The neural bases & distributional factors underlying learning and generalization of morphological inflections

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Goals

- What are the statistical factors affecting learning of morphological regularities in a 2nd language?

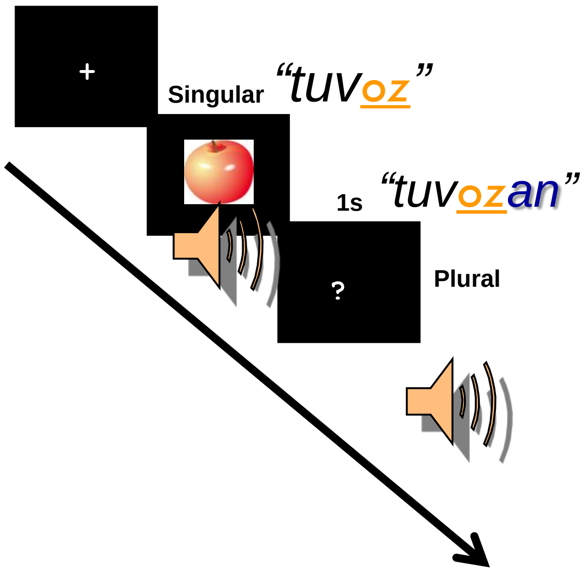
- Is there a "default inflection"?
  - Some models suggest that emergence of "regular" inflections in L1 does not depend on their statistical properties (e.g., Berent, Pinker & Shimron, 1999; Marcus et al., 1995)
  - Which statistical factors affect emergence of a "default inflection"?

Domain general statistical factors

- Suffix (type) frequency
  - Repetitions critical for procedural / perceptual learning
  - Shows effects but cannot explain alone emergence of "default".
- Predictability based on phonological cues
  - Critical in e.g. visual category learning
  - Shows effects, but its role is debated
- Affix Diversity: number of distinct cues predicting an affix
  - Plays role in generalization from motor, perceptual and category learning
  - May explain emergence of low-frequency "default" inflections

The Artificial Language

- 48 nouns in artificial language (CVCVC)
  - Aurally presented + object image
- Plural inflection by suffix:
  - 5 suffixes (VC), varying frequencies:



- Probabilistic phonological cue: rime- suffix

e.g.: *"tuvoz"→ "tuvozan"; "gishoz" → "gishozan"*.

"nishig" → nishigan"; "posig" → "posigan"

"napod" → "napodesh"; "nezod" → "nezodesh"

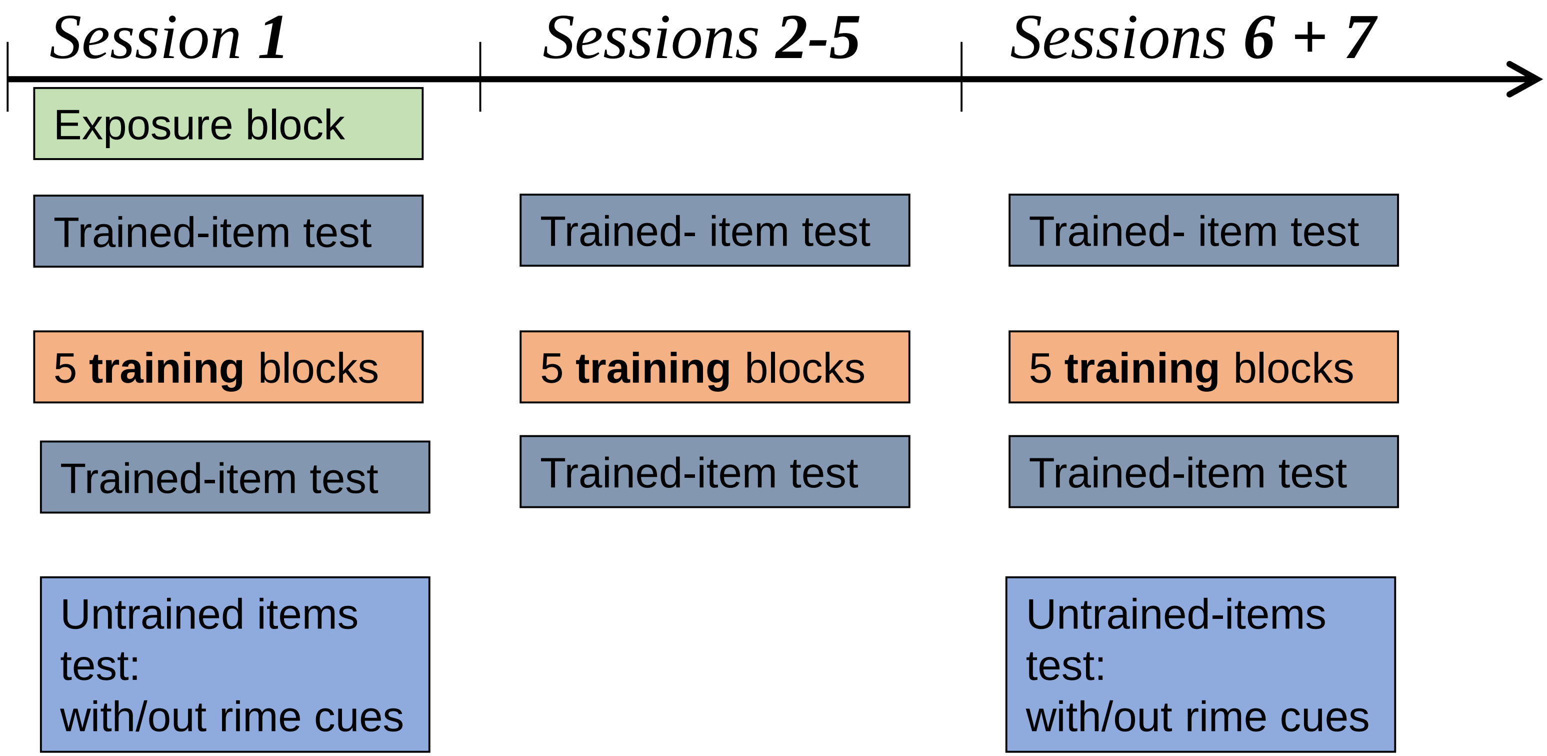
  - NOT explicit

Experimental groups

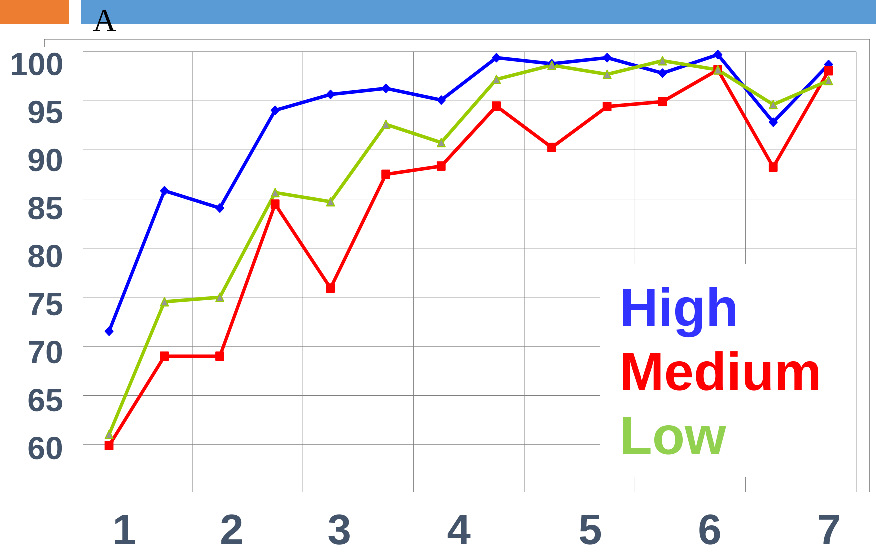
Group / Suffix type freq	A Probabilistic N=18	B Probabilistic N=18	C Deterministic N=17
1 High Freq. 50% (24 words)	**0.375**	**0.148**	**` 0.283**
1 Medium Freq. 25% (12 words)	**0.125**	**0.269**	**0.133**
3 Low Freq. 8.3% (3 X 4 words)	**0.194 (each suffix)**	**0.167 (each suffix)**	**0.194 (each suffix)**

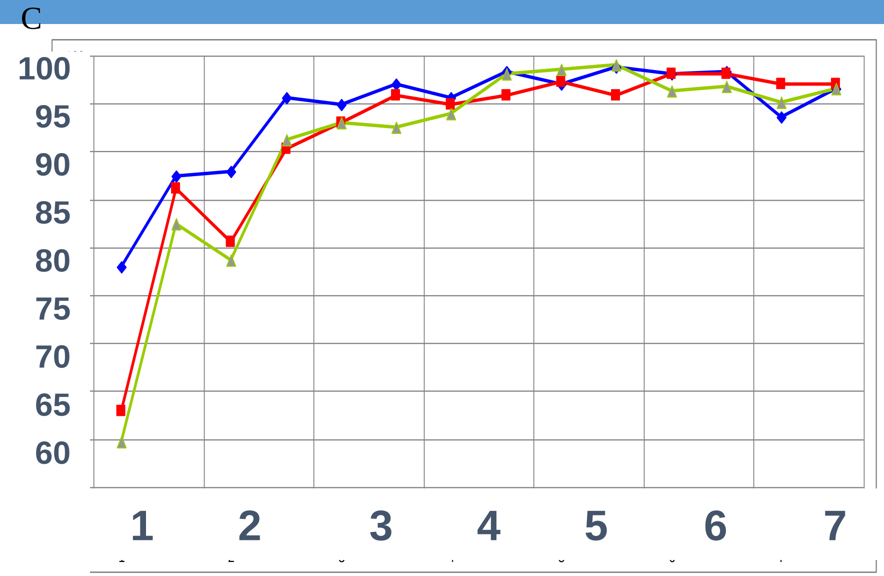
Suffix frequency – within subject
Suffix predictability – within and between subjects
Suffix phonological diversity – within and between subjects

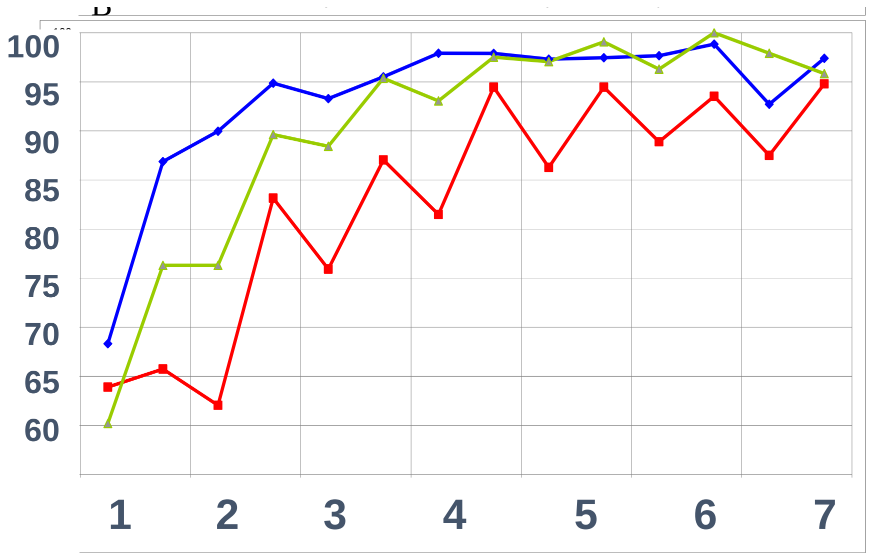
Multi-session training



Trained words: effect of suffix frequency



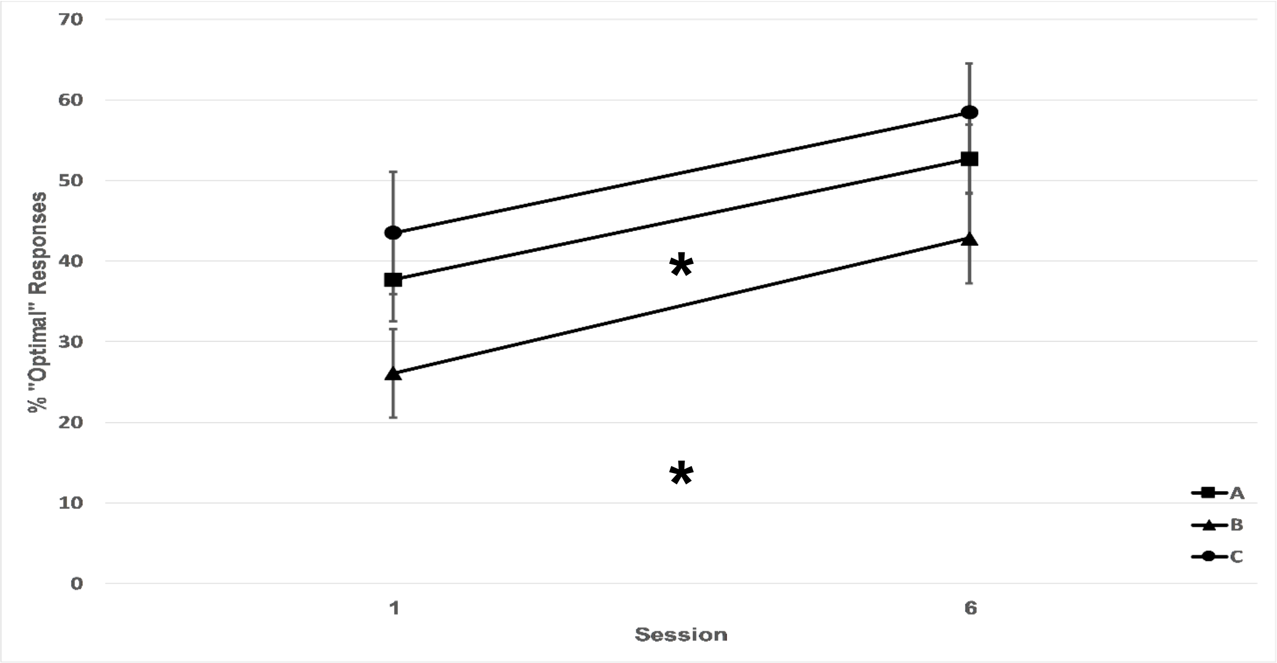




- Best performance on High freq. inflections
- but Low freq. is better/ equal to Medium.

Learning of morpho-phonological regularities

Application of "correct" suffixes to Untrained words <u>with rime cues</u>

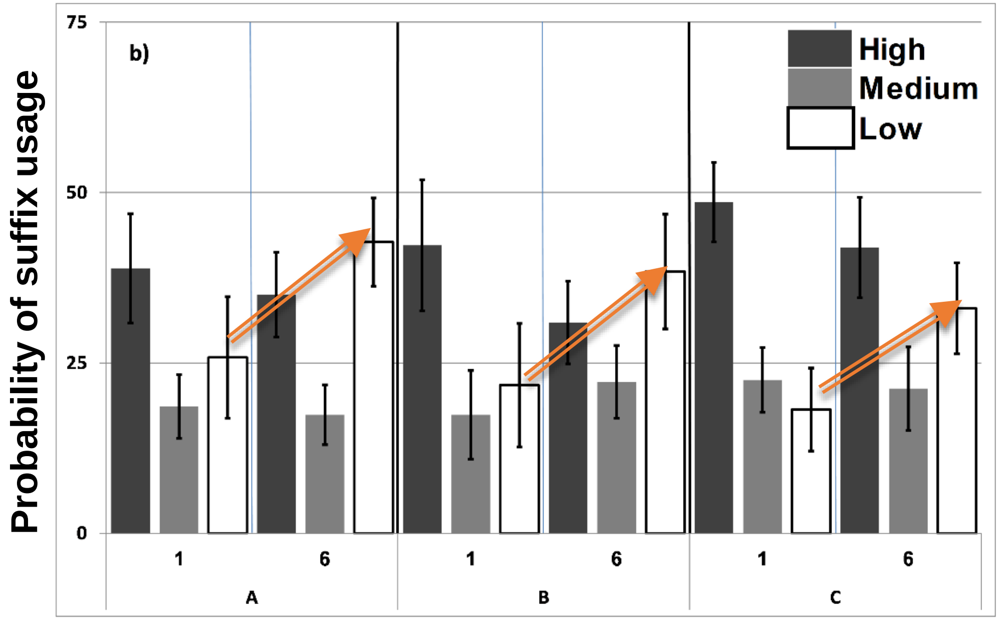


- Increase in application of "correct" responses

Inflection of untrained words without phonological cues

- Increase in application of Low frequency suffix
  - Beyond its frequency in trained stimuli
  - Especially in non-deterministic language

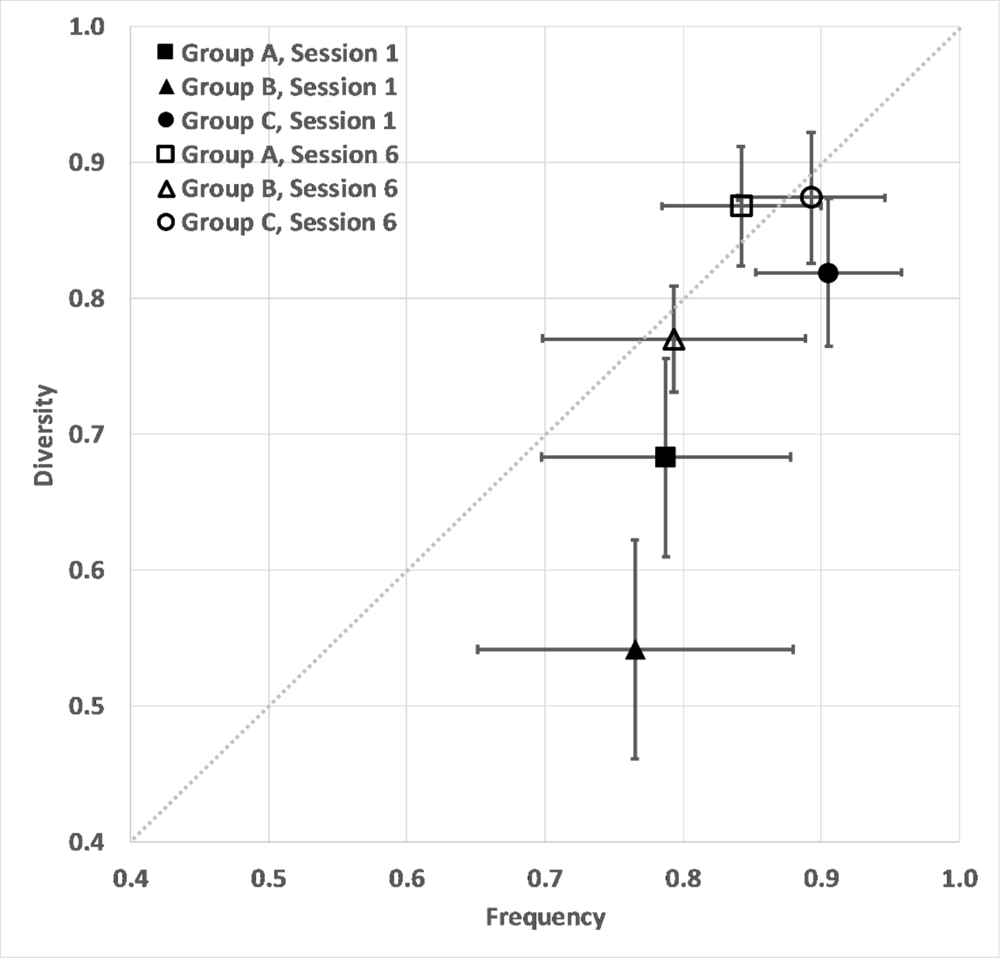
Application of suffixes to Untrained words <u>without rime cues</u>



Emergence of probabilistic "default"

- Cosine similarities
- Initially:
  - Greater reliance on suffix frequency > phonological diversity
- Later:
  - Increase in reliance on phonological diversity
    - Especially in non-deterministic languages

Untrained words without rime cues



Experiment 2: fMRI - Goals

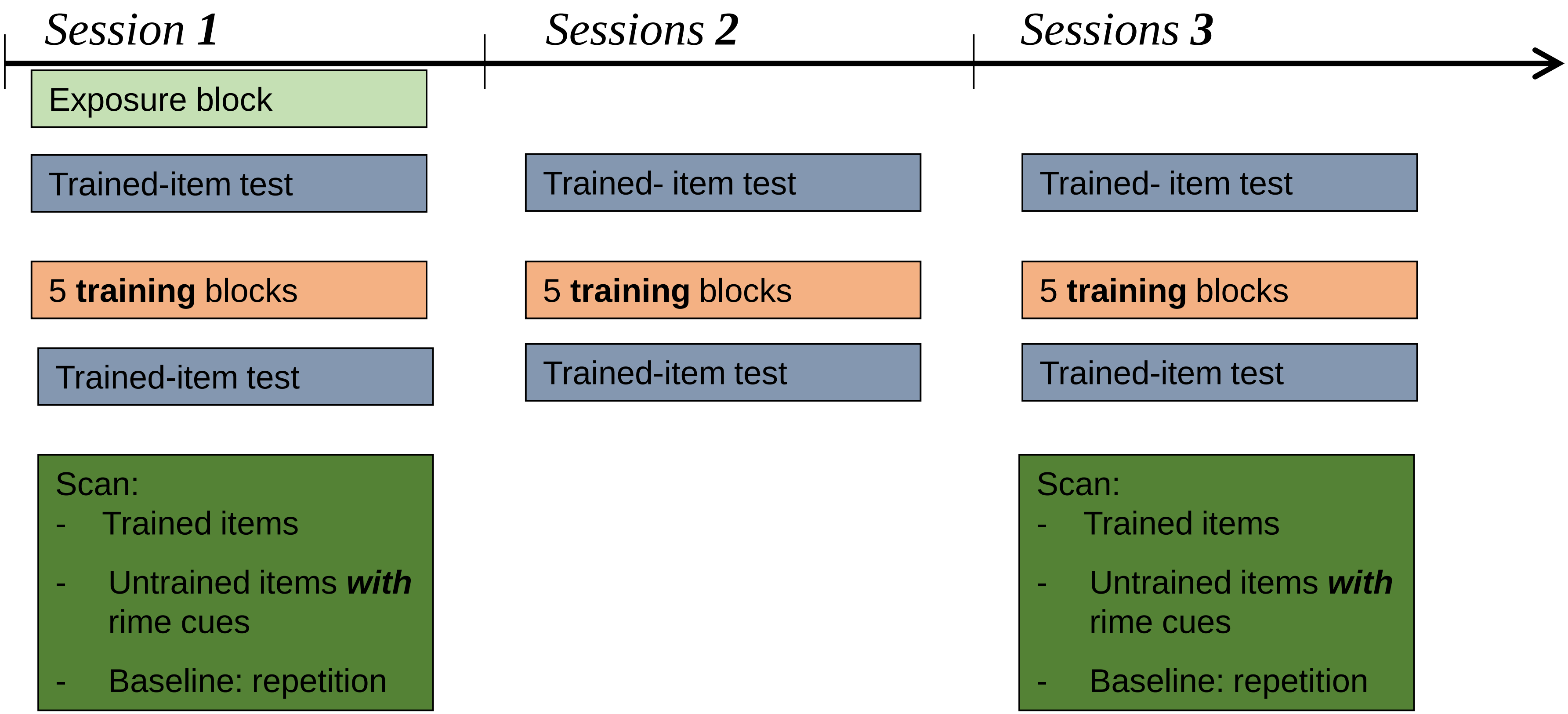
- Which neurocognitive learning mechanisms are involved in learning morphological inflections in a 2^{nd} language?
  - Procedural? Declarative? Both?

- Are they affected by these statistical factors
  - Suffix frequency
  - Predictability of phonological cues

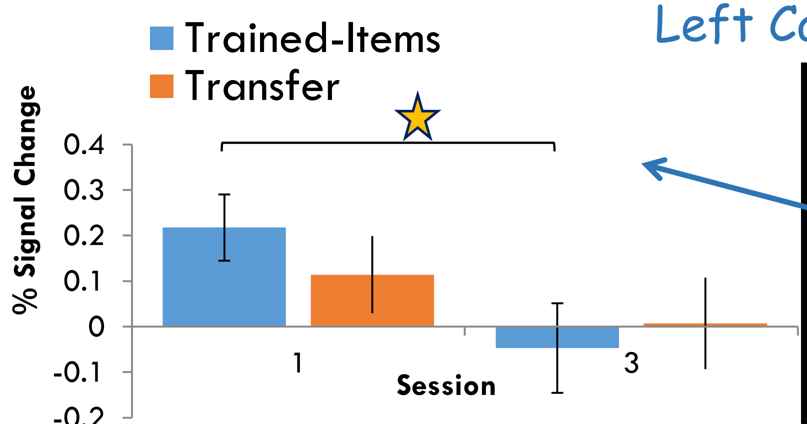
  - (Only trained & untrained words with rime cues were tested)

FMRI procedure

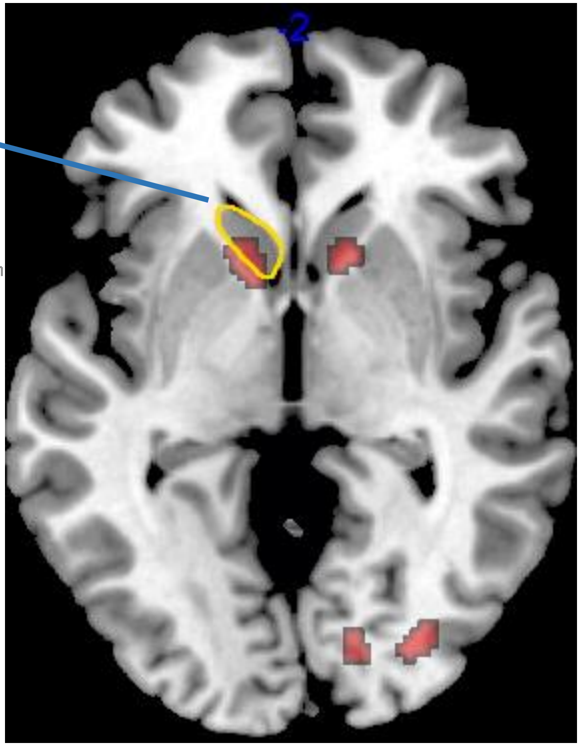
- 18 participants (native Hebrew speakers)
- Language A



Early involvement of Fronto-striatal regions



Left Caudate Head



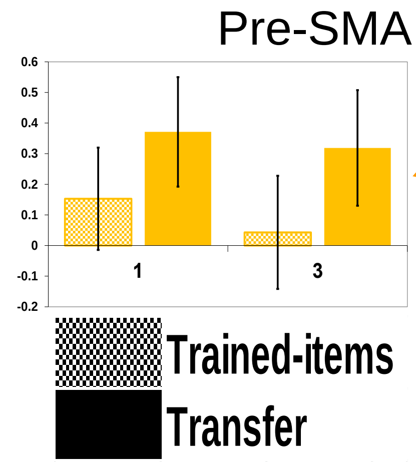
Nevat, Ullman, Eviatar, & Bitan, (2017)

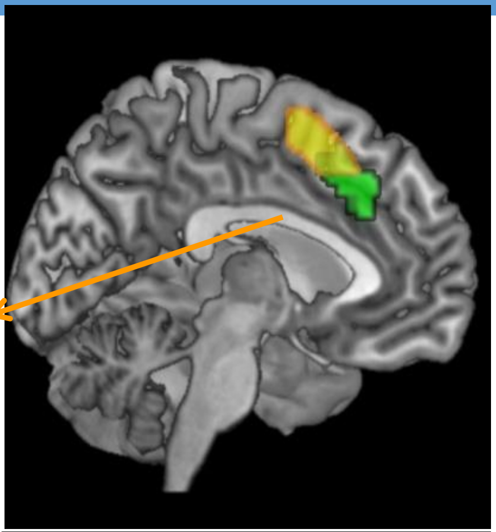
Sess. 1:
Low & Medium > High

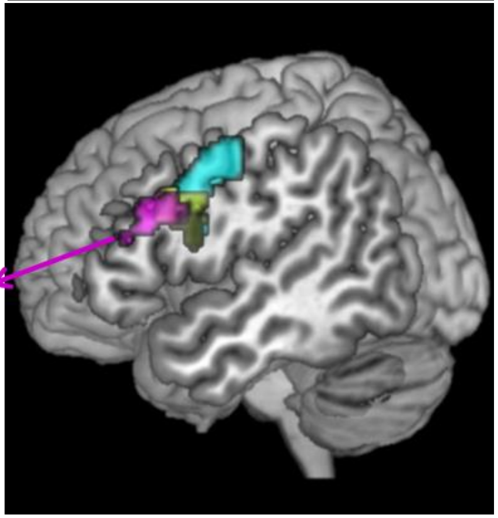
- Caudate nuc. decreases with training:
  - Involved in motor & perceptual learning
- Consistent with procedural skill learning
- Affected by statistical information: suffix frequency

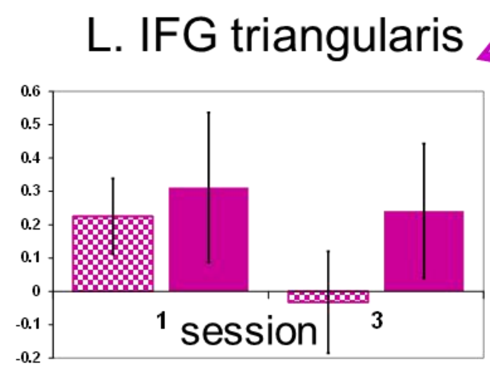
Untrained > trained words: "compositional"

- Reliance on phonological cues
  - Medial frontal/ Pre-SMA:
    - Assoc. with procedural
    - Positive correlation
  - Left IFG Triangularis
    - Declarative/ semantic retrieval
    - Negative correlation
- Correlated with awareness





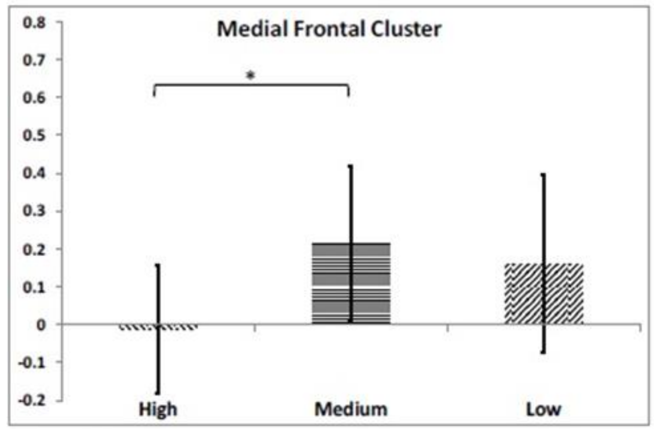


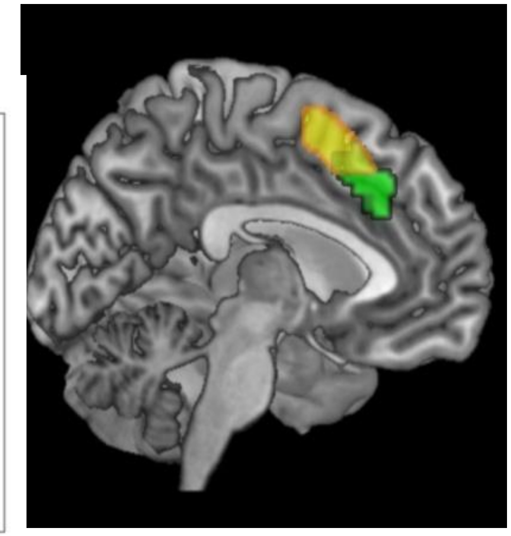


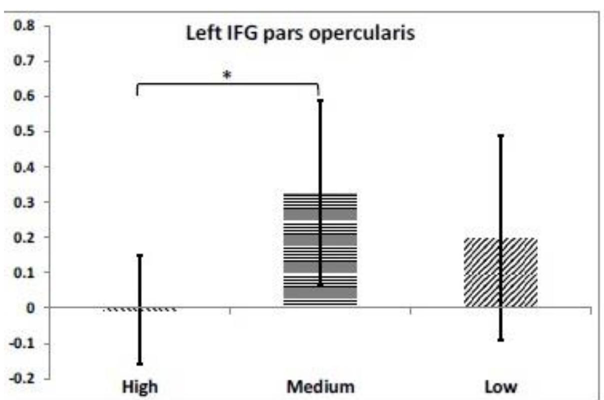
Nevat, Ullman, Eviatar, & Bitan, (2017)

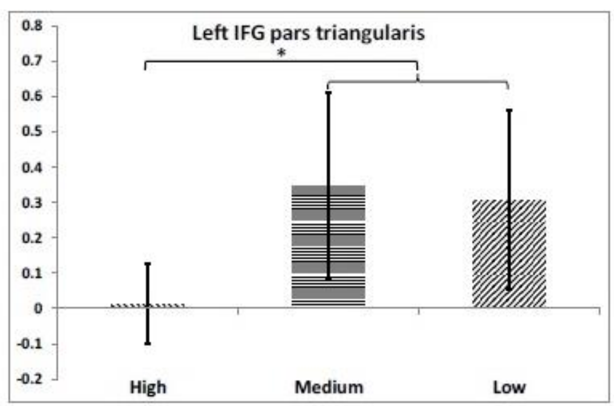
"Compositional" areas in *trained* items

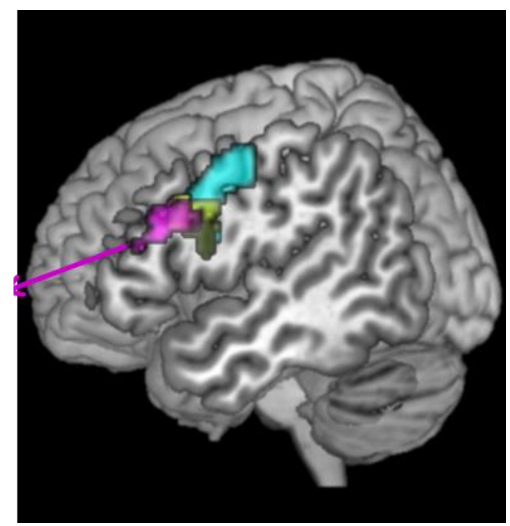
- In sess. 1:
- Less in high freq. suffixes.
- Greater reliance on storage?











Nevat, Ullman, Eviatar, & Bitan, (2017)

Conclusion-1

- Learning inflectional regularities in a novel language depends on statistical properties:
  - Affix type frequency and phonological predictability
- When inflecting new words, with no phonological similarity to trained words:
  - A default inflection emerges (even in a novel language)
  - Initially it is the high frequency suffix
  - After learning of phonological regularities – the "default" depends on both suffix frequency and suffix phonological diversity.

Conclusions-2

- Learning a novel grammar in adults
- Involves procedural learning mechanisms already in early stages of training.
- “Compositionality” (untrained>trained) involves language production mechanisms and is affected by learning of **phonological regularities**
- Familiar (trained) forms with high frequency suffixes are less “compositional”.

THANK YOU

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