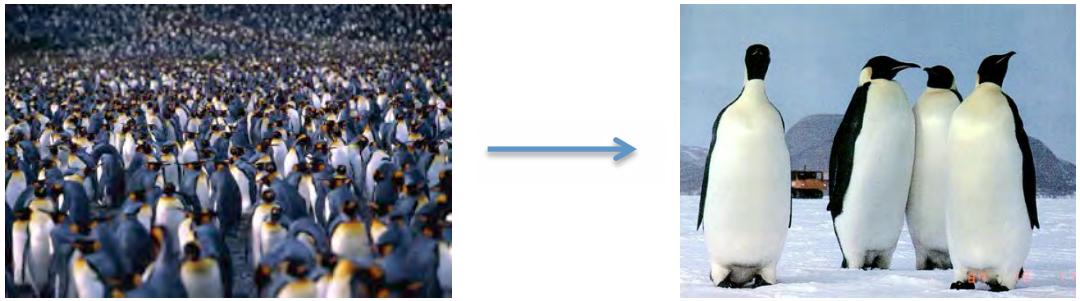
AM__ING puts KICK and JUMP together into the same category, in this case, verbs.

What are Frequent Frames?

So what do we mean by "Frequent" Frames?

Pick the top N frames seen in data.

Why? Frequency means salient enough in the input for the learner to notice and remember them.



Ex: Pick top 11 frames as most frequent, and categorize based on those 11 alone.

Frequent Frames cont.

- FFs have been shown to be successful at identifying adult grammatical categories on a variety of spoken languages (e.g., English, French, Turkish)

But what about a signed language?

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American Sign Language

- What makes looking at ASL interesting? Why bother?
  - If FF is a language-universal strategy, it should work on all human language, regardless of modality

ASL is not just gestural English

- ASL is a real complex human language with own syntax and vocabulary, not just a gestural gloss of English

Example ASL sentence:

GATE OPEN[T], IX BLACK HORSE CL-RUN CL-GATE/CL-HORSE-PATH

English translation:

The black horse ran through the open gate.

Looks very different!

ASL and Frequent Frames

- Big Question:
  - How well do Frequent Frames identify grammatical categories in ASL?
  - Can FFs perform well on a language with such a different modality?

American Sign Language

- Language data: BU ASLLRP corpus (Neidle, C. & Vogler, C. 2012)
  - 34 categories (like Noun, Verb, Aspect, Tense)
  - 1641 utterances (10820 word tokens, 2321 word types)
  - Average utterance length: 6.6 signs

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How do you test models of early language acquisition?

- How do we measure how well our models of learning strategies (like FFs) do?

Old way: compare against adult knowledge

Did you find all the nouns?

New way: how useful is the knowledge that's been learned?

i.e. can the information about nouns that you learned help you process language faster or better?

i.e. does this knowledge make language more predictable?

Introducing the computational measure of perplexity

- Perplexity is inversely related to probability, so low perplexity = higher probability of seeing the data

$$Perplexity(Words = w_1 w_2 ... w_N) = \sqrt[N]{\frac{1}{P(start - w_1 w_2 ... w_N - end)}}$$

If the probability is low because we didn't expect our data, then whatever we learned is not helpful.

Perplexity

- The sentence "I like nice penguins" should have a low perplexity score because the probability of the sentence is high

- The sentence "Penguins nice like I" should have a high perplexity score because the probability of the sentence is low

ASL and Frequent Frames

- Big Question reminder:
  - How well do Frequent Frames identify grammatical categories in ASL?
  - Can FFs perform well on a language with such a different modality?

The Plan

- Metrics of success:
  - Old way: Measuring against adult knowledge
  - New way: Measuring utility

- Training: Use word-level FFs to identify categories in ASL, using realistic ASL data

- Test:

Old way: Compare against adult grammatical categories

New way: Compare FF-based categories and adult grammatical categories on their ability to predict ASL language data

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Precision and Recall

- We'd like to end up with adult knowledge of grammatical categories
- With grammatical categories
  - Frame X: penguin, kitty
  - Nouns: penguin, kitty, idea, monkey, airplane

» My Precision will be how many words I guess right out of my guess (Frame X):

» Precision: 2/2 = 1.00, yay!

» My Recall will be how many words I guess right out of the correct group (Nouns):

» Recall: 2/5 = 0.40, boo!

» Accurate, but not very complete. We find that FFs tend to be pretty accurate but not very complete for most spoken languages

Results: ASL

- Precision and Recall:

# adult categories	# FF categories	Precision	Recall
34	11	0.415	0.005

Precision and recall scores range from 0 to 1. Precision significantly less than 1 indicates categories are not very accurate compared to the adult categories (e.g., a “noun” cluster includes other categories besides nouns), while recall near 0 indicates categories are very incomplete (e.g., the “noun” cluster only includes a small fraction of all nouns)

Results: ASL

- Given that perplexity is a measure of utility through predictability, how useful are the categories frequent frames identify in ASL at predicting sentences?

Perplexity: FFs-based categories	Perplexity: adult categories
9.8	45.5

1 infinity

Take Away

- Even though FFs are not very good at identifying adult grammatical categories in ASL, the FF-based categories are more useful for predicting language and thus the categories identified by FFs may be more useful to an early learner than adult knowledge

Future extensions

- Test perplexity on a variety of spoken languages with different properties
  - Are FFs generally more useful?

- ASL might perform better over sub-word levels
  - Rich morphology
  - Semi free word order
  - Shares these in common with Turkish
    - performed much better with morphemes as framing units as opposed to words (47% accuracy words, 90.5% accuracy morphemes)

thank you

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