Spare us the surprise

The interplay of paradigmatic predictability and frequency

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ISMo 2021

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Introduction

- A known inverse link between **frequency and paradigmatic predictability** of a word form (Wu, Cotterell & O'Donnell, 2019; Marcus et al. 1992; Bybee, 1985):
    - Paradigmatically unpredictable word forms (suppletives/irregulars) tend to be frequent
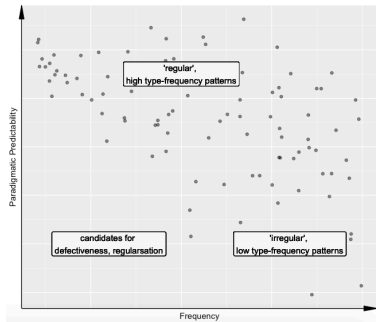   - Infrequent lexemes tend to have predictable word forms
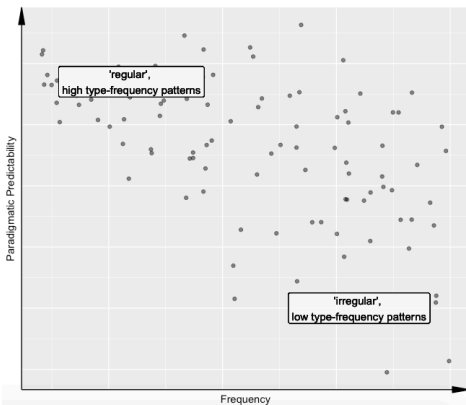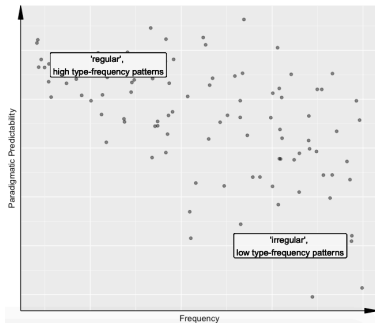
- The more high frequency a word form, the more it can afford to be paradigmatically unpredictable.
  - The unpredictable word form can be well anchored in memory thanks to its frequency

- If a paradigmatically unpredictable word is infrequent/in an infrequent context...
  - Regularisation (Eng. *helped* ← *holp*) (Lieberman et al. 2007)
  - Avoidance (*forego* → *foregoed?/forewent?*) (Albright, 2003; Sims, 2015)
  - If a whole context is infrequent and a locus of low predictability, it may drop out of use (It. *passato remoto*)

- A negative correlation between frequency and predictability
- For an unpredictable form to survive, it must be frequently attested
- Words can't afford to be both syntagmatically and paradigmatically unpredictable (Filipović Đurđević & Milin, 2019)
  - Frequent words are an expected way to continue a sentence (= syntagmatically more predictable), so they can tolerate paradigmatic uncertainty.

- When producing a sentence, we incrementally have to find words that
  1. are **inflectionally appropriate** (e.g. have the correct agreement, are the correct part of speech: *she eats/*eat dinner*)
  2. are **an appropriate lexical choice** (contribute the intended lexical semantics: *she eats/*coagulates dinner*)

- At each word boundary, the inflectional requirements are often clear
  - *"You should beware of the dog!" - "Indeed, yesterday, I ____ (it)!"* needs a past tense form.

- Several appropriate lexemes (HEED, BEWARE OF, WATCH OUT FOR). Some parameters for the choice:
  - Overall strength of the lexeme's mental representation (a function of recency, frequency in input, salience given context…)
  - The ease of accessibility of the necessary form of the lexeme (a function of predictability)

- How does paradigmatic predictability impact token frequency?
- The hypothesis:
    - at parity of lexeme frequency, less paradigmatically predictable words will be used less frequently.
    - The more frequent a lexeme, the less predictability will matter for frequency of use (frequent words need to be retrieved from memory rather than actively predicted)

- Several aspects of form predictability may be relevant to token frequency, e.g.:
    1. Local entropy: the uncertainty surrounding how to fill a given cell
        - PRS *fling* → PST $\begin{cases} \textit{flung?} \\ \textit{flang?} \\ \textit{flinged?} \end{cases}$
    2. Surprisal: the predictability of the particular form actually filling the cell
        - PRS *fling* → PST *flung*

- Following a corpus study, we conclude that the measure relevant for written production is surprisal How to operationalise?

- Need to measure:
  - given knowledge of the rest of the paradigm…
  - how confident should a speaker be that they are producing the right form in the necessary cell?

- This is clearly a variant of the Paradigm Cell Filling Problem (Ackerman, Blevins & Malouf, 2009; Ackerman & Malouf, 2013).
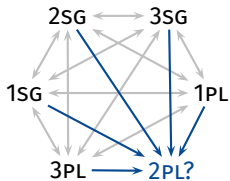
- We rely on a purely word-based approach to the PCFP of Bonami & Beniamine (2016)

Operationalising surprisal

- Beniamine's (2018) Qumin package was used for all computations.

- Intuitively: conditional probability of output form given the phonological shape of the input form

- Surprisal is computed over pairs of cells ($C1 \rightarrow C2$). For a given form pair...
  - Find all patterns compatible with the input form
  - $x = \frac{\text{type freq. of instantiated pattern}}{\text{type freq. of all applicable patterns}}$
  - Turn it into bits: $-log_2(x)$

$$\text{1PL IND PRES } \textit{sortons} \rightarrow \text{PST PART} \begin{cases} \textit{sorté?} \\ \textit{sortu?} \\ \textit{sorti?} \end{cases}$$

PATTERN	PATTERN TYPE FREQUENCY	SURPRISAL
Xons ~Xé	most lexemes	0.06
Xons ~Xu	~ 15 lexemes	4.7
Xons ~Xi	~ 5 lexemes	7.2

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- Average over predictor cells c to get an overall estimation of how surprising c' is given the rest of the paradigm.
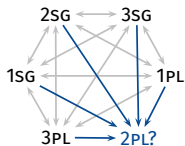
  - Ideally, this should be weighted by cell frequency.
    - But we do not have quality estimations of cell frequency, because of pervasive syncretism.
    - For lack of a better solution we use unweighted frequency.

- We set out to confirm that paradigmatic surprisal has a negative effect on token frequency throughout the lexicon.

- And that the effect is reversed for high-frequency lexemes.

- Case study: French verbal cells

- For the items within each cell, we constructed a model of the shape
  - *token frequency ~ surprisal + lexeme frequency + surprisal:lexeme frequency*
- The value of surprisal we employ is the **average surprisal** of the given form based on each of the other forms in the paradigm.
- Lemma frequency is included as a control variable (= familiarity)
- The interaction: test the intuition that **for high values of lemma frequency, surprisal matters less** (words with a strong representation in memory don't need to be predicted)
- Separate bayesian poisson regressions with weakly-informative priors were fitted to the data in each cell.

- Resources used:
  - Frequency counts: FrCoW (Schäfer & Bildhauer, 2016) for token and lemma counts.
  - Paradigms & excluding homographs: GLàFF (Hatout, Sajous & Calderone, 2014)
  - Surprisal: values computed using Qumin (Beniamine, 2018) on the Flexique verb dataset (Bonami, Caron & Plancq, 2014)

- Which cells in the paradigm of French verbs can we work with?
- Working with our dataset, we exclude…

Finite forms						
	1SG	2SG	3SG	1PL	2PL	3PL
IND.PRS	2	3	183	2	5	14
IND.IPFV	0	0	5083	10	10	5076
IND.PST	4484	4448	4694	5116	5116	5101
FUT	5211	5207	5213	5190	5212	5221
SBJV.PRS	0	250	2	8	7	13
SBJV.IPFV	4701	4725	5119	4726	4738	4740
COND	0	0	5220	5212	5212	5215
IMP	—	0	—	2	2	—

Nonfinite forms					
INF	PRS.PTCP	PST.PTCP			
		M.SG	F.SG	M.PL	F.PL
5006	4311	3935	3055	2903	3199

Number of verbs from Flexique with no homograph documented in the GLÀFF, by paradigm cell

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  - cells out of current usage (i.e. most attestations are likely to be archaic);
  - past participle cells, for which tagging is inherently unreliable.

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- The selected cells correspond to 3 areas of high interpredictability.

	FUT.1SG	FUT.2SG	FUT.3SG	FUT.1PL	FUT.2PL	FUT.3PL	COND.3SG	COND.1PL	COND.2PL	COND.3PL	IPFV.3SG	IPFV.3PL	PRS.PTCP	INF
FUT.1SG	0	0	0	0	0	0	0	0	0	0	0.24	0.24	0.24	0.23
FUT.2SG	0	0	0	0	0	0	0	0	0	0	0.24	0.24	0.24	0.23
FUT.3SG	0	0	0	0	0	0	0	0	0	0	0.24	0.24	0.24	0.23
FUT.1PL	0	0	0	0	0	0	0	0	0	0	0.24	0.24	0.24	0.23
FUT.2PL	0	0	0	0	0	0	0	0	0	0	0.24	0.24	0.24	0.23
FUT.3PL	0	0	0	0	0	0	0	0	0	0	0.24	0.24	0.24	0.23
COND.3SG	0	0	0	0	0	0	0	0	0	0	0.24	0.24	0.24	0.23
COND.1PL	0	0	0	0	0	0	0	0	0	0	0.24	0.24	0.24	0.23
COND.2PL	0	0	0	0	0	0	0	0	0	0	0.24	0.24	0.24	0.23
COND.3PL	0	0	0	0	0	0	0	0	0	0	0.24	0.24	0.24	0.23
IPFV.3SG	0.35	0.34	0.34	0.34	0.35	0.34	0.35	0.33	0.33	0.35	0	0	0.0004	0.34
IPFV.3PL	0.35	0.34	0.34	0.34	0.35	0.34	0.35	0.33	0.33	0.35	0	0	0.0004	0.33
PRS.PTCP	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.33	0.33	0.34	0	0	0	0.32
INF	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.076	0.077	0.074	0

Implicative entropy (Bonami & Beniamine, 2016) between selected cells

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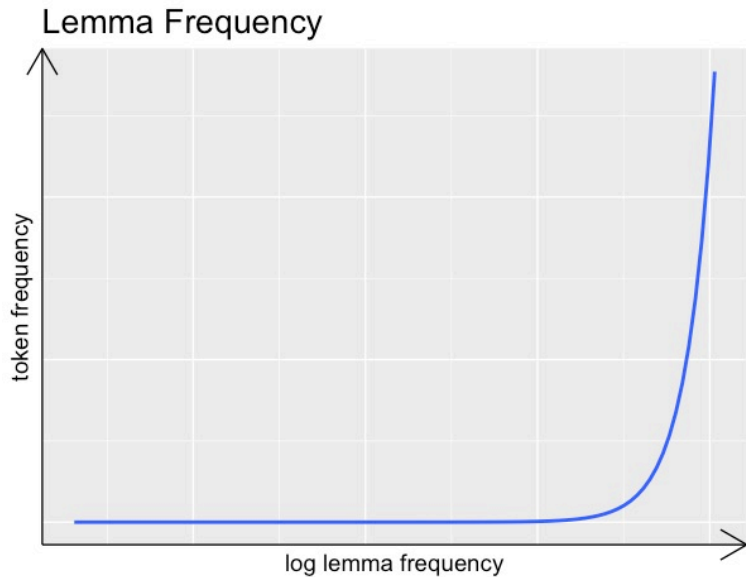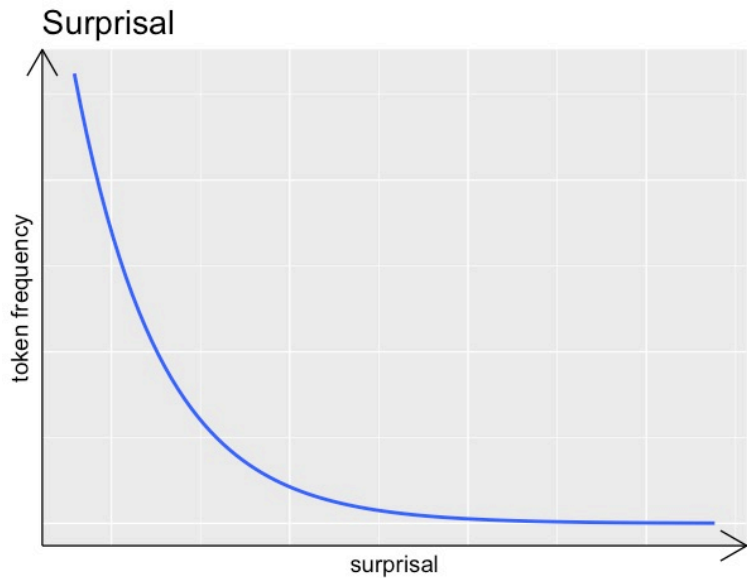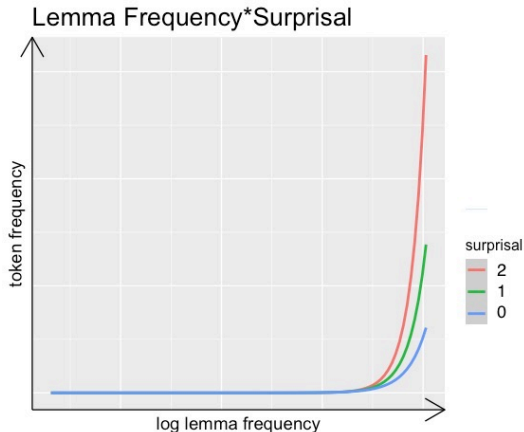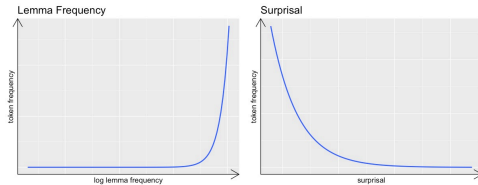
Lemma Frequency

Surprisal

- Lemma frequency has a uniform positive effect on token frequency in all cells.

- Surprisal had a negative effect in 12/14 cells, an effect indistiguishable from 0 in 1/14, and an unexpected positive effect in 1/14.

- The interaction between surprisal and lemma frequency had a positive coefficient in 11/14 cells and an effect indistiguishable from 0 in 1/14. 2/14 have unexpected negative coefficients.

- Overall, 11/14 cells behaved exactly as predicted, two behaved counter to expectations and one showed non-significant impact for surprisal and surprisal:lemma

Model Output - Coefficients

Cell	Lemma freq.	Surprisal	Interaction
FUT.1SG	0.9935	−0.3783	0.0675
FUT.2SG	1.0771	−0.2306	0.0447
FUT.3SG	1.1764	−0.0261	0.0073
FUT.1PL	0.9693	−0.1932	0.0415
FUT.2PL	1.1072	−0.3368	0.0647
FUT.3PL	1.1466	−0.0040	0.0088
COND.3SG	1.2509	−1.0392	0.1835
COND.1PL	1.2544	−1.7739	0.2876
COND.2PL	1.2583	−2.7622	0.4486
COND.3PL	1.2312	−1.3889	0.2404
IPFV.3SG	1.1707	−0.0441	−0.0010
IPFV.3PL	0.9352	−0.5588	0.0959
PRS.PTCP	0.5916	0.0545	0.0053
INF	0.9438	0.0620	−0.0089

████ Unexpected coefficient sign
████ 95% Credible interval overlaps with zero

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- Cells that didn't conform to predictions: infinitive, imperfect 3sg, present participle.

- These are by far the three most frequent cells in the dataset.

- Hypothesis: the effect of surprisal is therefore nullified at the level of the whole cell (same mechanism for frequent lexemes)
  - while the coefficients for surprisal and the interaction have unexpected monotonicity, their value is much smaller compared to other cells, and very close to 0 (for pres. part. it is indistinguisheable from 0)

- Overall, token frequency is negatively impacted by paradigmatic form predictability.
  - The pattern is reversed for items of high lemma frequency.
  - High frequency lexemes are more familiar to speakers, so the predictability of their word forms matters less for access/usage
- The method performs well on 11/14 cells, and the exceptions exist for principled reasons.
  - Showcases the importance of paradigmatic information in predicting frequency.
  - Frequent contexts and lexemes diminish the importance of paradigmatic predictability.

- Obtaining a good estimate of cell frequency (existing resources yield poor estimates, especially for the person dimension)
  - It would allow a weighed average of surprisal to be used
  - It would help interpret outlying results.
- Currently exploring the Italian verbal system with the same method (less homography)
  - Results going in roughly the same direction, some kinks to iron out
- Testing the general effect of surprisal psycholinguistically.
  - Speakers appear sensitive to paradigmatic surprisal between individual nonwords.

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