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ASSESSING MORPHOLOGICAL PRODUCTIVITY IN A CORPUS LANGUAGE: A DIACHRONIC STUDY OF ANCIENT GREEK DEVERBAL NOMINAL SUFFIXES

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Roadmap

1. Introduction
2. Methodological Framework
3. Measuring the Productivity of Ancient Greek Deverbal Nominal Suffixes
   - Distribution and Relative Frequency Across Time
   - *P* Measure
   - *P** Measure
   - LNRE Models
   - Suffix Interaction and Resolution of Rivalry
4. Conclusion

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1. Introduction

Background & Research Gap

- **Ancient Greek Deverbal Nominal Domain**
- **Well-studied from an Indo-European perspective**
  - *e.g.*, Debrunner 1916, Chantraine 1933, Benveniste 1948, Risch 1974
  - ➢ Focus: morphophonology & cross-linguistic comparison

- **Recent developments**
  - *-mo- in diachronic/typological framework (Napoli 2009)
  - Synchronic nominalizations (Civilleri 2010)

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- **Recent developments**
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  - Synchronic nominalizations (Civilleri 2010)

- **No quantitative & diachronic analysis of morphological productivity**

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Background & Research Gap

- Most empirical research on productivity in derivational morphology has focused on modern languages, mainly due to the availability of large electronic corpora and computational tools

  - ✓ English (Baayen 1989, 1992, 1993, 2009)
  - ✓ German (Evert and Lüdeling 2001)
  - ✓ Italian (Gaeta and Ricca 2003, 2005, 2006, Varvara 2019, 2020)
  - ✓ **Old Italian** (Štichauer 2006), which introduced a diachronic dimension

Aims, Corpus & Data Extraction

- **Research Aims**

1. **Measure productivity** of six AG deverbal nominal suffixes in diachrony:
   - ✓ -*eía*, -*mos*/-*mós*, -*sia*, -*sis*, -*tis*, -*tus* + their allomorphes

   (Chantraine 1953: only suffixes whose function of creating abstract names from verbs is already recognized, and whose phonetic substance is clear)

2. Using **corpus-based statistical methods** (Baayen 1989 et seq.)
3. **Evaluate applicability** of modern productivity measures to **Ancient Greek**

Aims, Corpus & Data Extraction

- **Corpus (< *Thesaurus Linguae Graecae*)**

1. ~4 million tokens from 8th c. BC to 6th c. AD
2. Divided into 4 sub-corpora: Archaic, Classical, Hellenistic, Imperial
3. Balanced by token count and genres
4. Philological consistency: only texts with available critical editions, commentaries, and translations

Historical Period	*Archaic*	*Classic*	*Hellenistic*	*Imperial*
Token	277.876	1.231.944	1.158.453	1.288.522
Literary genres	3	5	6	5

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Aims, Corpus & Data Extraction

- **Data extraction**

  - ✓ Based on Liddell-Scott-Jones lexicon (Perseus)
  - ✓ Manual checking for relevant deverbal nouns, excluding:
    - POS ≠ Noun
    - Non-deverbal derived nouns
    - Compounds
    - Proper nouns
    - Borrowings
    - Baseless formations
  - ✓ **Final dataset**: 1905 types and 50,637 tokens

2. Methodological Framework

Define productivity

- **Theoretical definition**

  - Plag 2006: The productivity of a given affix refers to its **potential** to form new words and the **extent** to which this potential is actually realized in language use

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  ✓ Extent = quantitative feature

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✓ **Extent = quantitative feature**

OPERATIONALIZATION

Define productivity

- **Operative definition** (< corpus-based statistical methods)
  - Productivity is:

✓ Synchronic

✓ Linked to the number of **hapax legomena**, i.e., words with a frequency of 1 in a given corpus

Define productivity

- **Operative definition** (< corpus-based statistical methods)
  - Productivity is:
  - ✓ Synchronic
  - ✓ Linked to the number of hapax legomena, i.e., words with a frequency of 1 in a given corpus

- **Hapax legomenon** = approximation of neologism
  - o In large corpora: unfamiliar words indicate an ongoing word formation process
  - o Psycholinguistics view:
  - ➤ Speakers decompose rare words into known morphemes
  - o **Productive rules** → many rare/new forms
  - o **Unproductive rules** → few high-frequency, well-established words

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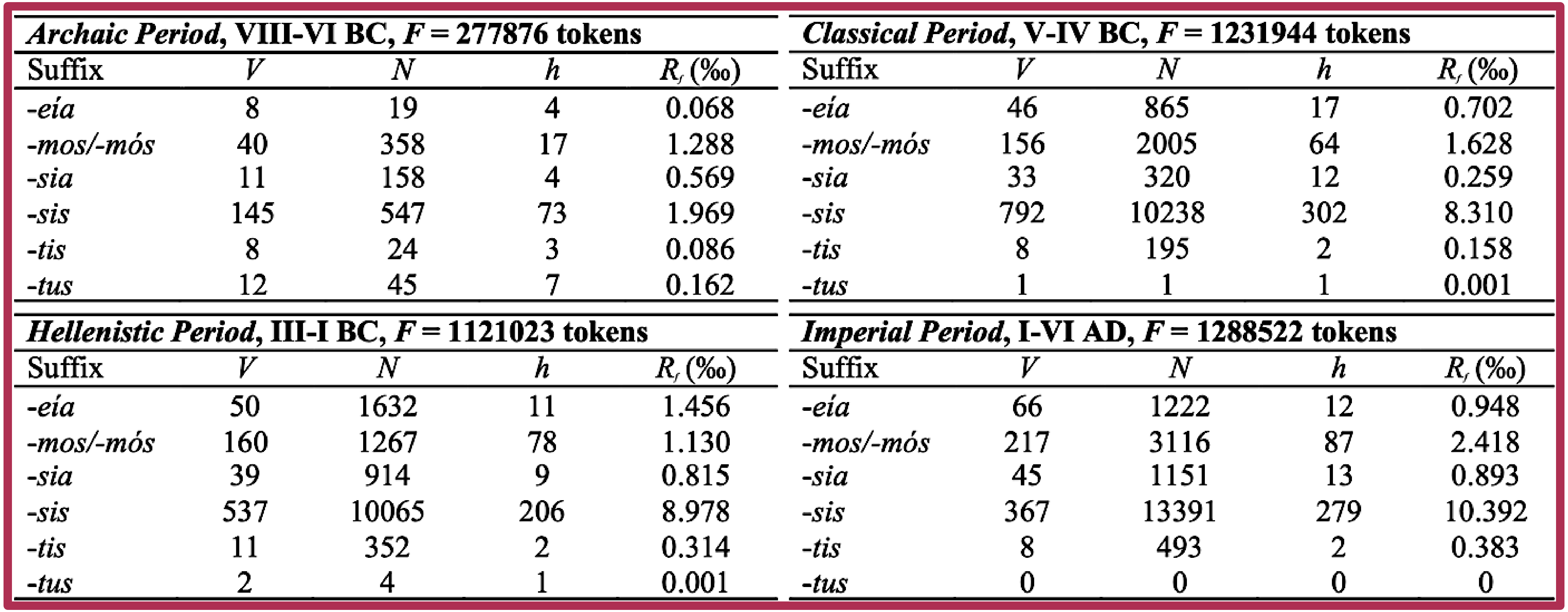
3. Measuring the Productivity of Ancient Greek Deverbal Nominal Suffixes

Distribution and Relative Frequency Across Time



Archaic Period, VIII-VI BC, *F* = 277876 tokens

Suffix	*V*	*N*	*h*	R_f (‰)
-eía	8	19	4	0.068
-mos/-mós	40	358	17	1.288
-sia	11	158	4	0.569
-sis	145	547	73	1.969
-tis	8	24	3	0.086
-tus	12	45	7	0.162

Classical Period, V-IV BC, *F* = 1231944 tokens

Suffix	*V*	*N*	*h*	R_f (‰)
-eía	46	865	17	0.702
-mos/-mós	156	2005	64	1.628
-sia	33	320	12	0.259
-sis	792	10238	302	8.310
-tis	8	195	2	0.158
-tus	1	1	1	0.001

Hellenistic Period, III-I BC, *F* = 1121023 tokens

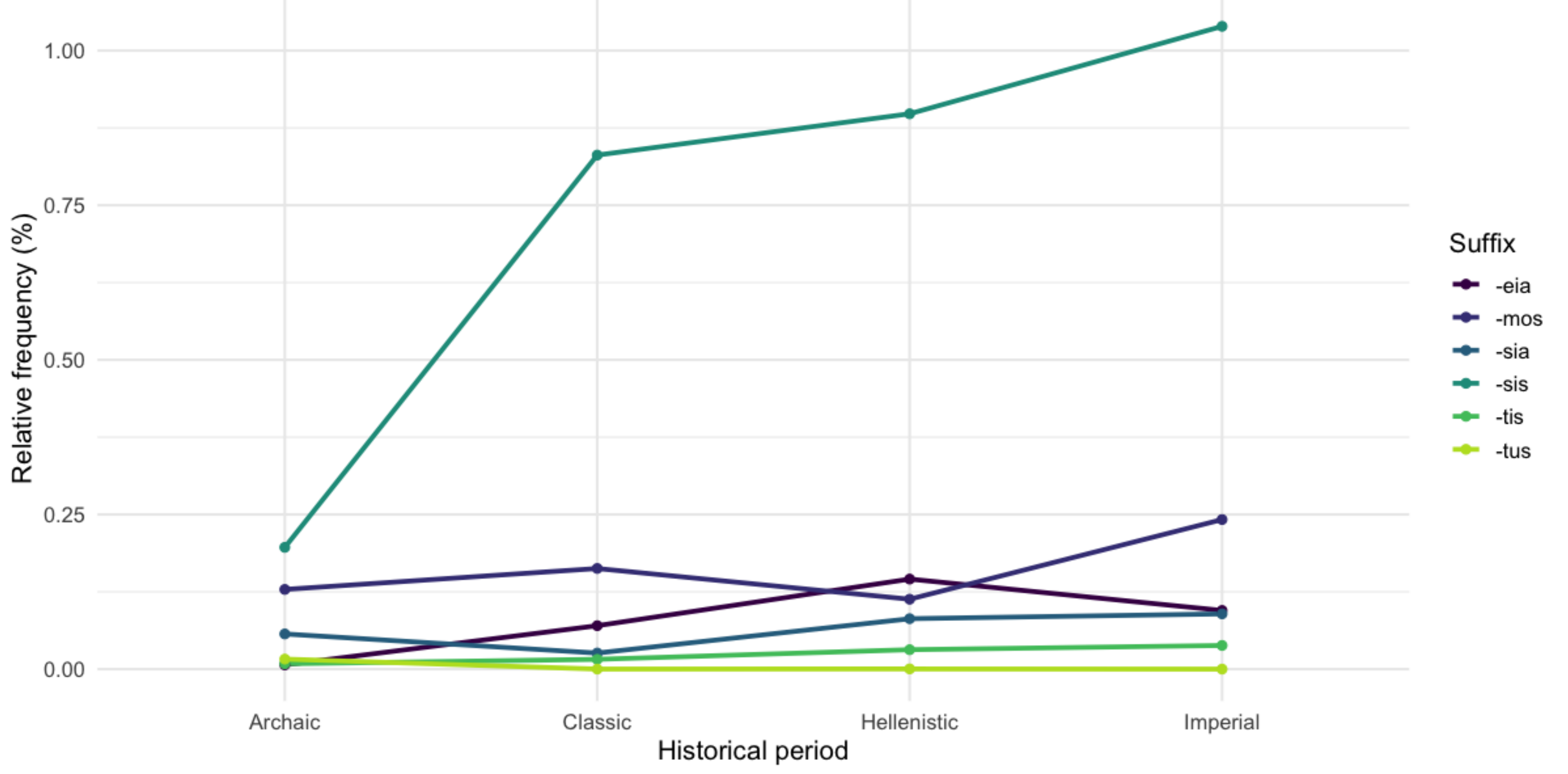
Suffix	*V*	*N*	*h*	R_f (‰)
-eía	50	1632	11	1.456
-mos/-mós	160	1267	78	1.130
-sia	39	914	9	0.815
-sis	537	10065	206	8.978
-tis	11	352	2	0.314
-tus	2	4	1	0.001

Imperial Period, I-VI AD, *F* = 1288522 tokens

Suffix	*V*	*N*	*h*	R_f (‰)
-eía	66	1222	12	0.948
-mos/-mós	217	3116	87	2.418
-sia	45	1151	13	0.893
-sis	367	13391	279	10.392
-tis	8	493	2	0.383
-tus	0	0	0	0

Distribution and Relative Frequency Across Time

- **Relative frequency trends** of suffixes across historical periods



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Distribution and Relative Frequency Across Time

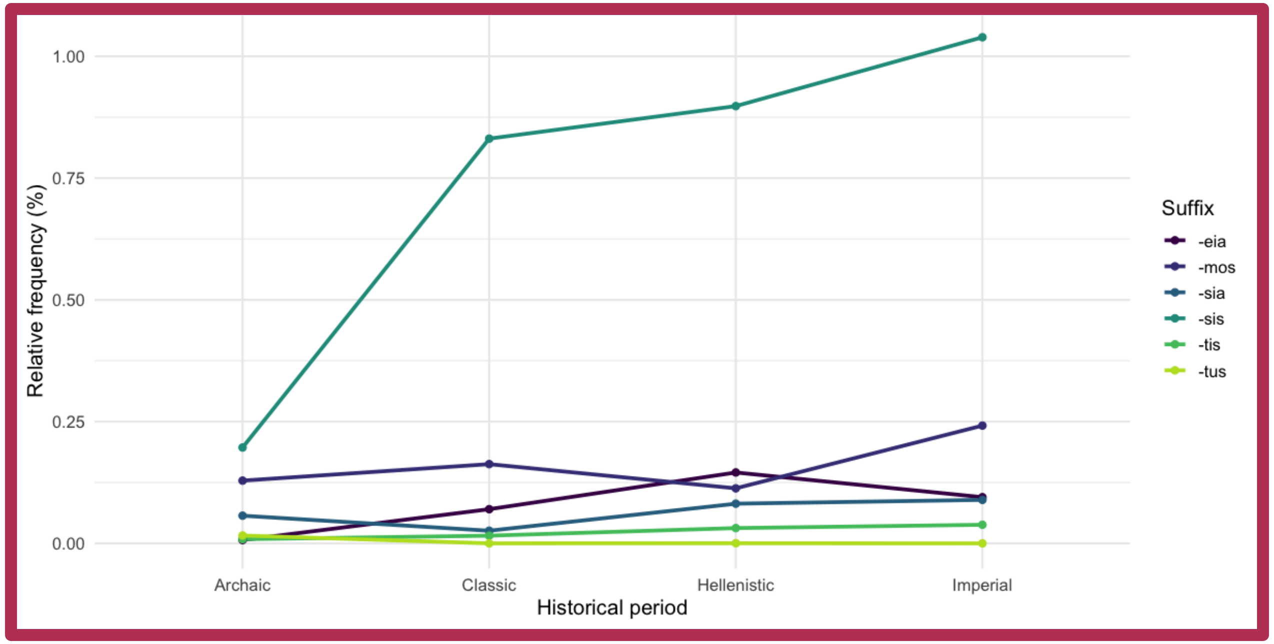
Chi-squared with simulated p-values (10,000 replicates)

➤ Result: $\boldsymbol{\chi^2}$ **= 3236.7, $\boldsymbol{p}$ = 9.999e-05**

➤ **Significant** association between **suffix type** and **period**

But weak effect size

→ Cramér's V = 0.149



P Measure

- ***P* (Potential Productivity, Baayen 2009)**
  - Formula: $P = h / N$
  - h = hapaxes with a given affix
  - N = total tokens with that affix

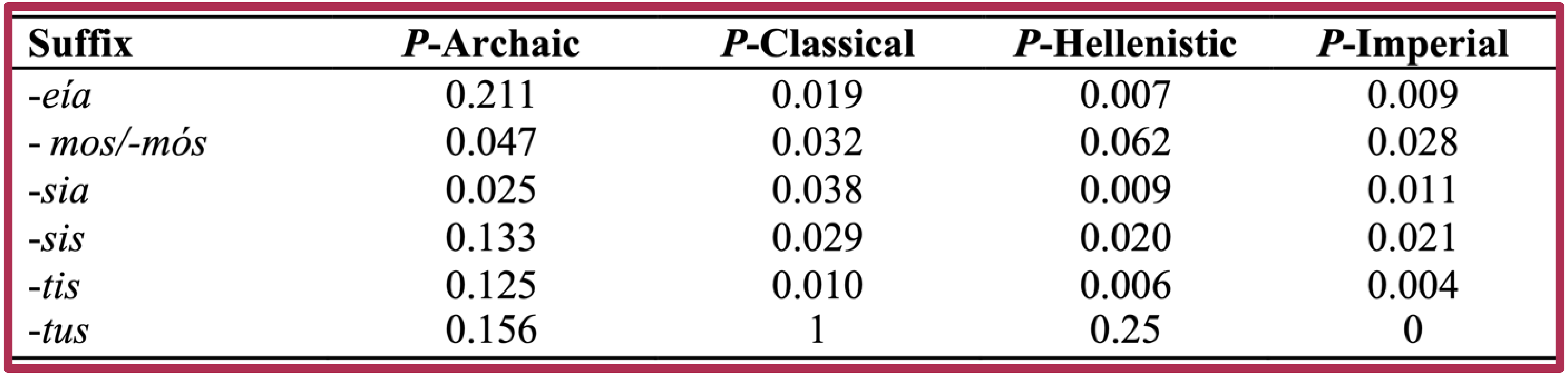
➤ Estimates the probability of encountering a new type after sampling N tokens with an affix

➤ Reflects the affix’s speed and capacity to expand its lexical inventory

- P is a decreasing function
- Approaches zero as N increases
- Overestimates rare suffixes
- Produces counterintuitive results when suffixes with very different token frequency are compared

P Measure in AG

- **Archaic phase → inflated *P* values due to small corpus size**
- -*tus* (rarest suffix) appears highly productive
- -*sis* (most frequent suffix) scores very low *P*, esp. in Classical & Hellenistic



Suffix	***P*-Archaic**	***P*-Classical**	***P*-Hellenistic**	***P*-Imperial**
-*eía*	0.211	0.019	0.007	0.009
- *mos*/-*mós*	0.047	0.032	0.062	0.028
-*sia*	0.025	0.038	0.009	0.011
-*sis*	0.133	0.029	0.020	0.021
-*tis*	0.125	0.010	0.006	0.004
-*tus*	0.156	1	0.25	0

*P** Measure

- ***P**** **(Expanding Productivity, Baayen 2009)**
  - Formula: *P* = h / H*
  - *h* = hapaxes with a given affix
  - *H* = total hapaxes in a corpus

➤ Enables comparisons across affixes

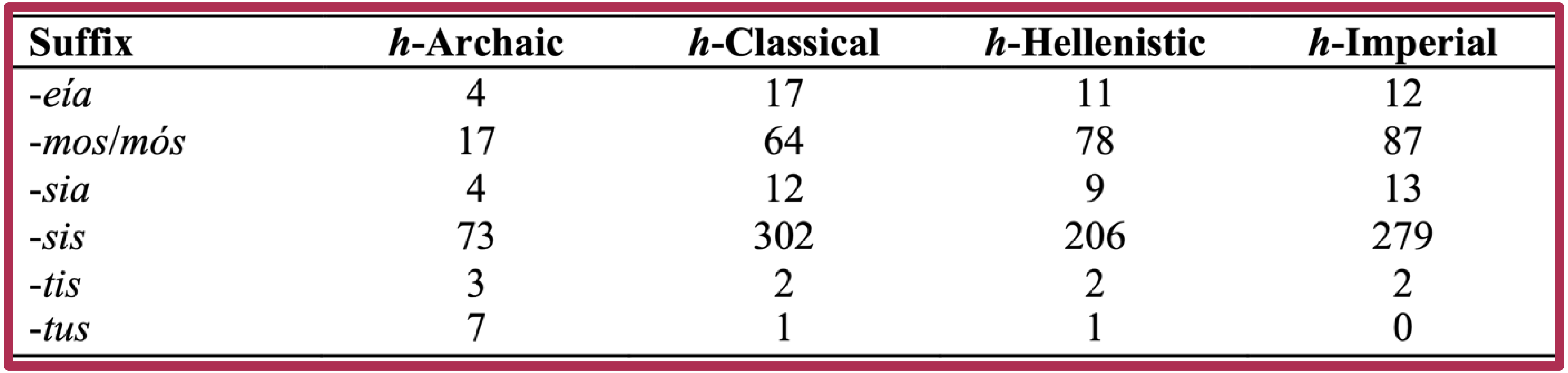
➤ Since *H* is constant, comparing *P** for the six suffixes is equivalent to directly compare the number of their hapaxes, regardless their total respective frequency

➤ **Conceptual critique**: reflects affix share of new words, not true productivity rate

I introduced the label P* for practical reasons

*P** Measure in AG

- -*sis* = most productive suffix across all periods → **core role in deverbal nominalization**
- -*mos/-mós* = **2nd most productive**, peaks in Hellenistic period (stylistic influence?)
- -*tus* = high in Archaic, then rapid decline, absent in Imperial era → **genre-specific use?**
- -*eía* & -*sia* = **low productivity overall**; -*sia* surpasses -*eía* only in Imperial phase (minor fluctuation not statistycally significant)
- -*tis* = **not productive** in any period



Suffix	*h*-Archaic	*h*-Classical	*h*-Hellenistic	*h*-Imperial
-*eía*	4	17	11	12
-*mos*/*mós*	17	64	78	87
-*sia*	4	12	9	13
-*sis*	73	302	206	279
-*tis*	3	2	2	2
-*tus*	7	1	1	0

LNRE Models

- P is negatively sensitive to token frequency variation across affixes
- P^* is less informative

- **Solution: LNRE Models (Large Number of Rare Events)**

➤ Predict hapax distribution beyond observed corpus size

➤ Estimate P for any N, even larger than observed

LNRE Models

Popular Models:

- **GIGP** (Generalized Inverse Gauss-Poisson)
- **fZM & ZM** (finite Zipf-Mandelbrot, Zipf-Mandelbrot)

  → (Implemented in zipfR - *R* package)

➤ Allow balanced comparisons across affixes with different frequencies

➤ Useful for ancient language corpora with uneven data distributions

LNRE models in AG

Model Used:

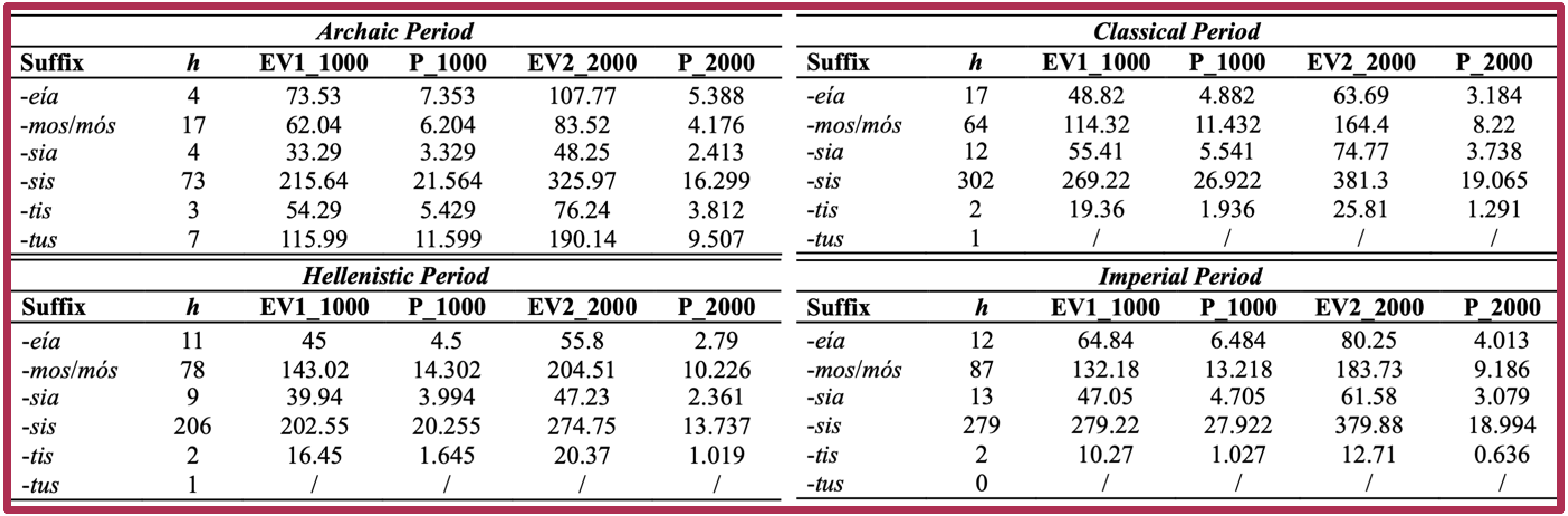
- **Zipf-Mandelbrot (ZM)**

➤ More reliable with small samples than fZM or GIGP (Evert & Baroni 2006)

➤ Based on observed frequency distributions estimates:

- Expected hapaxes for N = 1000 and N = 2000
- Corresponding productivity values: P_{1000}, P_{2000}

LNRE models in AG

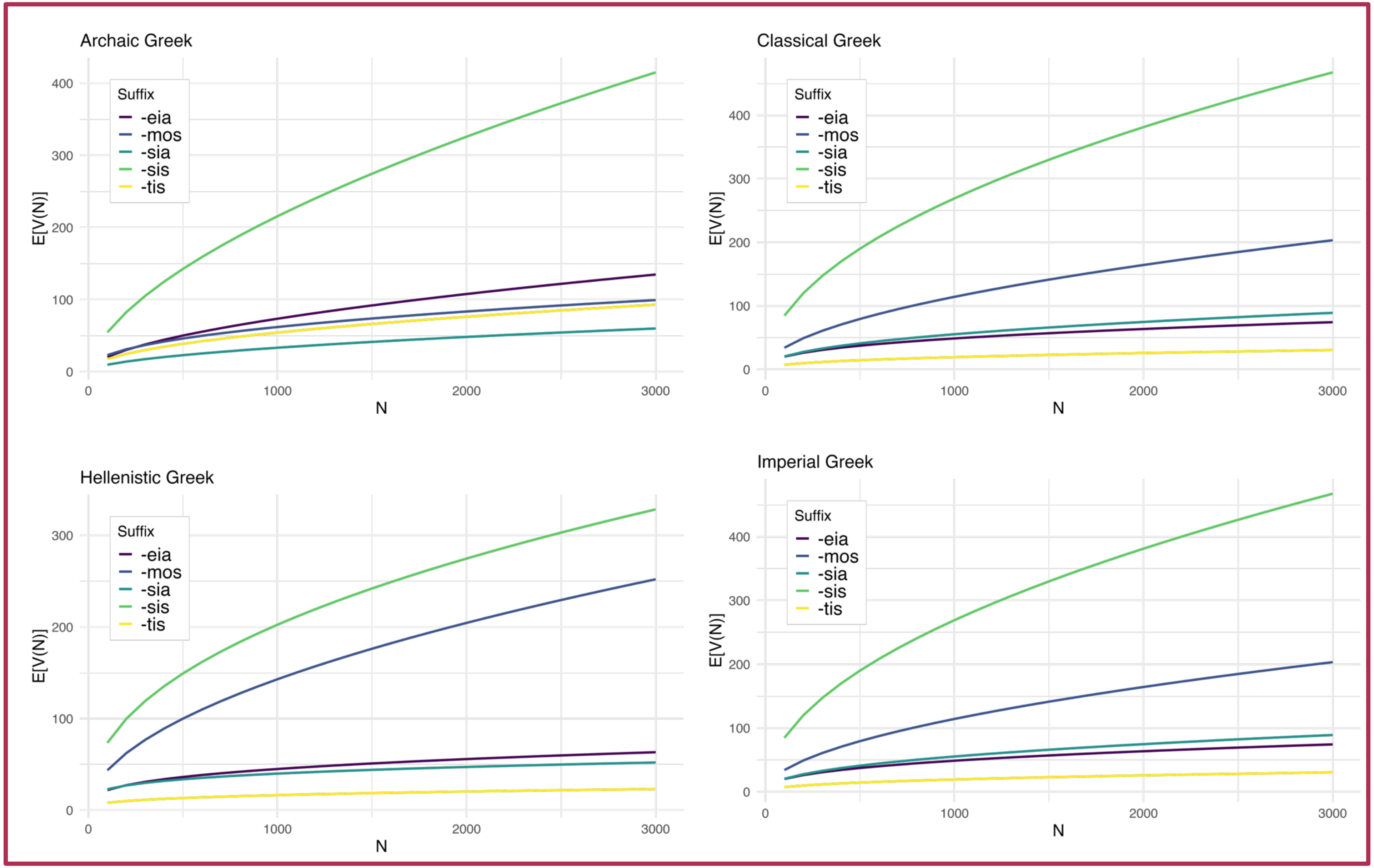


		Archaic Period			
Suffix	***h***	**EV1_1000**	**P_1000**	**EV2_2000**	**P_2000**
-eía	4	73.53	7.353	107.77	5.388
-mos/mós	17	62.04	6.204	83.52	4.176
-sia	4	33.29	3.329	48.25	2.413
-sis	73	215.64	21.564	325.97	16.299
-tis	3	54.29	5.429	76.24	3.812
-tus	7	115.99	11.599	190.14	9.507

		Classical Period			
Suffix	***h***	**EV1_1000**	**P_1000**	**EV2_2000**	**P_2000**
-eía	17	48.82	4.882	63.69	3.184
-mos/mós	64	114.32	11.432	164.4	8.22
-sia	12	55.41	5.541	74.77	3.738
-sis	302	269.22	26.922	381.3	19.065
-tis	2	19.36	1.936	25.81	1.291
-tus	1	/	/	/	/

		Hellenistic Period			
Suffix	***h***	**EV1_1000**	**P_1000**	**EV2_2000**	**P_2000**
-eía	11	45	4.5	55.8	2.79
-mos/mós	78	143.02	14.302	204.51	10.226
-sia	9	39.94	3.994	47.23	2.361
-sis	206	202.55	20.255	274.75	13.737
-tis	2	16.45	1.645	20.37	1.019
-tus	1	/	/	/	/

		Imperial Period			
Suffix	***h***	**EV1_1000**	**P_1000**	**EV2_2000**	**P_2000**
-eía	12	64.84	6.484	80.25	4.013
-mos/mós	87	132.18	13.218	183.73	9.186
-sia	13	47.05	4.705	61.58	3.079
-sis	279	279.22	27.922	379.88	18.994
-tis	2	10.27	1.027	12.71	0.636
-tus	0	/	/	/	/



Archaic Greek

Classical Greek

Hellenistic Greek

Imperial Greek

Suffix Interaction and Resolution of Rivalry

Goal: Explore possible competition among AG deverbal nominal suffixes

Motivation:

➤ Hypotheses in literature suggest morphological rivalry

➤ Notably: Chantraine (1933) proposes a competitive link between:

-sis ↔ *-mos/-mós*

-sis ↔ *-sia*

➤ Use quantitative data to test these claims and uncover new patterns of competition within the suffix system

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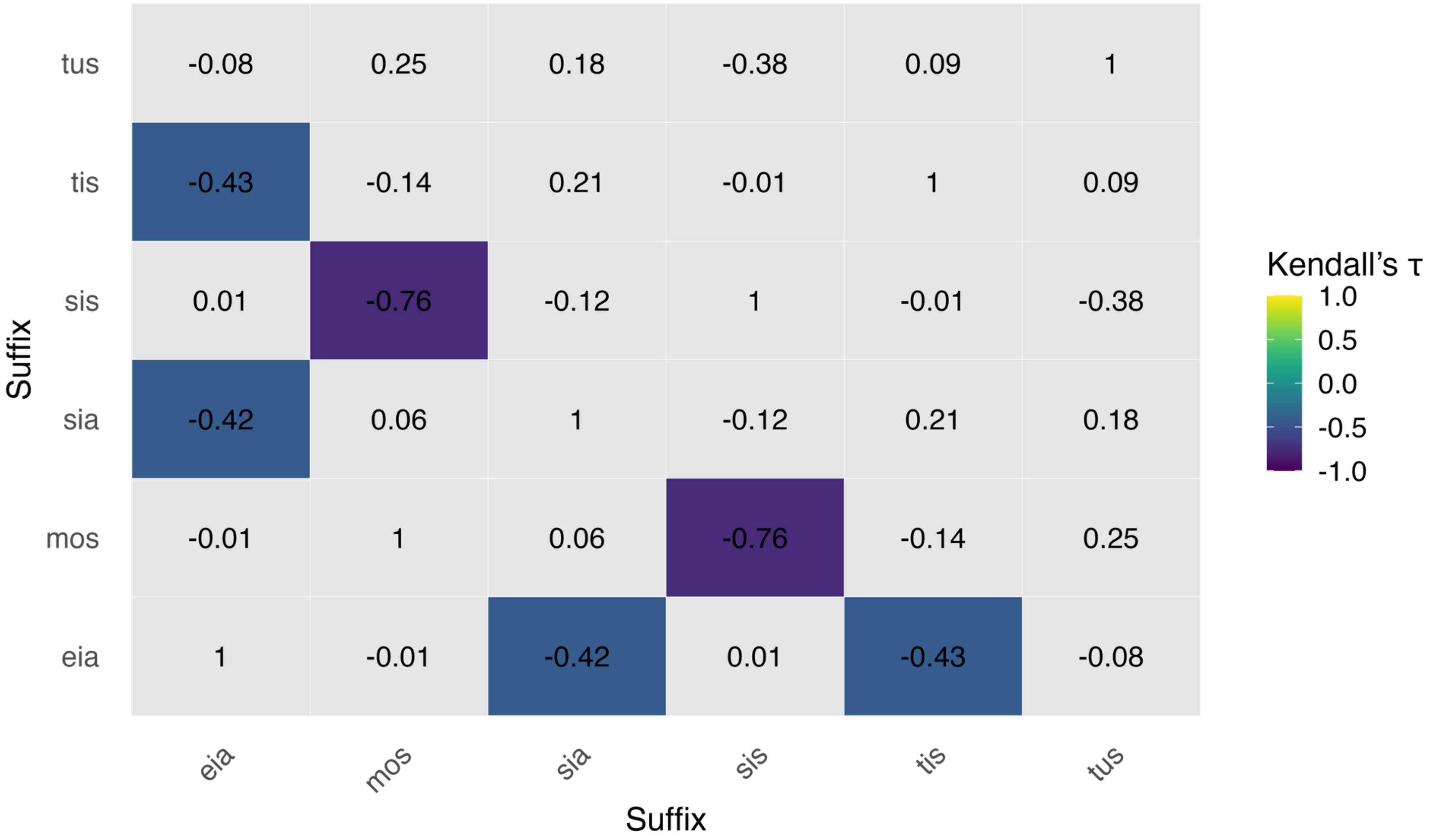
Suffix Interaction and Resolution of Rivalry (Kendall’s Tau correlation)

Suffix Interaction and Resolution of Rivalry

-sis* vs *-mos/-mós
→ strong negative correlation (*p = 5.34e-06*)



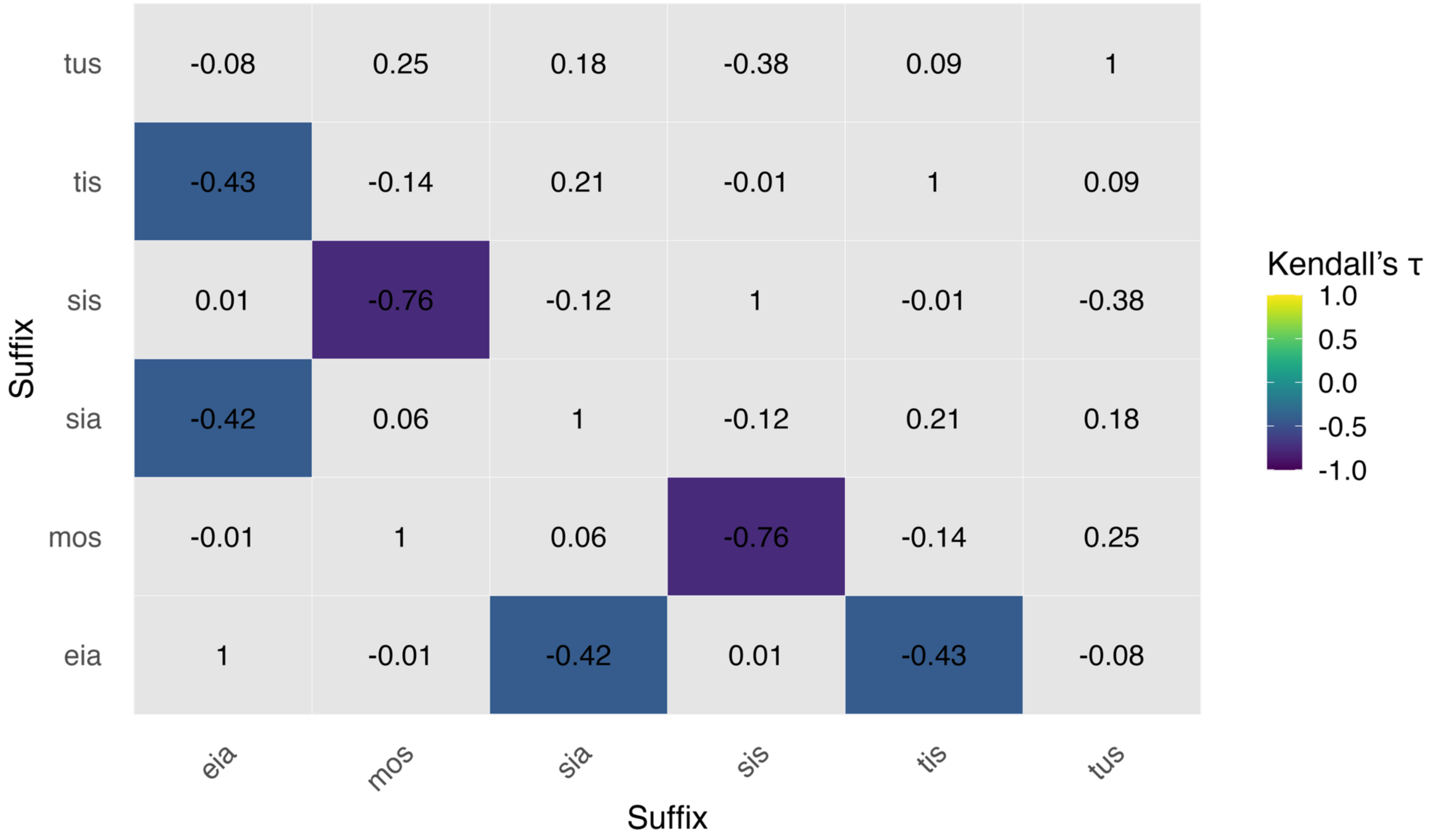
Suffix	eia	mos	sia	sis	tis	tus
tus	-0.08	0.25	0.18	-0.38	0.09	1
tis	-0.43	-0.14	0.21	-0.01	1	0.09
sis	0.01	-0.76	-0.12	1	-0.01	-0.38
sia	-0.42	0.06	1	-0.12	0.21	0.18
mos	-0.01	1	0.06	-0.76	-0.14	0.25
eia	1	-0.01	-0.42	0.01	-0.43	-0.08

Suffix Interaction and Resolution of Rivalry

×

-sia* vs *-sis

p = 4.84e-01



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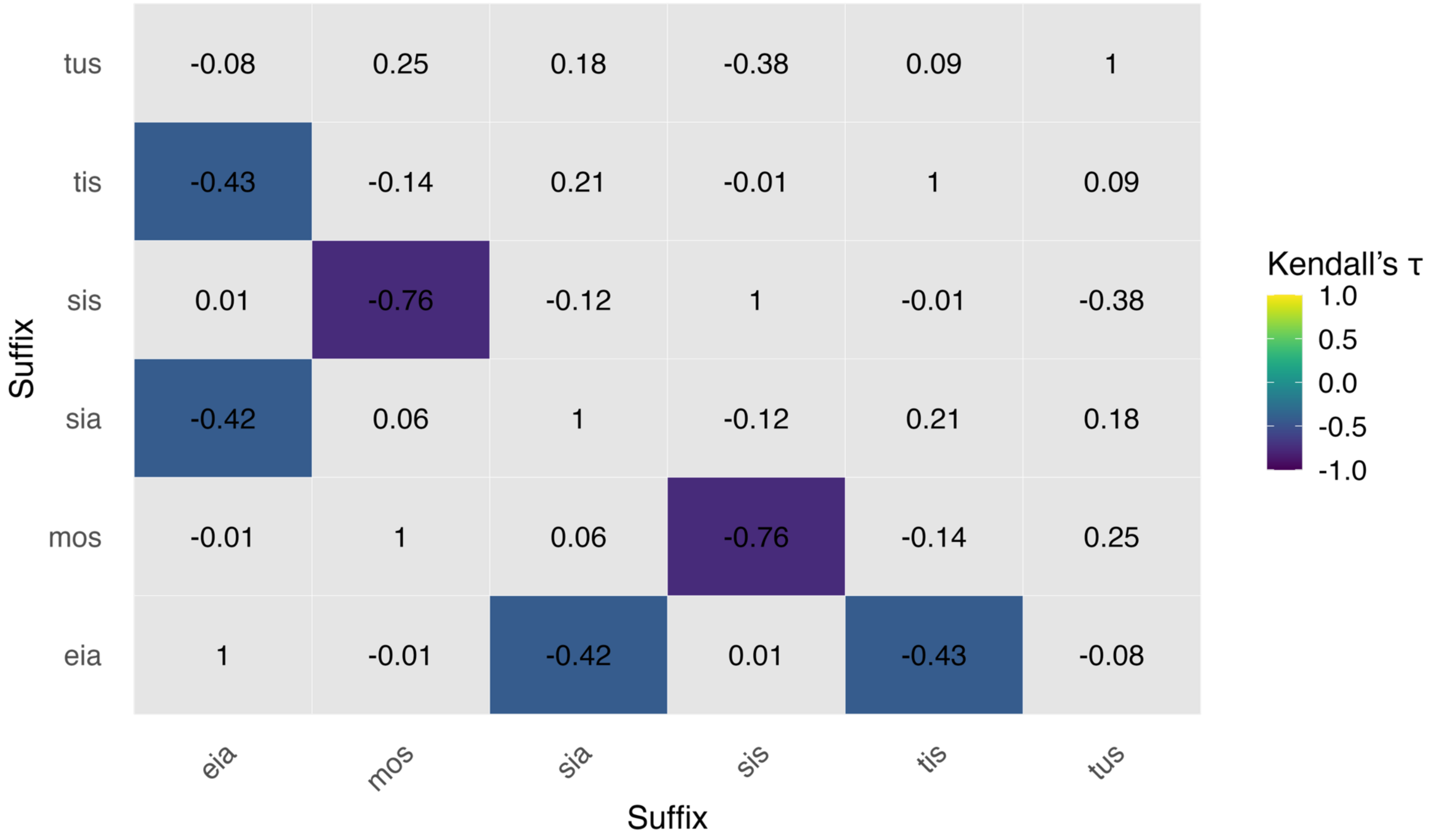
Suffix Interaction and Resolution of Rivalry

-sia* vs *-eía
→ moderate negative correlation (p = 0.0116)



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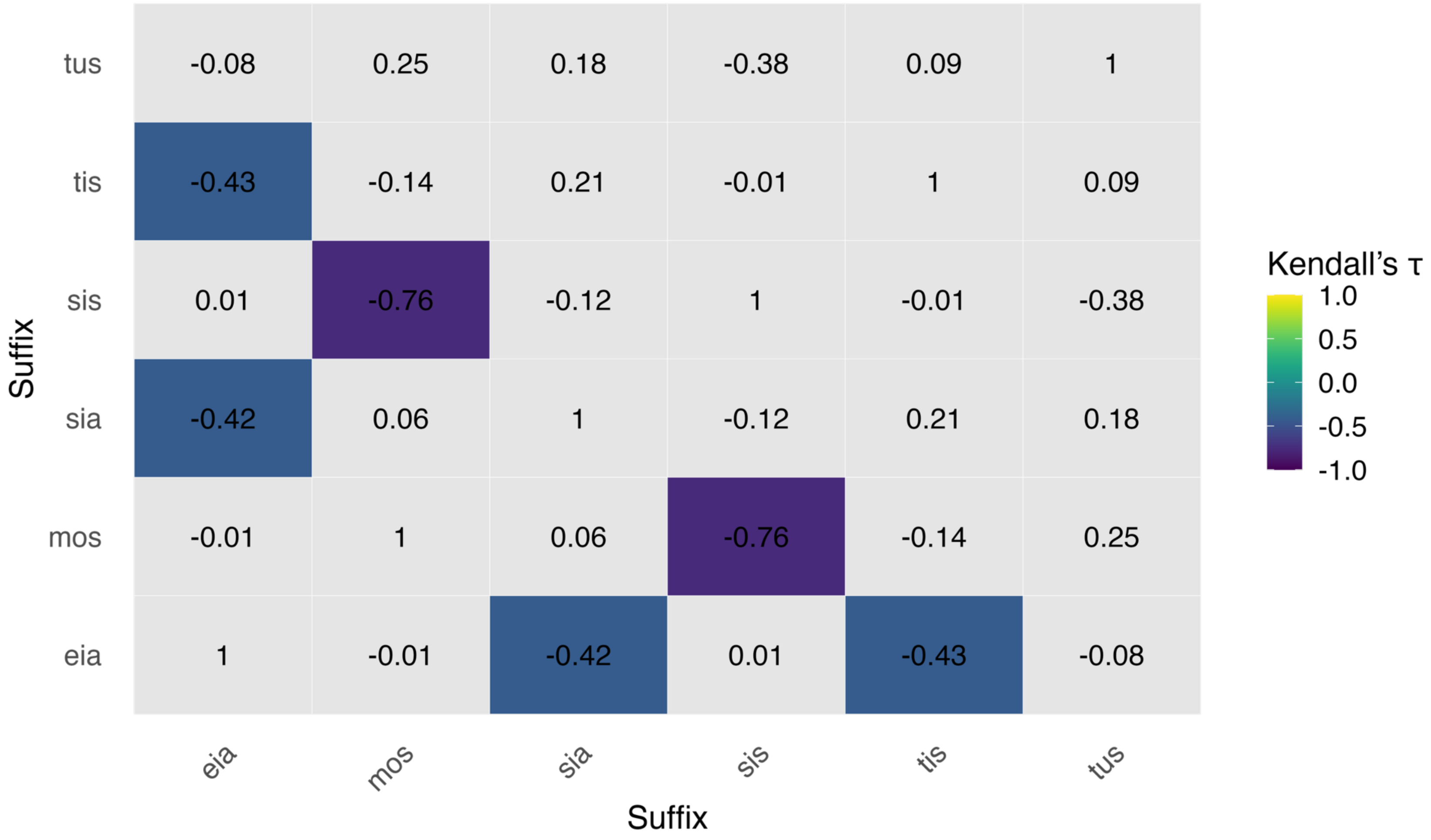
mos	-0.01	1	0.06	-0.76	-0.14	0.25
eia	1	-0.01	-0.42	0.01	-0.43	-0.08

Suffix Interaction and Resolution of Rivalry

-eía **vs** ***-tis***
→ weak negative correlation (*p* = 0.0138)



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Suffix Interaction and Resolution of Rivalry

- …–*sia* and –*sis*: Chantraine was wrong?
- Negative correlations suggest **resolved** past competition
  - Functional specialization
  - Genre-specific preferences
  - Suffix decline
- **Correlations reflect outcomes**, not active competition
- Further qualitative analysis needed to explore:
  - Genre-specific uses
  - Functional overlap or specialization
  - Possible **overabundance** patterns

4. Conclusions

Conclusions: Results

1. Methodological Contribution:

- First quantitative and diachronic study of the deverbal nominal domain in AG
- I applied:
  - ➤ *P* (Potential Productivity)
  - ➤ *P** (Expanding Productivity)
  - ➤ ZM Model (LNRE)

Conclusions: Results

2. Key Findings:

- -*sis* = most productive suffix across all periods
- -*mos*/*mós* = productive, esp. in Hellenistic period
- -*eía* and -*sia* = limited, unstable productivity
- -*tis* and -*tus* = non-productive (esp. -*tus*, limited to archaic epic)

Conclusions: Results

3. Suffix Competition:

- Significant negative correlations suggest resolved rivalry
  - ✓ *-sis* vs *-mos/mós*
  - ✓ *-sia* vs *-eía*
  - ✓ *-eía* vs *-tis*

No correlation ≠ no rivalry

Conclusions: Challenges

- **Challenges in Quantifying Morphological Productivity in Ancient Greek**

1. Data Sparsity and Imbalance
2. Structural Inhomogeneity of Diachronic Corpora
3. Limitations of automatic POS-tagging in Ancient Greek

Conclusions: Challenges

1. **Data Sparsity and Imbalance**

- **The corpus size negatively influences the metrics**
  - Ancient Greek corpora are limited in size, especially in early periods like the Archaic era
  - This leads to inflated productivity estimates for rare suffixes and underrepresentation of more common ones
  - Uneven suffix frequency across periods can distort quantitative results (e.g., high *P* for rare -*tus*, low *P* for frequent -*sis*)

Conclusions: Challenges

2. **Structural Inhomogeneity of Diachronic Corpora (cf. Štichauer 2006)**

- The corpus includes texts of diverse genres and authorship, unevenly distributed over time

- Some genres are absent in certain periods (e.g., historiography in the Archaic phase), which biases affix visibility

- Repetition effects from single authors can skew data – e.g., a coined form may appear multiple times within one work but not elsewhere
  → **LOSING OF A NEW COINAGE**

Conclusions: Challenges

3. Errors in Automatic PoS-tagging

- Automatic annotation can misclassify homographic forms (e.g., *amúxeis* as a noun or verb)

- This introduces noise into suffix frequency counts

- **Solution**: manual review of a representative sample to estimate and minimize error rate
  → **CURRENTLY IN PROGRESS**

Future Directions and Methodological Considerations

1. Integrated Approach to Productivity

- No single measure (*P*, *P**, or LNRE) is sufficient alone
- Combined use of multiple metrics offers a more reliable view, especially when results converge (e.g., ZM and P*)
- Requires **critical interpretation** informed by frequency distribution and corpus structure

Future Directions and Methodological Considerations

2. Suffix Usage by Literary Genre

- Currently analyzing suffix productivity across literary genres

- **Goal**: determine whether shifts in productivity reflect genuine morphological trends or stylistic preferences

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Future Directions and Methodological Considerations

3. Qualitative Exploration of Morphological Rivalry

- **Beyond correlation**

✓ Assess functional overlap, semantic nuances, and genre constraints

✓ Investigate cases of overabundance (multiple suffixes coexisting for the same function) and polyfunctionality

→ **CURRENTLY IN PROGRESS**

THANK YOU FOR YOUR ATTENTION ☺

(And special thanks to Richard Huyghe, who taught me most of this)

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