Derivation predicting inflection
The role of families, series and morphotactics

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19th International Morphology Meeting - Vienna, February 6-9 2020

Outline

1. Introduction
2. The impact of derivational information on the predictability of inflected wordforms
3. Predicting Inflection Classes: the role of derivational families and processes
4. Theoretical issues
5. Conclusions and future work

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Predictability in inflection

Recent research focusing on predictability in inflectional systems:

- set-theoretic approach: Principal Parts – set of inflected wordforms from which the whole paradigm of a lexeme can be inferred with no uncertainty (Stump & Finkel, 2013);
- information-theoretic approach: use of conditional entropy to measure the uncertainty in predicting one cell from another one.

Ackerman et al. (2009): Paradigm Cell Filling Problem (PCFP)

"What licenses reliable inferences about the inflected (and derived) surface forms of a lexical item?"

Inflectional predictability and derivation

- Inherent properties of a lexeme can be informative on its inflectional behaviour:
  - stem phonology (Guzmán Naranjo, 2019);
  - lexical semantics (Guzmán Naranjo, 2019);
  - gender (Stump & Finkel, 2013; Pellegrini, forthcoming).
- Another aspect that can be informative is the **derivational history** of a lexeme:
  - in some cases, the inflectional behaviour of a lexeme is determined by the derivational process by which it is formed (Bonami & Boyé, 2006);
  - in other cases, a lexeme inherits (at least partly) the inflectional behaviour of the base from which it derives (Stump 2001).
    → The aim of our talk is exploring the interplay between these two possibilities through a quantitative analysis of large lexica

Data

- We focus on Latin verb and noun paradigms

- Source of inflectional data:

  LatInfLexi (Pellegrini & Passarotti, 2018)

  - inflected lexicon containing 3348 verbs, 1048 nouns
  - obtained semi-automatically from the database of Lemlat 3.0 (Passarotti et al., 2018)

- Source of derivational information:

  Word Formation Latin (WFL) database (Litta et al., 2016)

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INFLECTIONAL PREDICTIONS WITHOUT DERIVATIONAL INFO

The uncertainty in guessing the content of a paradigm cell given knowledge of another form can be measured using **conditional entropy** (cf. Bonami & Boyé, 2014; Beniamine, 2018)

A toy example with Latin data: how difficult is it to predict PRS.ACT.IND.3SG knowing PRS.ACT.IND.1SG?

lexeme (meaning)	PRS.ACT.IND.1SG	PRS.ACT.IND.3SG	**pattern/context**
'to dedicate'	*dicō*	*dicat*	Xō-Xat / C_#
'to take a little'	*lībō*	*lībat*	Xō-Xat / C_#
'to fold'	*plicō*	*plicat*	Xō-Xat / C_#
'to fold back'	*replicō*	*replicat*	Xō-Xat / C_#
'to unfold'	*explicō*	*explicat*	Xō-Xat / C_#
'to say'	*dīco*	*dīcit*	Xō-Xit / C_#
'to drink'	*bibō*	*bibit*	Xō-Xit / C_#
'to write'	*scrībō*	*scrībit*	Xō-Xit / C_#
'to write in'	*inscrībō*	*inscrībit*	Xō-Xit / C_#
'to write together'	*conscrībō*	*conscrībit*	Xō-Xit / C_#

$$H = -\left[\left(\frac{5}{10}\cdot\log_2\frac{5}{10}\right)+\left(\frac{5}{10}\cdot\log_2\frac{5}{10}\right)\right] = 1 \text{ bit}$$

INFLECTIONAL PREDICTIONS WITHOUT DERIVATIONAL INFO

Assumption: speakers <u>do not have</u> any <u>information</u> on **derivational relatedness**

lexeme (meaning)	**PRS.ACT.IND.1SG**	**PRS.ACT.IND.3SG**	**pattern/context**
'to dedicate'	*dicō*	*dicat*	Xō-Xat / C_#
'to take a little'	*lībō*	*lībat*	Xō-Xat / C_#
'to fold'	*plicō*	*plicat*	Xō-Xat / C_#
'to fold back'	*replicō*	*replicat*	Xō-Xat / C_#
'to unfold'	*explicō*	*explicat*	Xō-Xat / C_#
'to say'	*dīco*	*dīcit*	Xō-Xit / C_#
'to drink'	*bibō*	*bibit*	Xō-Xit / C_#
'to write'	*scrībō*	*scrībit*	Xō-Xit / C_#
'to write in'	*inscrībō*	*inscrībit*	Xō-Xit / C_#
'to write together'	*conscrībō*	*conscrībit*	Xō-Xit / C_#
'to write back'	*rescrībō*	?	P(Xō-Xat)=5/10 P(Xō-Xit)=5/10
'to call'	*vocō*	?	P(Xō-Xat)=5/10 P(Xō-Xit)=5/10

INFLECTIONAL PREDICTIONS WITHOUT DERIVATIONAL INFO

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lexeme (meaning)	**PRS.ACT.IND.1SG**	**PRS.ACT.IND.3SG**	**pattern/context**
'to dedicate'	*dicō*	*dicat*	Xō-Xat / C_#
'to take a little'	*lībō*	*lībat*	Xō-Xat / C_#
'to fold'	*plicō*	*plicat*	Xō-Xat / C_#
'to fold back'	*replicō*	*replicat*	Xō-Xat / C_#
'to unfold'	*explicō*	*explicat*	Xō-Xat / C_#
'to say'	*dīco*	*dīcit*	Xō-Xit / C_#
'to drink'	*bibō*	*bibit*	Xō-Xit / C_#
'to write'	*scrībō*	*scrībit*	Xō-Xit / C_#
'to write in'	*inscrībō*	*inscrībit*	Xō-Xit / C_#
'to write together'	*conscrībō*	*conscrībit*	Xō-Xit / C_#
'to write back'	*rescrībō*	?	P(Xō-Xat)=5/5 P(Xō-Xit)=5/5
'to call'	*vocō*	?	P(Xō-Xat)=5/5 P(Xō-Xit)=5/5

INFLECTIONAL PREDICTIONS WITH DERIVATIONAL INFO

Assumption: speakers do have information on **derivational relatedness**: lexemes that derive from the **same base**

lexeme (meaning)	**PRS.ACT.IND.1SG**	**PRS.ACT.IND.3SG**	**derivational info**	**pattern/context**
'to dedicate'	*dicō*	*dicat*	underived	Xō-Xat / C_#
'to take a little'	*lībō*	*lībat*	underived	Xō-Xat / C_#
'to fold'	*plicō*	*plicat*	underived	Xō-Xat / C_#
'to fold back'	*replicō*	*replicat*	< *plico*	Xō-Xat / C_#
'to unfold'	*explicō*	*explicat*	< *plico*	Xō-Xat / C_#
'to say'	*dīco*	*dīcit*	underived	Xō-Xit / C_#
'to drink'	*bibō*	*bibit*	underived	Xō-Xit / C_#
'to write'	*scrībō*	*scrībit*	underived	Xō-Xit / C_#
'to write in'	*inscrībō*	*inscrībit*	< *scribo*	Xō-Xit / C_#
'to write together'	*conscrībō*	*conscrībit*	< *scribo*	Xō-Xit / C_#
'to write back'	*rescrībō*	?	< *scribo*	P(Xō-Xat)=0 P(Xō-Xit)=2/2
'to call'	*vocō*	?	underived	P(Xō-Xat)=3/6 P(Xō-Xit)=3/6

INFLECTIONAL PREDICTIONS WITH DERIVATIONAL INFO

Assumption: speakers do have information on **derivational relatedness**: lexemes that derive from the **same base**

lexeme (meaning)	**PRS.ACT.IND.1SG**	**PRS.ACT.IND.3SG**	**derivational info**	**pattern/context**
'to dedicate'	*dicō*	*dicat*	underived	Xō-Xat / C_#
'to take a little'	*lībō*	*lībat*	underived	Xō-Xat / C_#
'to fold'	*plicō*	*plicat*	underived	Xō-Xat / C_#
'to fold back'	*replicō*	*replicat*	< *plico*	Xō-Xat / C_#
'to unfold'	*explicō*	*explicat*	< *plico*	Xō-Xat / C_#
'to say'	*dīco*	*dīcit*	underived	Xō-Xit / C_#
'to drink'	*bibō*	*bibit*	underived	Xō-Xit / C_#
'to write'	*scrībō*	*scrībit*	underived	Xō-Xit / C_#
'to write in'	*inscrībō*	*inscrībit*	< *scribo*	Xō-Xit / C_#
'to write together'	*conscrībō*	*conscrībit*	< *scribo*	Xō-Xit / C_#
'to write back'	*rescrībō*	?	< *scribo*	P(Xo-Xat)=0 P(Xo-Xit)=2/2
'to call'	*vocō*	?	underived	P(Xo-Xat)=3/6 P(Xo-Xit)=3/6

underived:

$$H = -\left[\left(\frac{3}{6}\cdot\log_2\frac{3}{6}\right)+\left(\frac{3}{6}\cdot\log_2\frac{3}{6}\right)\right] = 1 \text{ bit}$$

< *plico*:

$$H = -\left(\frac{2}{2}\cdot\log_2\frac{2}{2}\right) = 0 \text{ bit}$$

< *scribo*:

$$H = -\left(\frac{2}{2}\cdot\log_2\frac{2}{2}\right) = 0 \text{ bit}$$

$$\mathbf{H} = \left[\left(\frac{6}{10}\cdot 1\right)+\left(\frac{4}{10}\cdot 0\right)\right] = \mathbf{0.6 \text{ bit}}$$

INFLECTIONAL PREDICTIONS WITH DERIVATIONAL INFO

Assumption: speakers do have information on **derivational relatedness**: lexemes that are formed by means of the **same suffix**

lexeme (meaning)	**PRS.ACT.IND.1SG**	**PRS.ACT.IND.3SG**	**derivational info**	**pattern/context**
'to dedicate'	*dicō*	*dicat*	underived	Xō-Xat / C_#
'to take a little'	*līcō*	*līcat*	underived	Xō-Xat / C_#
'to rattle much'	*crepitō*	*crepitat*	suffix *-it-*	Xō-Xat / C_#
'to cry out aloud'	*clāmitō*	*clāmitat*	suffix *-it-*	Xō-Xat / C_#
'to flee eagerly'	*fugitō*	*fugitat*	suffix *-it-*	Xō-Xat / C_#
'to say'	*dīco*	*dīcit*	underived	Xō-Xit / C_#
'to drink'	*bibō*	*bibit*	underived	Xō-Xit / C_#
'to grow red'	*rubēscō*	*rubēscit*	suffix *-sc-*	Xō-Xit / C_#
'to become ill'	*aegrēscō*	*aegrēscit*	suffix *-sc-*	Xō-Xit / C_#
'to become white'	*albēscō*	*albēscit*	suffix *-sc-*	Xō-Xit / C_#
'to seek earnestly'	*quaeritō*	?	suffix *-it-*	P(Xō-Xat)=3/3 P(Xō-Xit)=0
'to call'	*vocō*	?	underived	P(Xō-Xat)=2/4 P(Xō-Xit)=2/4

INFLECTIONAL PREDICTIONS WITH DERIVATIONAL INFO

Assumption: speakers do have information on **derivational relatedness**: lexemes that are formed by means of the **same suffix**

lexeme (meaning)	PRS.ACT.IND.1SG	PRS.ACT.IND.3SG	**derivational info**	**pattern/context**
'to dedicate'	*dicō*	*dicat*	underived	Xō-Xat / C_#
'to take a little'	*lībō*	*lībat*	underived	Xō-Xat / C_#
'to rattle much'	*crepitō*	*crepitat*	suffix *-it-*	Xō-Xat / C_#
'to cry out aloud'	*clāmitō*	*clāmitat*	suffix *-it-*	Xō-Xat / C_#
'to flee eagerly'	*fugitō*	*fugitat*	suffix *-it-*	Xō-Xat / C_#
'to say'	*dīco*	*dīcit*	underived	Xō-Xit / C_#
'to drink'	*bibō*	*bibit*	underived	Xō-Xit / C_#
'to grow red'	*rubēscō*	*rubēscit*	suffix *-sc-*	Xō-Xit / C_#
'to become ill'	*aegrēscō*	*aegrēscit*	suffix *-sc-*	Xō-Xit / C_#
'to become white'	*albēscō*	*albēscit*	suffix *-sc-*	Xō-Xit / C_#
'to seek earnestly'	*quaeritō*	?	suffix *-it-*	P(Xō-Xat)=0 P(Xō-Xit)=3/3
'to call'	*vocō*	?	underived	P(Xō-Xat)=2/4 P(Xō-Xit)=2/4

underived:

$$H = -\left[\left(\frac{2}{4}\cdot\log_2\frac{2}{4}\right)+\left(\frac{2}{4}\cdot\log_2\frac{2}{4}\right)\right] = 1 \text{ bit}$$

suffix *-it-*:

$$H = -\left(\frac{3}{3}\cdot\log_2\frac{3}{3}\right) = 0 \text{ bit}$$

suffix *-sc-*:

$$H = -\left(\frac{3}{3}\cdot\log_2\frac{3}{3}\right) = 0 \text{ bit}$$

$$\mathbf{H} = \left[\left(\frac{4}{10}\cdot 1\right)+\left(\frac{6}{10}\cdot 0\right)\right] = \mathbf{0.4\ bit}$$

Results

➢ What is the impact of such facts on real data?

→ To answer this question, we compare **average implicative entropy** – i.e., the conditional entropy of guessing cell A from cell B, averaged across all pairs of cells – with and without different pieces of derivational information

➢ Classification of the **verbs** of LatInfLexi according to their **ancestor** – i.e., the base from which they ultimately derive

H(A|B, ancestor)	0.08
H(A|B)	0.28

➢ Classification of the **nouns** of LatInfLexi according to the derivational **suffix** they

H(A|B, suffix)	0.31
H(A|B)	0.36

(computations performed using Qumin (Beniamine, 2018))

The inflectional behaviour of derived lexemes

➢ Verbs that derive from the same base usually inflect alike:

lexeme (meaning)	**derivational info**	**PRS.ACT.IND.1SG**	**PRS.ACT.INF**	**PRF.ACT.IND.1SG**	**SUP.ACC**
DICO (‘to say’)	underived	*dīcō*	*dīcere*	*dīxī*	*dīctum*
EDICO (‘to declare’)	< *dico*	*ēdīcō*	*ēdīcere*	*ēdīxī*	*ēdīctum*
MALEDICO (‘to curse’)	< *dico*	*maledīcō*	*maledīcere*	*maledīxī*	*maledīctum*

➢ However, there are cases of verbs related to the same base that inflect differently:

lexeme (meaning)	**derivational info**	**PRS.ACT.IND.1SG**	**PRS.ACT.INF**	**PRF.ACT.IND.1SG**	**SUP.ACC**
FACIO (‘to make’)	underived	*faciō*	*facere*	*fēcī*	*factum*
CALEFACIO (‘to make warm’)	< *facio*	*calefaciō*	*calefacere*	*calefēcī*	*calefactum*
INFICIO (‘to put into’)	< *facio*	*inficiō*	*inficere*	*infēcī*	*infectum*

- weakening of short vowels in non-initial syllables in Old Latin:

/in/+/fa.ki.o:/→ /in.fi.ki.o:/ (open syllable); /in/+/fak.tum/ → /in.fɛk.tum/ (closed syllable)

The inflectional behaviour of derived lexemes

➢ Nouns formed by means of the same derivational suffix almost always inflect alike:

lexeme (meaning)	**derivational info**	**NOM.SG**	**GEN.SG**	**ACC.SG**
LAUDATIO (‘praising’)	suffix *-ti-*	*laudātiō*	*laudātiōnis*	*laudātiōnem*
LARGITIO (‘granting’)	suffix *-ti-*	*largītiō*	*largītiōnis*	*largītiōnem*

➢ Only one exception:

lexeme (meaning)	**derivational info**	**NOM.SG**	**GEN.SG**	**ACC.SG**
TABELLA (‘little board’)	suffix *-ll-*	*tabella*	*tabellae*	*tabellam*
LIBELLUS (‘little book’)	suffix *-ll-*	*libellus*	*libellī*	*libellum*

- diminutive suffixes transparent to the gender of the base
  TABULA (F) → TABELLA (F, decl. I)
  LIBER (M) → LIBELLUS (M, decl. II)

Discussion

- Speakers can predict inflection more accurately if they know the place of a lexeme in the derivation network
- The reduction in uncertainty is very strong when the classification of verbs according to their ancestor is taken into account
- It is less relevant when taking into account the classification of nouns according to the derivational suffix they display
- However, the difference we observe is probably simply due to the different quantitative relevance of the two classifications

classification	% derived lexemes
ancestors (verbs)	64.5 %
derivational suffixes (nouns)	22.5 %

- With average implicative entropy, it is difficult to carefully evaluate the different contribution of various aspects of the derivational history

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Predicting Inflection Class assignment

- In the previous section, the assessment of inflectional predictability was very realistic and fine-grained
  - average implicative entropy, estimating the uncertainty in the PCFP, i.e. in predicting the content of each paradigm cell, given knowledge of other inflected wordforms
  - however, in this way it is difficult to precisely evaluate the different contribution of various aspects of the derivational history
- In this section, we rely on a more coarse-grained and abstract assessment of inflectional predictability
  - we focus on uncertainty in predicting Inflection Class (IC), rather than individual wordforms
  - this allows us to be more detailed on the different facets of derivation involved

Coding of derivational information

- We classify the lexemes of our sample according to the IC they belong to and to several derivational aspects:
  - derivational family (coded using the ancestor);
  - derivational prefixes/suffixes;
  - last derivational operation performed according to WFL database.

lexeme	**conjugation**	**derivational family**	**derivational prefix**	**derivational suffix**	**last operation**
creo	I	creo (V)	_	_	_
cresco	III	creo (V)	_	*-sc*	suffixation
recreo	I	creo (V)	*re-*	_	prefixation
accresco	III	creo (V)	*ad-*	*-sc*	prefixation
corono	I	corona (N)	_	_	conversion

- We exclude:
  - lexemes belonging to a family with only one member;
  - lexemes displaying a prefix or suffix that only appears once in our dataset;
  - compound lexemes.

Results

➢ We then compute the conditional entropy of predicting IC given information on different derivational predictors

	verbs (2851)	nouns (367)
H(IC)	1.94	1.979
H(IC|family)	0.373	0.929
H(IC|prefix)	1.875	1.855
H(IC|suffix)	1.82	1.121
H(IC|family, prefix)	0.109	0.233
H(IC|family, suffix)	0.174	0.172
H(IC|prefix, suffix)	1.816	0.580
H(IC|family, prefix, suffix)	0.105	0.093

- The derivational family is a very good predictor, especially for verbs
- Prefixes are poor predictors for both verbs and nouns
- Suffixes seem to be poor predictors for verbs, better for nouns
- Joint knowledge of the three pieces of information leads to almost perfect predictability

Results

➢ Only lexemes that contain a suffix:

	verbs (246)	nouns (163)
H(IC)	0.989	1.606
H(IC|suffix)	0	0.066
H(IC|family)	0.144	0.44
IG(IC,family)	0.845	1.166

➢ Only lexemes that contain a prefix:

	verbs (2145)	nouns (86)
H(IC)	1.949	1.988
H(IC|prefix)	1.896	1.539
H(IC|family)	0.249	0.635
IG(IC,family)	1.7	1.353

- In suffixed lexemes, knowledge of the suffix leads to (almost) perfect predictability
- In prefixed lexemes, knowledge of the prefix provides little to no information
- H(IC|family) is lower for suffixed lexemes than for prefixed lexemes
- This happens because the overall distribution of ICs is more uniform among suffixed lexemes, especially for verbs: see the values of unconditioned entropy H(IC)
- However, the information gain IG(IC,family) – i.e., the difference between H(IC) and H(IC|family) – is higher in prefixed lexemes

Results

To sum up:

- derivational suffixes are highly predictive of IC;
- derivational prefixes are not very informative on IC membership;
- derivational families:
  - are overall good predictors;
  - but they allow for a greater information gain for prefixed lexemes than for suffixed lexemes.

This suggests that IC membership is mostly determined by the **last morph** in the stem – the one adjacent to inflectional affixes

Results

- To check this, we code the first (leftmost) and last (rightmost) morph (excluding inflectional affixes) appearing in each lexeme in our sample

lexeme	conjugation	family	prefix	suffix	last operation	first morph	last morph
creo	I	creo (V)	_	_	_	*creo*	*creo*
cresco	III	creo (V)	_	*-sc*	suffixation	*creo*	*-sco*
recreo	I	creo (V)	*re-*	_	prefixation	*re-*	*creo*
accresco	III	creo (V)	*ad-*	*-sc*	prefixation	*ad-*	*-sco*

- We then compute:
  - H(IC|last) - the conditional entropy of guessing IC knowing the last morph
  - H(IC|first) - the conditional entropy of guessing IC knowing the first morph

	verbs (2851)	nouns (367)
H(IC)	1.94	1.979
H(IC|last)	0.223	0.303
H(IC|first)	1.532	0.955
H(IC|family)	0.373	0.929

Last morph:

- much better predictor than the first morph
- even more predictive than the derivational family

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Morphs matter!

- Our results are due to a systematic asymmetry between prefixation and suffixation:
  - prefixed lexemes
    → inflectional behavior inherited from the base
    e.g. CONFERO ‘bring together’: PRS.ACT.IND.1SG *con-ferō*, PRF.ACT.IND.1SG *con-tulī*
    (like in the base FERO ‘bring’: PRS.ACT.IND.1SG *ferō*, PRF.ACT.IND.1SG *tulī*)
  - suffixed lexemes
    → inflectional behavior specified by the process
    e.g. LAUDATIO ‘praising’: NOM.SG *laudā-tio*, GEN.SG *laudā-tiōnis*
    (like in other nouns in *-tio*, e.g. LARGITIO ‘granting’: NOM.SG *largī-tio*, GEN.SG *largī-tiōnis*)

- It is the last morph that determines the inflectional behaviour of a lexeme
  → The surface linear order of morphs seems to matter more than the identity of processes!

Problems for an a-morphous approach

- On the one hand, this state of affairs is not really surprising, and it is the usual situation in Indo-European languages with (mainly) suffixal inflection
- On the other hand, there is no obvious reason why this should be the case
- The converse possibilities are perfectly conceivable, and sometimes attested
  - suffixes transparent to the inflectional behavior of their base
    → cf. some Italian diminutives:
    e.g. DITINO 'small finger' : SG *ditino*, PL *i ditini / le ditine / **le ditina***
    (like in the base DITO 'finger': SG *dito*, PL *dita*)
- Therefore, the observed asymmetry calls for an explanation
- This goes against the expectations of an a-morphous approach (cf. Anderson, 1992; Stump, 2001)
- This is compatible with approaches that use ordered lists of morphs as morphological representations (cf. Crysmann, 2002; Luis & Spencer, 2005; Crysmann & Bonami, 2016)

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Conclusions

- Derivational information allows for a relevant reduction of uncertainty in the PCFP and in IC assignment
- Different aspects of the derivational history of lexemes contribute differently to inflectional predictability:
  - suffixes predict IC almost categorically, when present;
  - conversely, prefixes are not very informative on IC assignment;
  - the derivational family of a lexeme is a good predictor of its IC;
  - the Information Gain obtained by taking the derivational family into account is higher for prefixed verbs than for suffixed verbs;
  - the last morph is the most relevant piece of information in order to predict IC.
- Linearly organized morphs play an important role in IC assignment.

Future work

- Asymmetry between prefixed and suffixed lexemes as for the kind of derivational information that proves more useful
- Is this just the outcome of historical accidents of Latin (and possibly other Indo-European languages), or a universal tendency?
  → To answer this question, we need to extend the investigation to other languages:
  - Non-Indo-European languages with (mainly) suffixal inflection?
  - Languages with (mainly) prefixal inflection?
  - Languages with templatic morphology?

References (1)

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THANK YOU!

Conversion

➢ Converted lexemes only:

	verbs (252)	nouns (132)
H(IC)	0.467	1.870
H(IC|family)	0.062	0.372
H(IC|prefix)	0.428	1.601
H(IC|suffix)	0.467	1.870

➢ All lexemes:

	verbs (2851)	nouns (367)
H(IC)	1.94	1.979
H(IC|family)	0.373	0.929
H(IC|prefix)	1.875	1.855
H(IC|suffix)	1.82	1.121

- The overall situation in converted lexemes is similar to the one of the whole lexicon
- What is most striking is the difference in unconditioned entropy between converted verbs and all verbs
  → most converted verbs belong to the 1st conjugation
  ⇒ knowing that we are dealing with a converted verb, there is little uncertainty on IC