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# On the interaction of implicative structure and type frequency in inflectional systems

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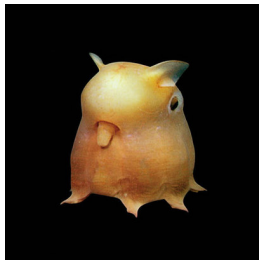
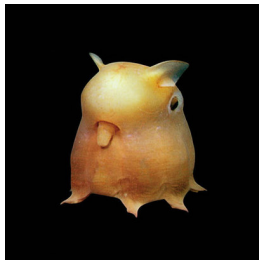
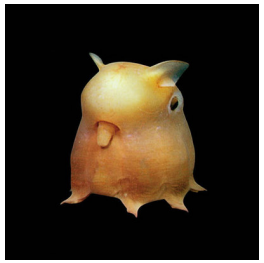
# Some big(gish) questions for today

- How do sources of information minimize the uncertainty associated with predicting unknown inflected forms?
  - Paradigm Cell Filling Problem, PCFP (Ackerman, Blevins, and Malouf 2009)
  - This is a *'lankus'* What are these? *'lanki'?*

- Typological question: To what extent are languages similar in how sources of information interact?

# PCFP and implicative structure

- Low Entropy Conjecture
  - "…enumerative morphological complexity is effectively unrestricted, as long as the average conditional entropy, a measure of integrative complexity, is low" (Ackerman and Malouf 2013:436)

$$H(A|B) = \sum_{b \in B, a \in A} p(b,a) \log_2 \frac{p(b)}{p(b,a)}$$

| SINGULAR (A) | virus | syllabus | corpus |
|---|---|---|---|
| PLURAL (B) | viruses | syllabi | corpora |

# PCFP and implicative structure

- Implicative paradigmatic structure is …
  - Not the only kind of information that can do work towards solving the PCFP
  - Not necessarily independent of other info
  - Low entropy can exist in the absence of implicative structure doing any work

# Sources of information

- Implicative paradigmatic structure
  - inflected forms vary in how much they are predictive of and/or predictable from other inflected forms
- Inflectional class type frequency
  - inflection classes differ in the number of lexemes they represent

(Wurzel 1989; Ackerman and Malouf 2013; Baerman and Corbett 2012; Sims 2015; Stump and Finkel 2013)

# Starting point: describing the systems

- The description of the system can strongly influence analysis of system's complexity (Bonami 2013)
- An assumption that some/many 'irregular' lexemes fall outside of the morphological system risks underestimating the actual complexity speakers deal with
- Rather than assume a particular analysis of the system, we empirically explore the extent to which granularity of inflectional information affects the results

# More complex descriptions

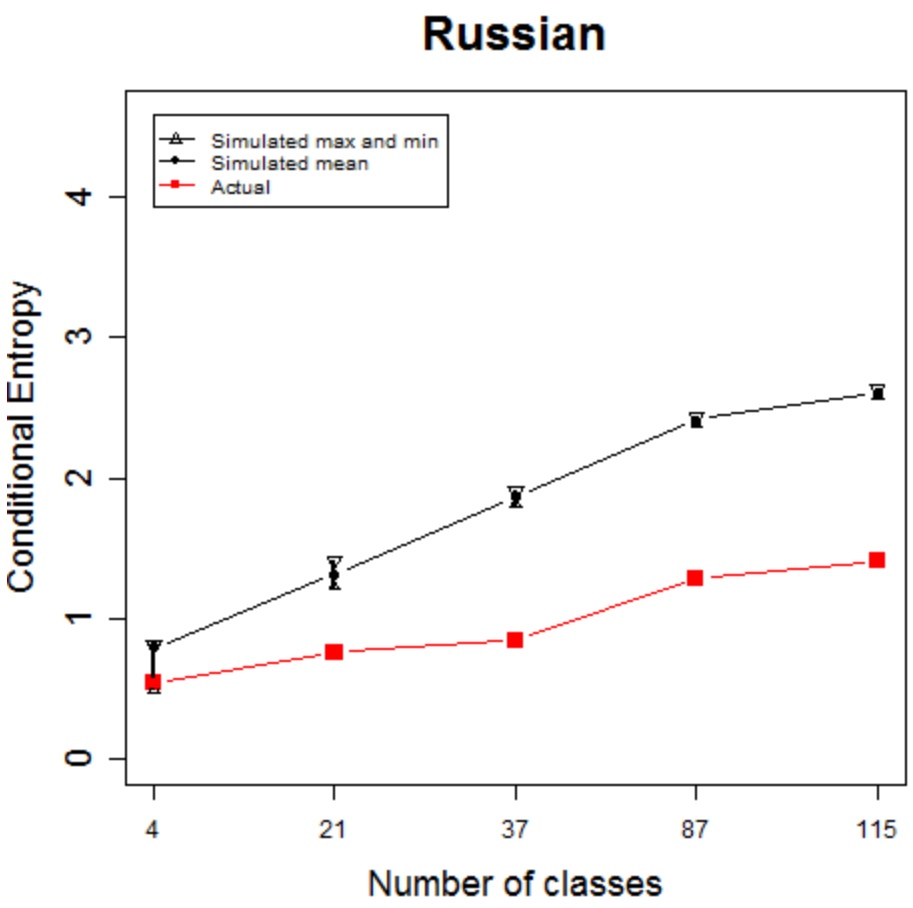
- Russian (43,486 nouns):
  - 6 cases x 2 numbers = 12 paradigm cells
  - morphological class info and type frequencies from *Grammatičeskij slovar' russkogo jazyka (Zaliznjak 1977)*
- Greek (27,270 nouns):
  - 3 cases x 2 numbers = 6 paradigm cells
  - morphological class info from *Lexikó tīs koinḯs neoellīnikḯs* (Triantafillidis Institute 1998)
  - type frequencies from Hellenic National Corpus (hnc.ilsp.gr/en/)

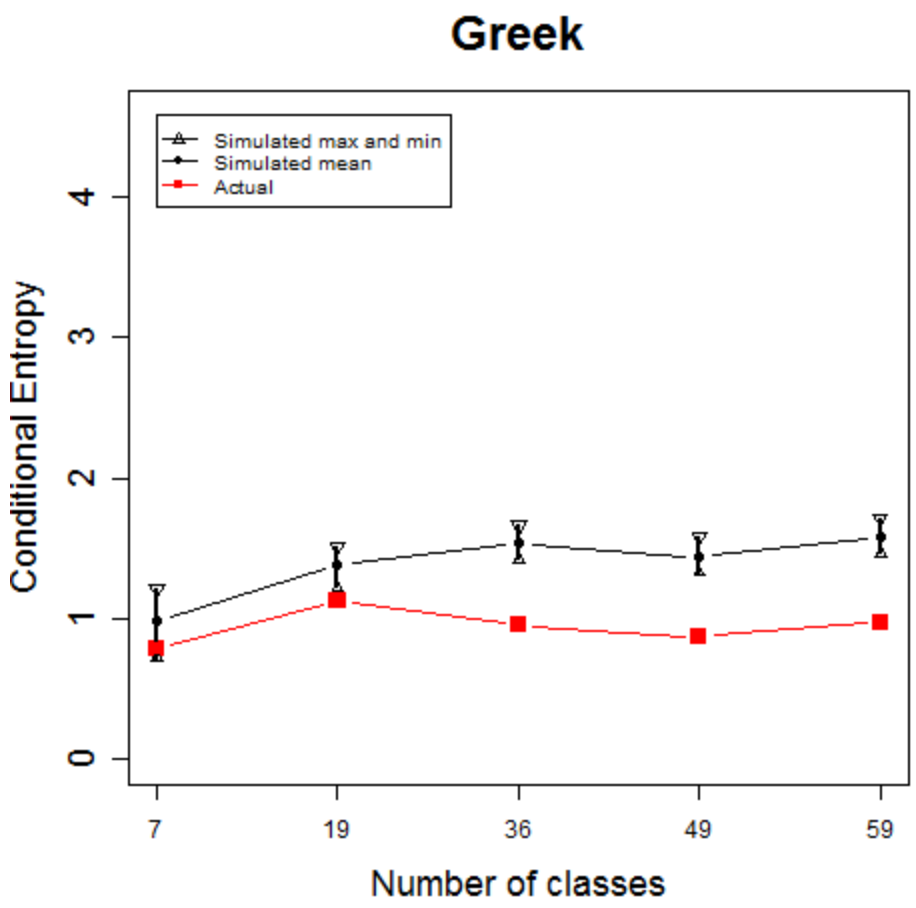
# Granularity of inflection class info

| Russian nouns | | | | | | |
|---|---|---|---|---|---|---|
| Number of classes | | Suffixes | Animacy | Stem changes | Stress | Defectiveness |
| 4 | | (+) | | | | |
| 21 | | + | + | | | |
| 37 | | + | + | + | | |
| 87 | | + | + | + | + | |
| 115 | | + | + | + | + | + |

| Greek nouns | | | | | | |
|---|---|---|---|---|---|---|
| Number of classes | | Suffixes | Inflectional stress | Stem changes | Lexical stress | Defectiveness |
| 7 | | + | | | | |
| 19 | | + | + | | | |
| 36 | | + | + | + | | |
| 49 | | + | + | + | + | |
| 59 | | + | + | + | + | + |

# Conditional entropy



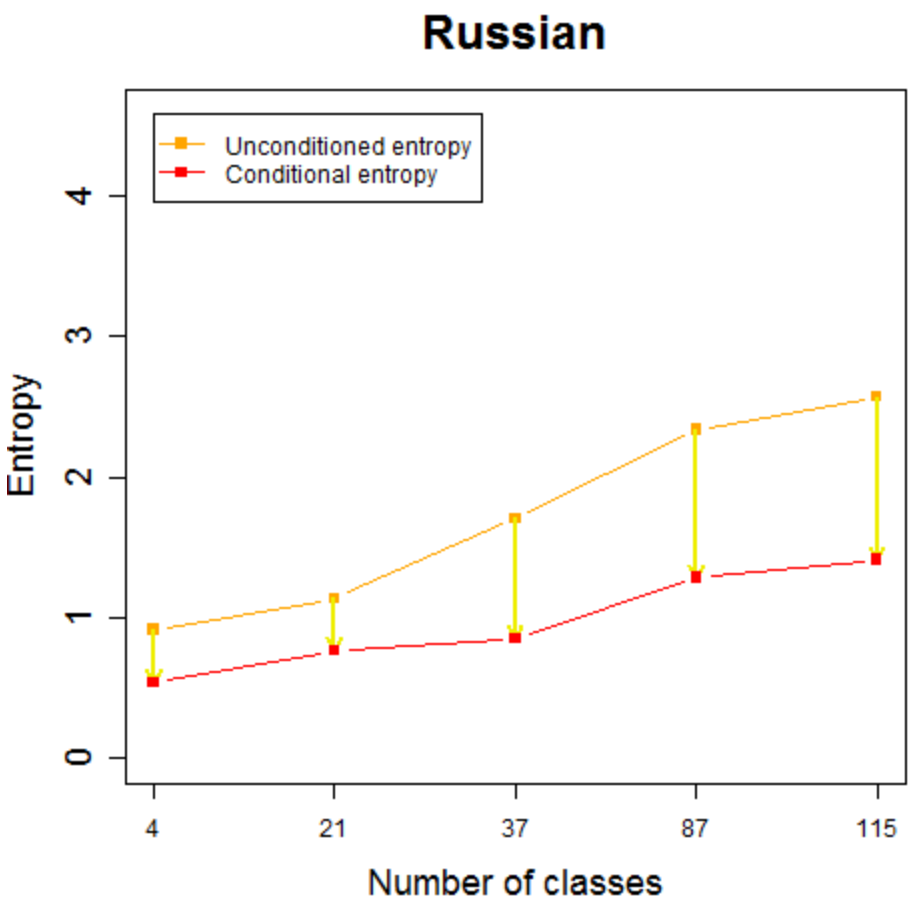



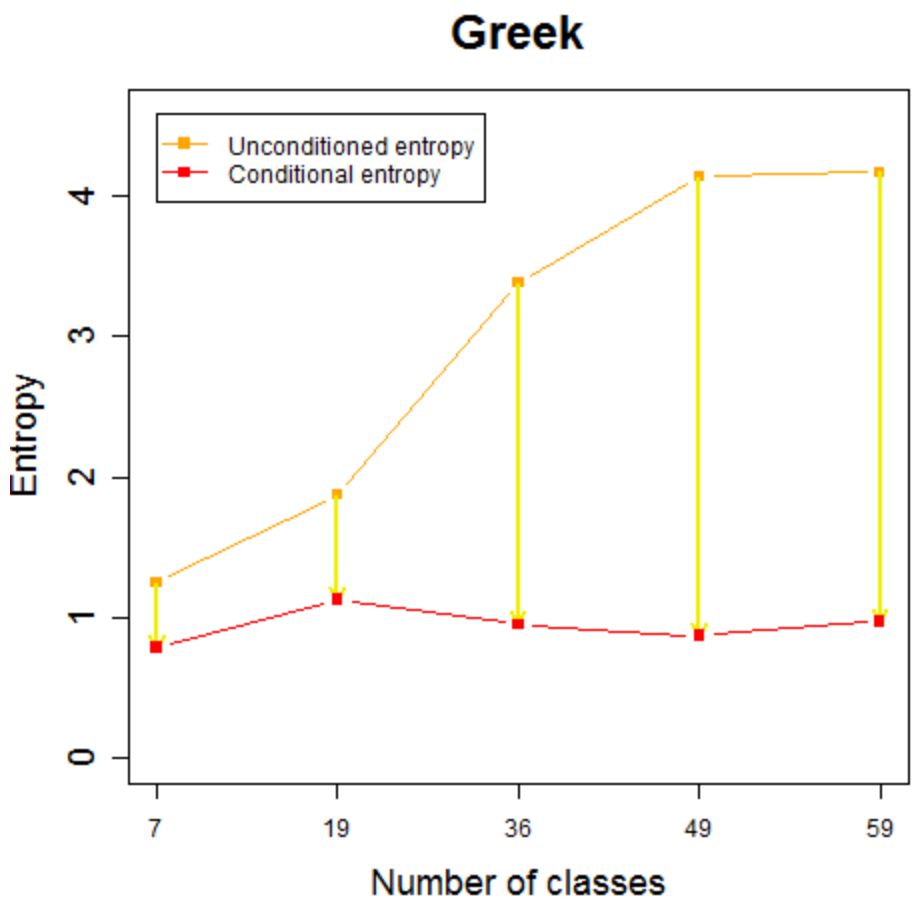

- In both languages, average uncertainty is less than by chance at all granularities; consistent with Low Entropy Conjecture
- Mostly, difference from chance increases as granularity increases

# Implicative work

- Our (re)definition of *work*: the reduction in the entropy of a system due to a given information source
- Implicative work - difference between entropy and conditional entropy
  - Entropy: $$H(A) = -\sum_{a \in A} p(a) \log_2 p(a)$$
  - Conditional entropy: $$H(A|B) = \sum_{b \in B, a \in A} p(b,a) \log_2 \frac{p(b)}{p(b,a)}$$
  - Implicative work: (Mutual information) $$I(A;B) = H(A) - H(A|B)$$

# Implicative work




- Overall, implicative work increases as granularity increases

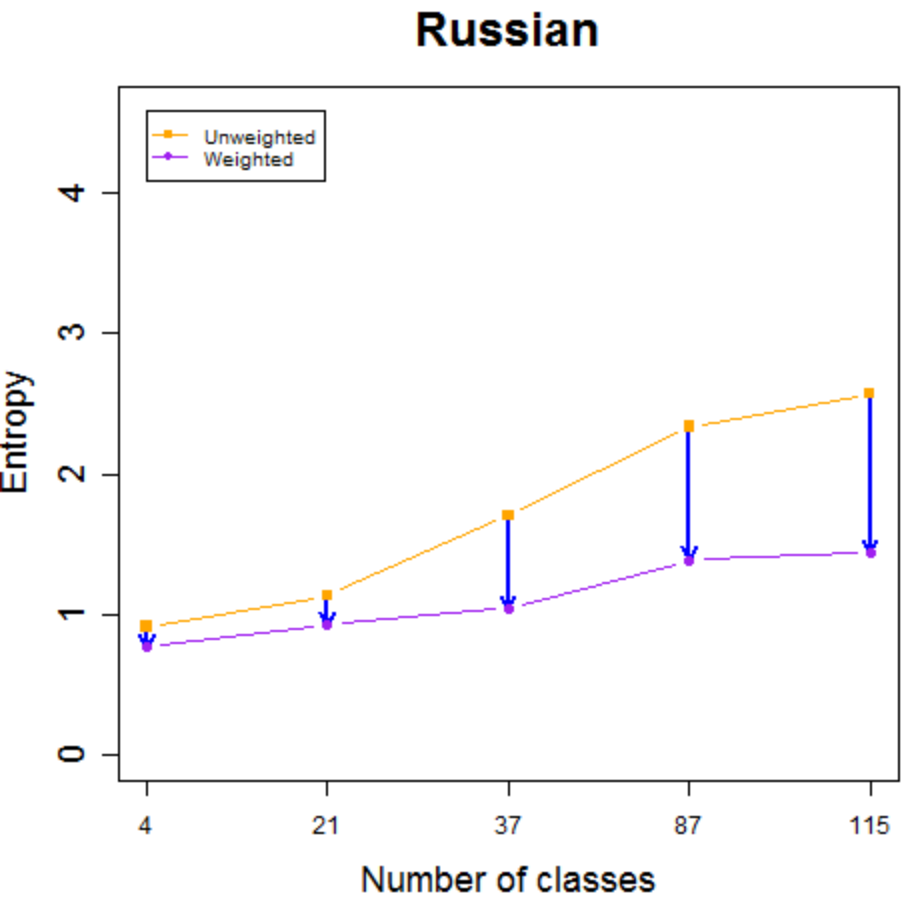
# Type frequency work

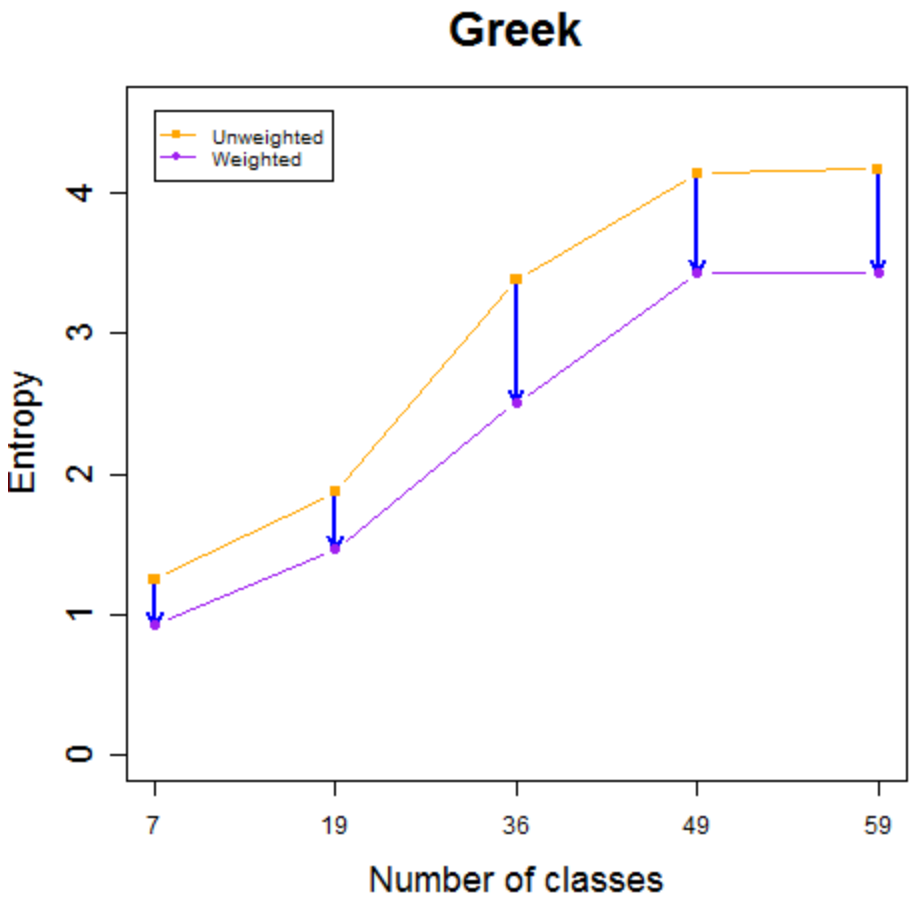
- Some classes contain thousands of lexemes, others have only one

- Type frequency work: Difference between entropy when calculated based on evenly weighted (U) and type frequency weighted (W) data structures

  - Type frequency work = $H(A)_U - H(A)_W$

# Type frequency work



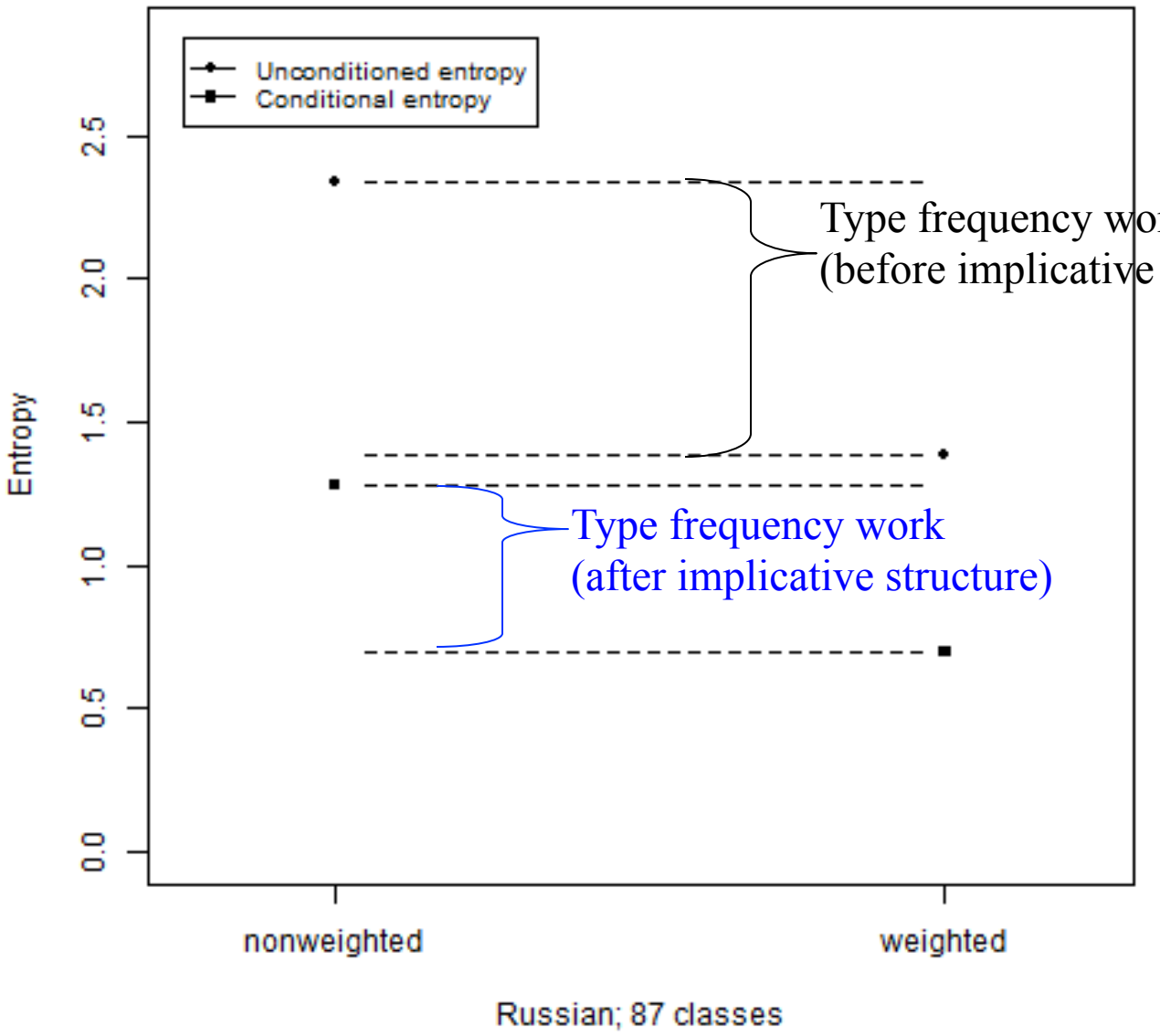

- Weighting by type frequency lowers entropy, more so in finer granularities

# What's really doing the work?

- Both implicational structure and type frequency have the capacity to do work by lowering the entropy of the system (and do so in Russian and Greek)

- To what extent are their contributions independent and/or overlapping?

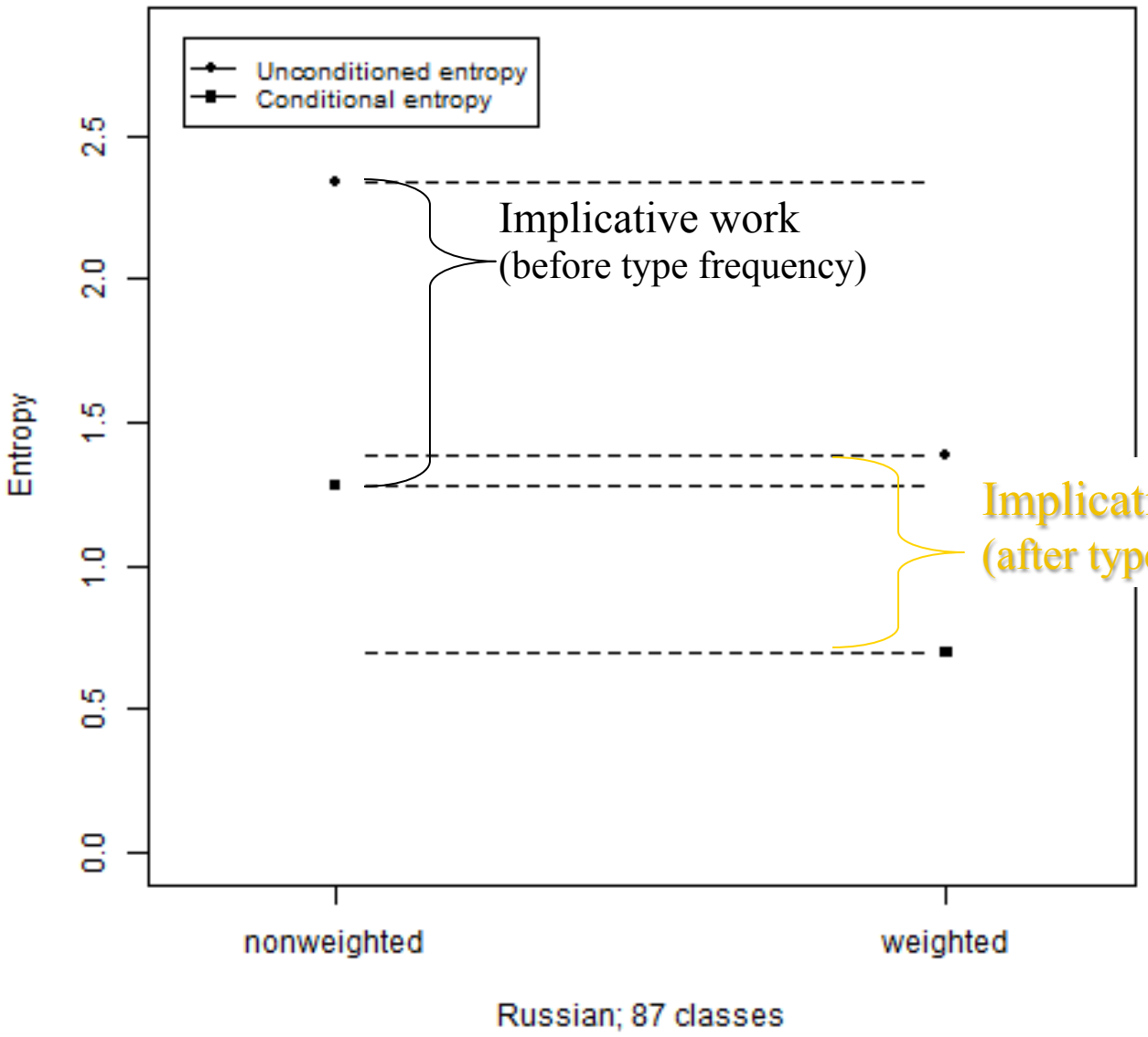
## Calculating work

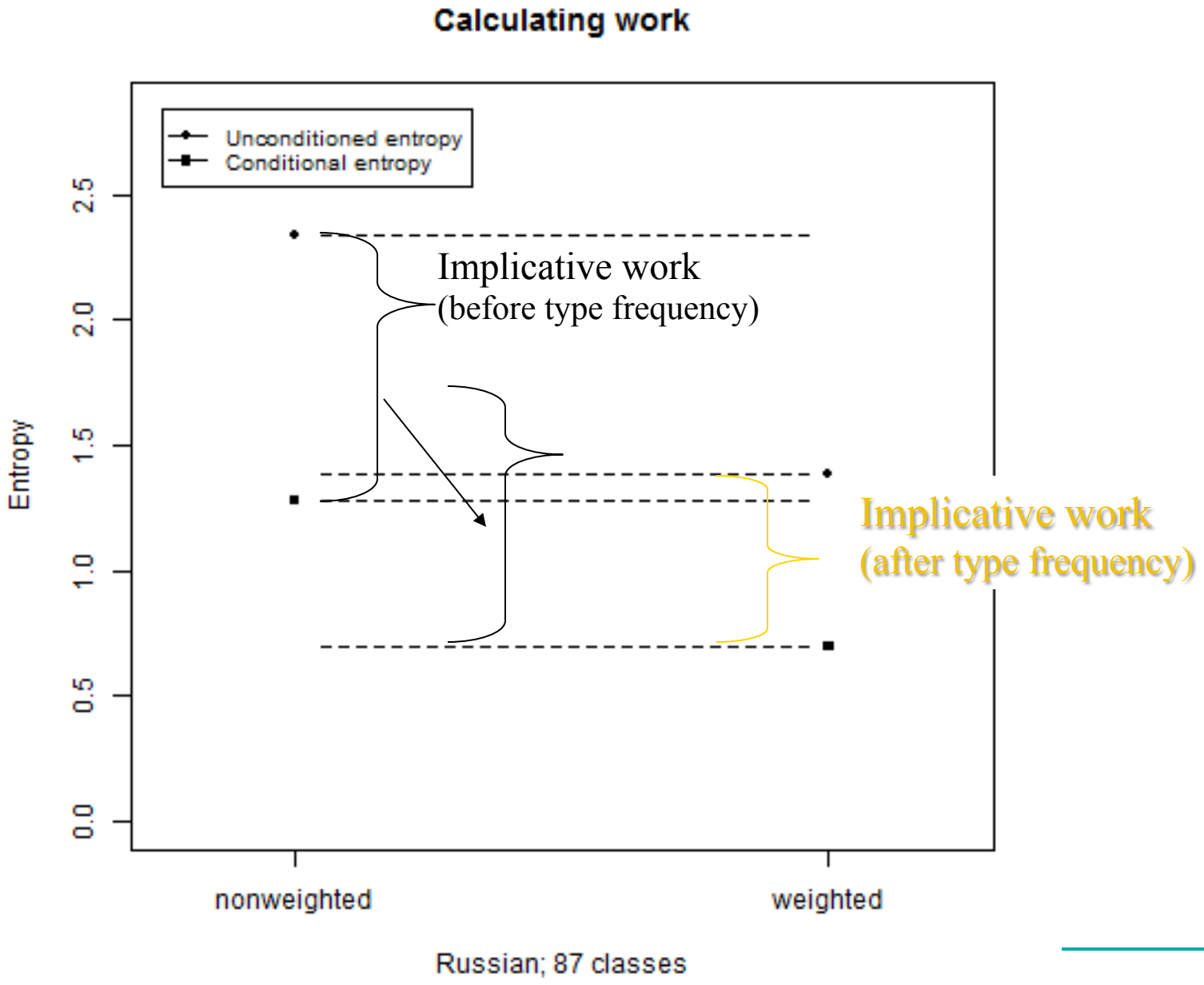


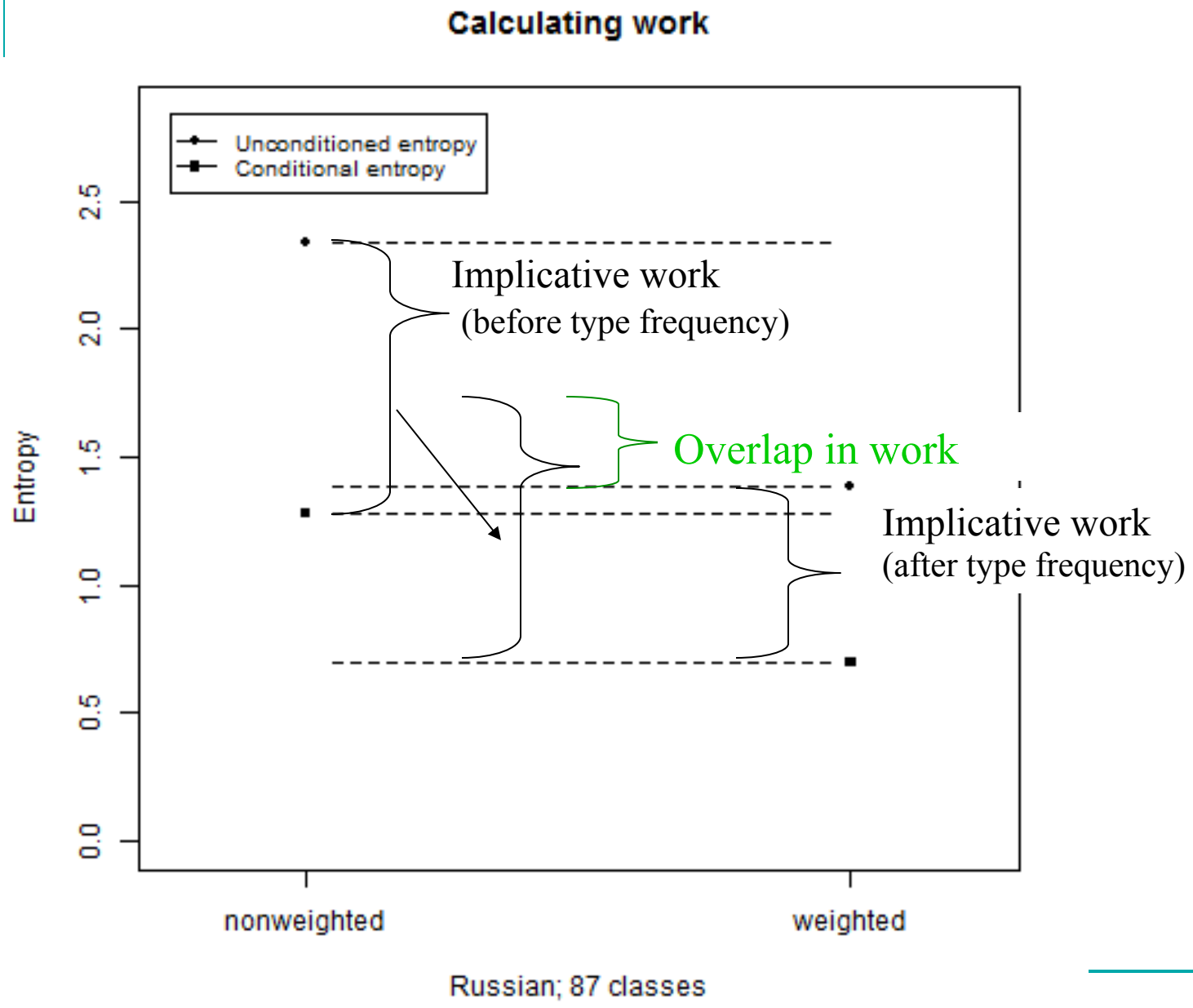

Type frequency work
(before implicative structure)

Type frequency work
(after implicative structure)

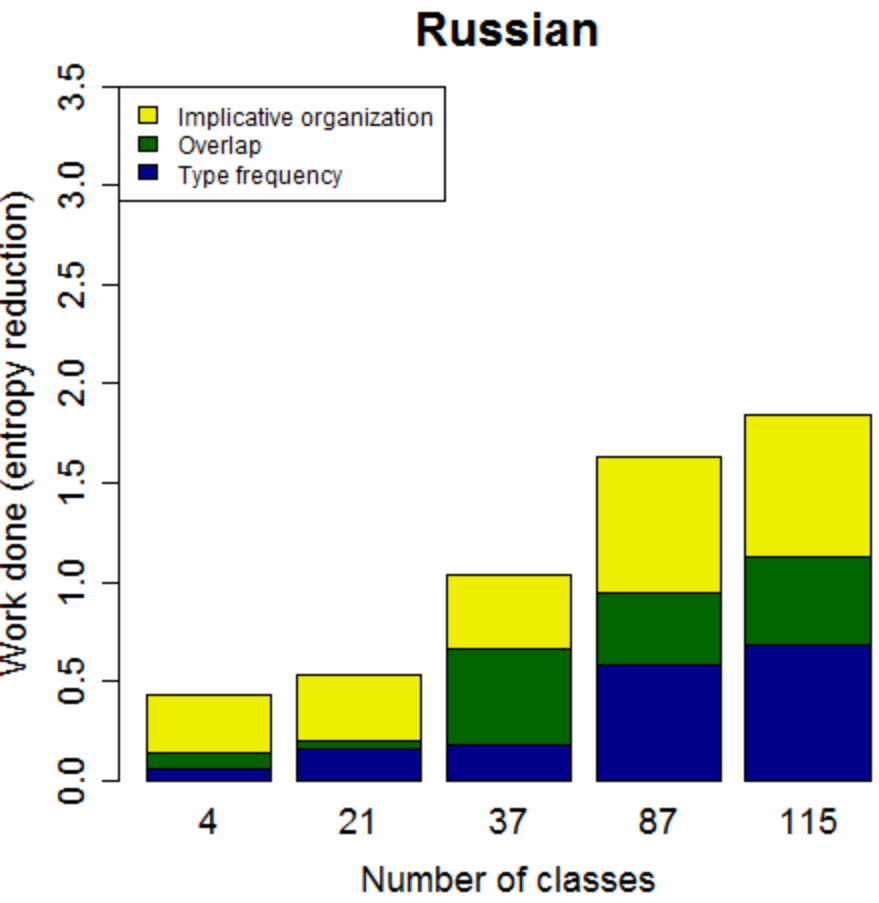
## Calculating work

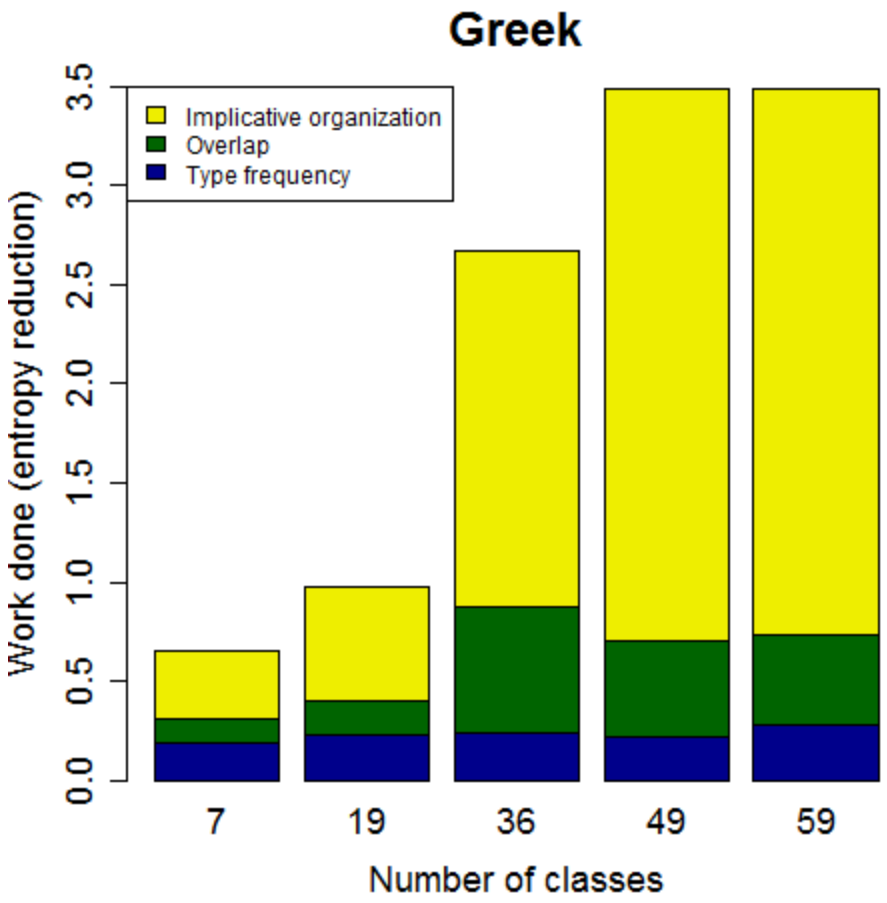



Calculating work
Unconditioned entropy
Conditional entropy
Implicative work
(before type frequency)
Implicative work
(after type frequency)
Entropy
0.0
0.5
1.0
1.5
2.0
2.5
nonweighted
weighted
Russian; 87 classes


Calculating work
Unconditioned entropy
Conditional entropy
Implicative work
(before type frequency)
Overlap in work
Implicative work
(after type frequency)
Entropy
0.0
0.5
1.0
1.5
2.0
2.5
nonweighted
weighted
Russian; 87 classes

# Proportion of work done in Russian and Greek



# Conclusions

- Both Russian and Greek exhibit lower conditional entropy than expected from chance, regardless of inflection class granularity and type frequency weighting
  - consistent with Low Entropy Conjecture
- However, the extent to which type frequency and implicative structure do work differs
  - Implicative structure plays a greater role in Greek (regardless of granularity), despite Greek having fewer paradigm cells
  - The extent to which implicative structure and type frequency are redundant sources of information differs

# Ongoing work…

- Expanding this type of analysis to more languages
- Testing of the cognitive reality of implicative structure for speakers

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