

A wug-test of Catalan consonant alternations

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(1) Introduction

- Catalan is a Romance language spoken in Catalonia and neighbouring areas.
- Extensive descriptive/analytical work on the phonology of Catalan – notably, Mascaró (1976) and Wheeler (2005).
- Consonant alternations at the right edge of stems have been of particular interest to phonologists.
 - These phenomena all relate to active research questions: exceptionality, opacity, saltation, UR learning.
- Data from Mascaró (1976), Wheeler (2005), and Kenstowicz & Kisseberth's (1979) textbook have been widely used in modelling the learning of alternations (e.g., Cotterell et al., 2015; Shilen & Wilson, 2022; Rasin et al., 2021; Wang & Hayes, in progress).
- No work to date has tested how/whether Catalan speakers generalize these patterns in the lexicon.
- We present the results of a wug test (Berko, 1958) to address this gap.

Road map:

1. Overview of Catalan consonant alternations
2. Study of these alternations within a lexical corpus
3. Experimental Results
4. Modelling
5. Discussion and Interpretation

THE PHONOLOGICAL PATTERNING OF CATALAN CONSONANT ALTERNATIONS

(2) Phenomena

- The following descriptions are only representative of *Central Catalan* – the variety of Catalan spoken in Eastern Catalonia (Barcelona, Girona, and surrounding regions).
- For illustrative purposes, we also present the classical rule-based derivations of the following phenomena.
- *2.1 /r/-deletion*
 - Stem-final coda /r/ is deleted.
 - [r] surfaces in feminine forms when the [r] is in the onset but is deleted in masculine forms where it is in the coda (e.g., [klar-ə] (f.) ~ [kla] (m.) ‘clear’).
 - But there are stems that don’t delete, like [pur] below.

(a) /r/-deletion paradigms

| <i>m. sg.</i> | <i>m. pl.</i> | <i>f. sg.</i> | <i>f. pl.</i> | <i>Gloss</i> |
|---------------|---------------|---------------|---------------|--------------|
| [du] | [du-s] | [dur-ə] | [dur-ə-s] | ‘hard’ |
| [kla] | [kla-s] | [klar-ə] | [klar-ə-s] | ‘clear’ |
| [pur] | [pur-s] | [pur-ə] | [pur-ə-s] | ‘pure’ |

- From our lexical analysis, 6.5% of stems with coda /r/ form exceptions to this process (e.g., [pur-ə] (f.) ~ [pur] (m.) ‘pure’)
- Exceptions are lexically specific and do not seem entirely phonologically predictable (Wheeler, 2005). However, there are overall **tendencies** that are phonologically and morphologically conditioned.
- *2.2 /n/-deletion*
 - Stem-final /n/ is deleted word finally.
 - [n] surfaces in the masculine plural and in feminine forms where it is not word-final, but it is deleted in the masculine singular when it would be word final (e.g., [bo] (m. sg.) ~ [bon-ə] (f. sg.) ~ [bon-s] (m. pl.) ‘good’).
 - /n/-deletion is also exceptional (e.g., [nen] (m.) ~ [nen-ə] (f.) ‘child’) – around 10% of /n/-final stems form exceptions.

(b) /n/-deletion paradigms

| <i>m. sg.</i> | <i>m. pl.</i> | <i>f. sg.</i> | <i>f. pl.</i> | <i>Gloss</i> |
|---------------|---------------|---------------|---------------|--------------|
| [bo] | [bon-s] | [bon-ə] | [bon-ə-s] | ‘good’ |
| [ple] | [plen-s] | [plen-ə] | [plen-ə-s] | ‘full’ |
| [nen] | [nen-s] | [nen-ə] | [nen-ə-s] | ‘child’ |

- Exceptions are lexically specific and do not seem entirely predictable (Wheeler, 2005). However, as with /r/-deletion, there are broad tendencies.

(c) Illustrative SPE-style derivations for /n/- and /r/-deletion

| | | | | |
|-----------|-----------|-----------|-----------|-----------------------------------------------------------|
| ‘good-m.’ | ‘good-f.’ | ‘hard-m.’ | ‘hard-f.’ | |
| /bon/ | /bon-ə/ | /dur/ | /dur-ə/ | URs |
| bo | — | — | — | <i>Final /n/ Deletion:</i> n → ∅ / ____] _{word} |
| — | — | du | — | <i>Final /r/ Deletion:</i> r → ∅ / ____] _{word} |
| [bo] | [bonə] | [du] | [durə] | SRs |

- 2.3 *Final cluster reduction and opacity*
 - Broadly, homorganic stop clusters are simplified word finally.
 - [san] (m.) ~ [sant-ə] (f.) ‘holy’
 - We are particularly interested in the [nt] ~ [n] alternation as it interacts opaquely with /n/-deletion.
 - /nt/ → [n] but /n/ → ∅

(d) Illustrative SPE-style derivations for opaque cluster simplification

| | | |
|-----------|-----------|-----------------------------------------------------------------|
| ‘holy-m.’ | ‘holy-f.’ | |
| /sant/ | /sant-ə/ | URs |
| — | — | <i>Final /n/ Deletion:</i> n → ∅ / ____] _{word} |
| san | — | <i>Cluster Simplification:</i> t → ∅ / n ____] _{word} |
| [san] | [santə] | SRs |

- /n/-deletion is not surface true (barring lexical exceptions) as it *underapplies*. A word-final [n] that is the result of final cluster reduction is never deleted.
 - A UR like /sant/ can never be realized as *[sa].
 - /n/-deletion *counterfeeds* final cluster reduction.
 - Rule-based approaches can easily account for this interaction, but classical OT cannot without amplifying the class of Faithfulness constraints.
- 2.4 *Final obstruent devoicing and saltation*
 - Voiced obstruents exceptionlessly become voiceless finally.
 - [gris] (m. sg.) ~ [grizus] (m. pl.) ‘grey’
 - Stems ending in /z/ exhibit a surprising pattern.
 - [bɔ̃tʃ] (m.) ~ [bɔ̃zə] (f.) ‘crazy’; where we would expect *[bɔ̃ʃ]

(e) Saltation of /z/ to [tʃ] (in one rule-based analysis)

| | | |
|------------|------------|------------------------------------------------------------------|
| ‘crazy-m.’ | ‘crazy-f.’ | |
| /bɔ̃z/ | /bɔ̃z-ə/ | URs |
| bɔ̃dʒ | — | <i>Final Hardening:</i> z → dʒ / ____] _{word} |
| bɔ̃tʃ | — | <i>Final Devoicing:</i> [-son] → [-vce] / ____] _{word} |
| [bɔ̃tʃ] | [bɔ̃zə] | SRs |

- Word-final [ʃ] is well-formed in Catalan.
 - [kə'laʃ] (m. sg.) ~ [kə'laʃus] (m. pl.) ‘drawer’

- This is an example of *saltation* (Łubowicz, 2002; Ito & Mester, 2003; Hayes & White, 2015)
- [ʃ] is close to [ʒ] featurally, yet the phonology “skips over” the segment [ʃ] and produces [tʃ]. Changing just one feature should be enough to satisfy Final Devoicing, but the grammar changes two instead.
 - [ʒ]: [+voice, –delayed release]
 - [ʃ]: [–voice, –delayed release]
 - [tʃ]: [–voice, +delayed release]
- Saltation is challenging for classical OT as well.

(3) Why wug-test? — the research questions

- Our wug-test will touch on four main issues:
 - 1) What productive generalizations do learners make from exceptional data?
 - This will be shown by the results of /n/- and /r/-deletion.
 - Zuraw (2000) and subsequent work predicts that learners *frequency match*.
 - Are there particular phonological environment where these processes are particularly productive/non-productive, and do native speakers show awareness of these environments by frequency-matching them?
 - How do speakers deviate from frequency matching?
 - UG biases can distort frequency matching (Becker et al., 2011 in Turkish; Becker et al., 2012 in English f-voicing; Ernestus & Baayen, 2003 in Dutch; Hayes & Londe, 2006 in Hungarian)
 - 2) Can an opaque alternation be productive?
 - This will be shown by the results of cluster simplification which interacts opaquely with /n/-deletion.
 - Sanders (2003) argues that Polish counterbleeding opacity is not productive and is instead dealt with by memorization.
 - 3) Can saltation be productive? Is it likely to be repaired?
 - This will be tested via the /ʒ/ ~ [tʃ] alternation.
 - Previous experimental work has posited innate biases against saltation (White, 2014 in adult English-speakers; White & Sundara, 2014 in 12-month-old infants).
 - Hayes & White (2015) provide a P-map based account for why saltation is disfavoured in learning.
 - 4) How do speakers generate underlying forms when given incomplete information?
 - E.g., Given a masculine wug form such as [kide̞], there are several possible URs: /kiden/ (reversing /n/-deletion), /kide̞r/ (reversing /r/-deletion), and /kide̞/.
 - Ernestus and Baayen (2003) find that speakers use probabilistic cues to guess the underlying voicing of stem-final obstruents in Dutch — are similar effects found in Catalan?

(4) How the alternations pattern in the Catalan lexicon – a corpus study

- We first wanted to establish the status of these phenomena in the lexicon.
 - What is the rate of exceptionality?
 - Are exceptions phonologically conditioned?
- 4.1 *Corpus construction*
 - Wikiextract (Ylonen, 2022) was used to extract all Catalan Wiktionary entries.
 - Total of 185,530 distinct word forms
 - Only words that had masculine singular, masculine plural, feminine singular, and feminine plural forms explicitly listed in Wiktionary were considered.
 - Yielded 5761 paradigms
 - Neither /r/-deletion nor cluster simplification are indicated orthographically (final /r/ and /t/ in /nt/ clusters are spelled but not pronounced) but other processes are. Thus, IPA transcriptions were needed.
 - For words with IPA transcriptions on Wiktionary already, the listed transcriptions for Central Catalan were used.
 - Otherwise, IPA transcriptions were automatically generated using the *catalan2ipa* package (Groß, 2019) and then manually checked by a trained native-speaker linguist (Victoria).
 - The frequencies from this lexicon are presented below.
- 4.2 *Contextual factors that influence /n/- and /r/-deletion*
 - /n/- and /r/-deletion are both phonologically (position of stress in stem) and morphologically (more frequent in highly frequent morphemes) conditioned (Wheeler, 2005) as in (f).
 - We work with a set of ad hoc categories that reflect the relevant distinctions.
 - *-in* or *-dor*: Two highly frequent suffixes where /n/ and /r/ delete exceptionlessly (Mascaró, 1976). The *-in* suffix forms demonyms and other nouns and adjectives ('related to'), whereas *-dor* forms deverbal nouns ('agentive') and adjectives ('characteristic of').
 - [əd.mi.nis.trə'do.rə] (f.) ~ [əd.mi.nis.trə'do] (m.) 'administrator'
 - [ər.ʒən'ti.nə] (f.) ~ [ər.ʒən'ti] (m.) 'Argentine'
 - Paroxytone: Stems with penultimate stress tend to retain /n/ and /r/.
 - [ˈprɔs.pə.rə] (f.) ~ [ˈprɔs.pər] (m.) 'prosperous'
 - [əw'tək.tu.nə] (f.) ~ [əw'tək.tun] (m.) 'autochthonous'
 - Monosyllabicity: In Catalan, monosyllables contain proportionally more exceptions to deletion than the lexicon as a whole (Wheeler, 2005). Becker et al. (2012) argue that this is due to a UG effect of monosyllables resisting alternation.
 - ['kla.rə] (f.) ~ ['kla] (m.) 'clear', but ['pu.rə] (f.) ~ ['pur] (m.) 'pure'
 - ['bə.nə] (f.) ~ ['bə] (m.) 'good', but ['nɛ.nə] (f.) ~ ['nɛn] (m.) 'child'
 - Other: All stems which do not fall into one of the above categories. These stems are polysyllabic but do not have penultimate stress. Such stems delete more often than paroxytones and monosyllables but not as much as *-in* or *-dor*.
 - [kə.tə'la.nə] (f.) ~ [kə.tə'la] (m.) 'Catalan'

(f) Frequency of /n/- and /r/-deletion in the corpus

| | /n/ | | | /r/ | | |
|--------------|-------------|--------------|---------------|-------------|--------------|---------------|
| | /n/ deleted | /n/ retained | Deletion rate | /r/ deleted | /r/ retained | Deletion rate |
| All | 495 | 53 | 0.901 | 460 | 32 | 0.935 |
| -in or -dor | 105 | 0 | 1.000 | 205 | 0 | 1.000 |
| Paroxytone | 1 | 26 | 0.037 | 2 | 22 | 0.083 |
| Monosyllabic | 8 | 7 | 0.533 | 3 | 4 | 0.429 |
| Other | 390 | 20 | 0.951 | 250 | 6 | 0.977 |

- /n/- and /r/-deletion are exceptionless in *-in* and *-dor*
- Paroxytones almost never delete /n/ or /r/.
- Monosyllables have only a modest rate of /n/- and /r/-deletion.
- All other stems have a high rate of deletion.

(g) Frequency of /nt/ cluster simplification in the lexicon

| | /t/ deleted | /t/ retained | Cluster reduction rate |
|--------------|-------------|--------------|------------------------|
| All | 40 | 0 | 1 |
| Paroxytone | 0 | 0 | — |
| Monosyllabic | 5 | 0 | 1 |
| Other | 35 | 0 | 1 |

- /nt/ cluster simplification is exceptionless and is not phonologically conditioned.

(h) Frequency of saltation

| | /z/ → [tʃ] | /z/ → [ʃ] | Saltation rate |
|--------------|------------|-----------|----------------|
| All | 7 | 0 | 1 |
| Paroxytone | 0 | 0 | — |
| Monosyllabic | 2 | 0 | 1 |
| Other | 5 | 0 | 1 |

- Saltation is exceptionless.
- It is poorly attested; however, there are a few more verb stems (~7) which display this alternation; these are not included in our list of nominal/adjective paradigms. Some of these are highly frequent (e.g., [ˈbatʃ] ‘go.1.SG.PRES.IND’ ~ [ˈba.ʃi] ‘go.1.SG.PRES.SJV’)
- To address our second research question (the induction of URs), we also collected frequencies of various stem-final alternations depending on the *final vowel*. Below are the three vowels that had the most distinct preferences for the three possible alternations.

(i) Frequency of stem-final alternations by vowel

| Masculine-final vowel | Feminine in [...n-ə] | Feminine in [...r-ə] | Feminine in [...-ə] (hiatus) |
|-----------------------|--------------------------------------------------------|------------------------------------------------------------|-----------------------------------------|
| ['ɛ] | 120 1.000 [ə'mɛ] ~ [ə'mɛ.nə] 'pleasant' | 0 0 | 0 0 |
| ['o] | 38 0.124 [pə'tro] ~ [pə'tro.nə] 'boss, owner' | 269 0.876 [im.bən'to] ~ [im.bən'to.rə] 'inventor' | 0 0 |
| ['u] | 4 0.308 [ku'mu] ~ [ku'mu.nə] 'common' | 7 0.538 [sə'gu] ~ [sə'gu.rə] 'safe' | 2 0.154 [kru] ~ ['kru.ə] 'raw' |

- ['ɛ]-final stems exceptionlessly take [n].
- ['o]-final stems strongly prefer [r].
- ['u]-final stems had variable behaviour.
- Note that there is no vowel that outright prefers hiatus, but [u] has the strongest such preference.

DESCRIPTION OF EXPERIMENT

(5) Experimental Design

- 5.1 Stimulus design
 - The wug items were designed to be a maximally confound-free test of the above phenomena. To accomplish this, we used the following principles:
 - **Phonotactic acceptability:** The wug items should be of reasonable phonotactic probability. We wrote a script to randomly generate wug items by concatenating attested sequences of Catalan segments. The items were selected among those with the highest phonotactic probabilities.
 - **Novelty:** We checked that all wug forms were indeed novel: i.e., not existing words. Moreover, we checked that all possible masculine, feminine, singular, and plural forms were also novel.
 - **Variegation:** Following the above principles, we also ensured that the items contained a wide range of distinct consonants and vowels to control for any accidental factors that may affect judgements.
 - **Native-speaker judgement:** Wug items were assessed intuitively for their naturalness by a native speaker (Victoria) and sometimes slightly modified to ensure naturalness, novelty and variegation.

- 130 different wug forms were created across 13 different subconditions (10 for each subcondition) and are given below.

- 5.2 Subconditions

(j) Experimental subconditions

| <i>Phenomenon</i> | <i>Subconditions</i> |
|---------------------------------------|------------------------------------------------------|
| /n/-deletion | 4: /-in/, monosyllabic, penultimate stress, default |
| /r/-deletion | 4: /-dor/, monosyllabic, penultimate stress, default |
| Final cluster reduction | 1: /nt/ final stems |
| Final obstruent devoicing (saltation) | 1: /ʒ/ final stems |
| UR Generation | 3: [ɛ], [o], [u] final stems |

- For /n/- and /r/-deletion, each subcondition has varying levels of exceptions, as shown in (f) above.
- The three vowel-final subconditions reflect the three preferences in (i) – epenthesis of [r], epenthesis of [n], and other.
- /n/-deletion, /r/-deletion, /nt/-final, and /ʒ/-final wugs were all provided in the feminine form (**Fem-to-Masc** condition).
- Vowel final stems were all provided in the masculine form (**Masc-to-Fem** condition).

- 5.3 Frames

- An example of a frame is shown in (k).
- The content of the frame paragraphs was crafted to encourage participants to treat the wug forms as antiquated words in Catalan that had gone out of use, rather than as loanwords (which involve the confound of faithfulness to the foreign language source).

(k) Sample frame paragraph

WUG-fem.

Una obra WUG-fem₁ era una peça d'art on s'havien aplicat tècniques mixtes amb ornaments de metalls i pedres precioses. Al segle XV, un artista català va crear la primera escultura ₂, feta de marbre, pedres precioses, i or. El primer quadre ₃ no es va crear a Espanya fins al segle XVII.

‘A work was a piece of art where they had applied mixed media with precious metals and stone ornaments. In the 15th century, a Catalan artist created the first sculpture, made of marble, precious stones and gold. The first painting was not created in Spain until the 17th century.’

- Wugs were placed in frame paragraphs with first an isolated presentation of the form followed by a presentation of the wug in a sentence.
 - The second sentence contained a pause where the participants were prompted to repeat back the initial wug form.
 - Final sentence contained a pause where only a feminine form (for the Masc-to-Fem condition) or a masculine form (for the Fem-to-Masc condition) and the participants were prompted to provide the relevant form.
 - The required gender was easily apprehended by participants, since there were multiple words in the frame that grammatically agreed with the wug word.
 - All 130 frames were read aloud and recorded by a native speaker (Victoria).
- *5.4 Procedure*
 - The experiments were created using LabVanced (Finger et al., 2017).
 - The participants received a link to the experiment and participated online using their own computer.
 - Each participant took part in 26 trials (2 items per subcondition).
 - At the first blank, they recorded themselves repeating the wug form — this was done to assess whether they had internalized the form correctly.
 - At the second blank, they recorded themselves saying the inflected form (the feminine in the Masc-to-Fem condition and masculine in the Fem-to-Masc condition).
 - Before the start of the experiment, each participant participated in two practice trials using similar paragraphs.
 - One consisted of a real word (*botànic*).
 - One consisted of a wug word (*gresa*) that did not exhibit any alternation of interest.
 - *5.5 Participants*
 - The final data included 37 participants.
 - 6 additional participants were excluded for the following reasons:
 - Age of acquisition of Catalan after infancy: 2
 - Self-identification as Valencian speakers: 2
 - Failed at real word training task: 2

RESULTS

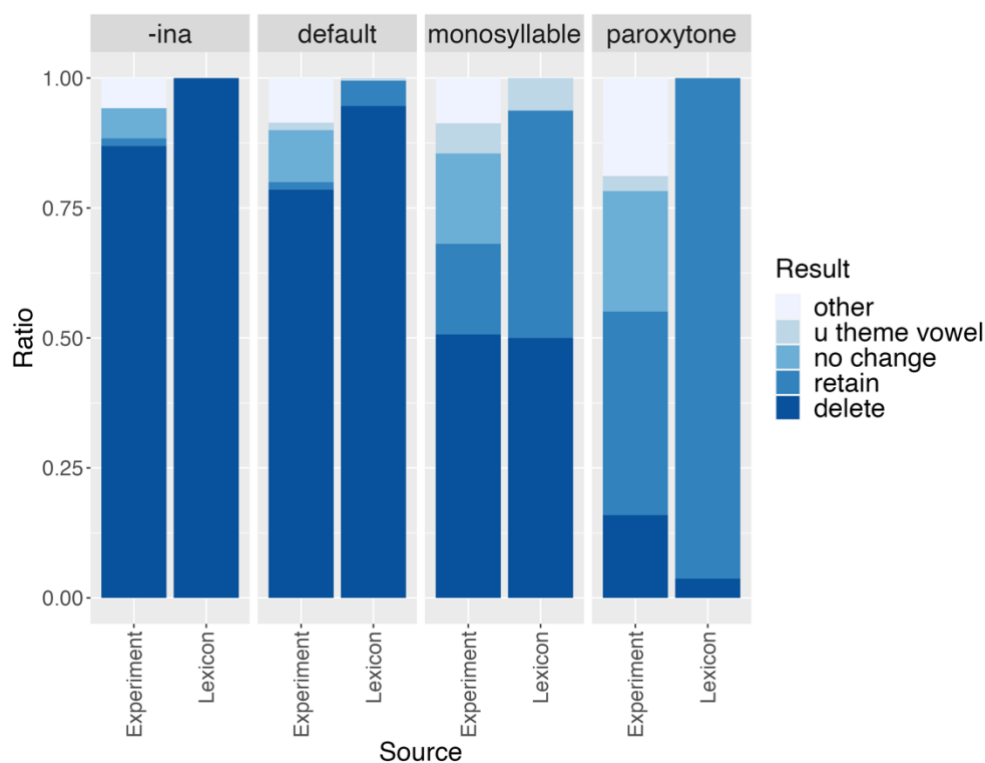
(6) Results

- All recordings were transcribed by two phonetically-trained transcribers (Kevin and Bruce).
- Any disagreements were adjudicated by a third native-speaker transcriber (Victoria)
- 916 total tokens were included in the analysis.
- 46 additional test tokens were excluded where the participants incorrectly repeated the wug form.

- 6.1 Preliminary: “Avoidant” Responses
 - Korean children are willing to commit morphological errors if it enables them to avoid making a guess about phonological alternation (Do, 2018).
 - We think we may be getting the same behavior from Catalan-speaking adults, who overemploy two very marginal morphological patterns to this end:
 - **No change**: use the same form in both the masculine and feminine (attested, 41 cases out of 5761 paradigms in our database, example: [ə'le.grə] (m.) ~ [ə'le.grə] (f.) ‘happy’).
 - **[u] as masculine theme vowel**: This corresponds to Romance [-o] and has been deleted in the great majority of masculines, but a few real cases remain (attested, 40 cases out of 5761 paradigms in our database, example: [bu'ra.tʃu] (m.) ~ [bu'ra.tʃə] (f.) ‘drunk’).
 - Either strategy obviates the need to apply phonology.
 - Such responses are still included in our presentation of the experimental findings.
 - See discussion (9) below.

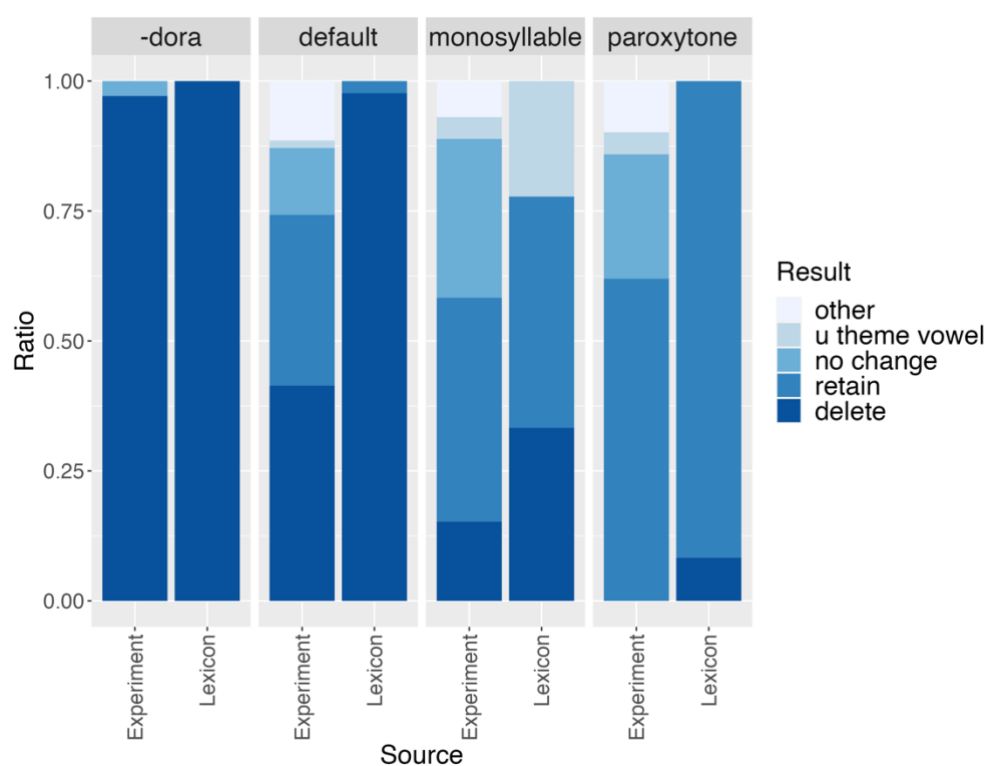
- 6.2 /n/-deletion results
 - Sample outputs for the wug form: [sə'da.nə]
 - Delete = [sə'da] (majority pattern in lexicon)
 - Retain = [sə'dan] (exceptional pattern in lexicon)
 - No change = [sə'da.nə] (exceedingly rare but attested in lexicon)
 - u theme vowel = [sə'da.nu] (rare but attested in lexicon)

(I) /n/-deletion lexical vs. experimental results



- /n/-deletion is productive in that Catalan speakers apply it to novel forms.
 - They also *frequency match* by condition (i.e., number of syllables, stress, and morphology).
- 6.3 /r/-deletion results
 - Sample outputs for the wug form: [u.li'da.rə]
 - Delete = [u.li'da] (majority pattern in lexicon)
 - Retain = [u.li'dar] (exceptional pattern in lexicon)
 - No change = [u.li'da.rə] (exceedingly rare but attested in lexicon)
 - u theme vowel = [u.li'da.ru] (rare but attested in lexicon)

(m) /r/-deletion lexical vs. experimental results



- /r/-deletion is productive as speakers apply it to novel forms.
- Catalan speakers match the lexicon qualitatively.
- However, in general, /r/-deletion is considerably less frequent than ostensibly similar /n/-deletion.
- /r/-deletion is almost exceptionless in the *-dor* condition, the only exceptions are when the participant repeated the wug form without inflecting it.

- 6.4 /nt/ cluster simplification results
 - Sample outputs for the wug form: [pə'kun.tə]
 - Apply Rule = [pə'kun] (attested in lexicon)
 - Faithful = [pə'kunt] (unattested in lexicon)
 - Repeat base = [pə'kun.tə] (unattested in lexicon)
 - Transparent = [pə'ku] (unattested in lexicon)

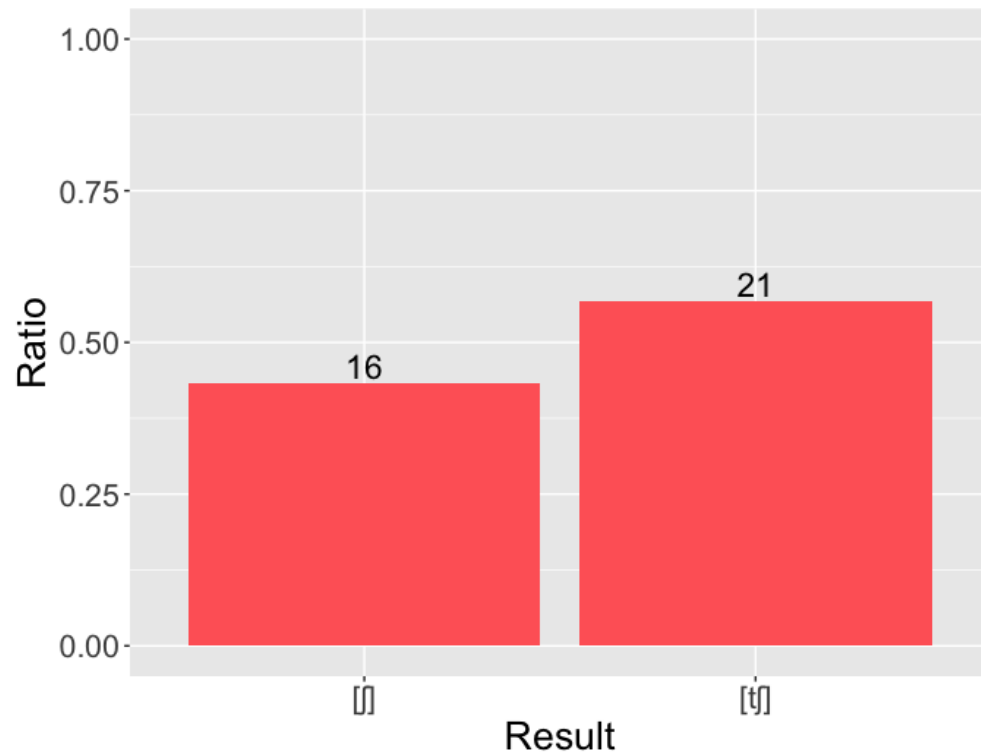
(n) /nt/ cluster simplification experimental results



- Recall that /nt/ cluster simplification is exceptionless in the lexicon (g).
- Why, then, are we getting all these [nt] responses? See 9.3 below.

- 6.5 Saltation results
 - Sample outputs for the wug form: [ʎu'da.ʒə]
 - [ʎu'daʃ] (attested in lexicon)
 - [ʎu'daʒ] (unattested in lexicon)

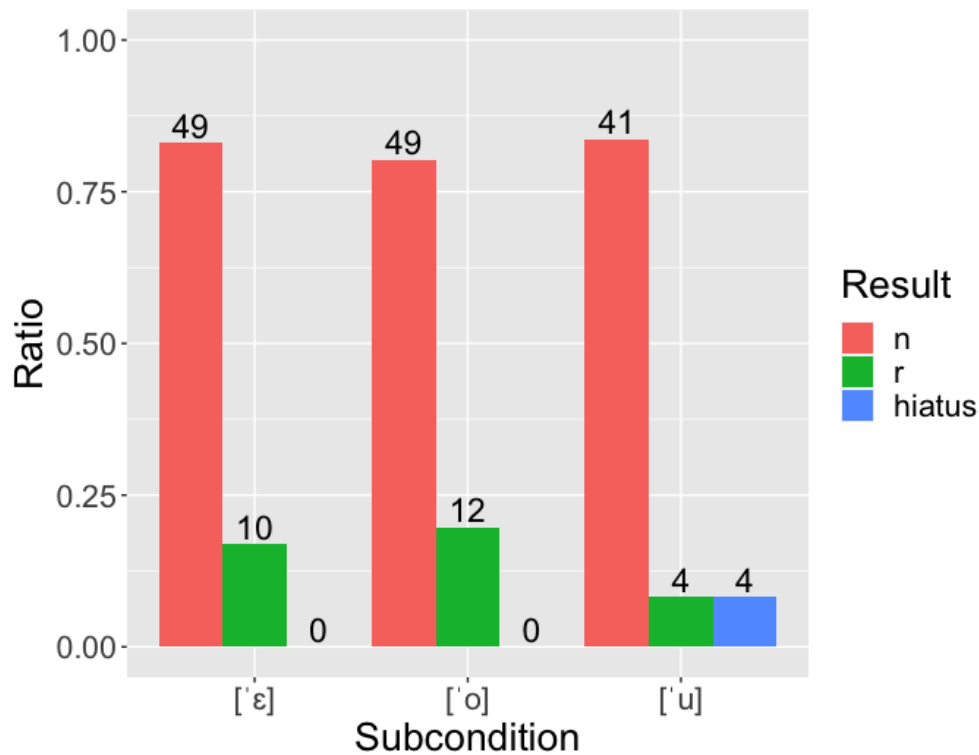
(o) Saltation experimental results



- Recall that saltation is exceptionless in the input but there are only 7 cases in our lexicon (h). There are a limited number of verbal stems not in our lexicon where this alternation can be observed as well.
- Saltation is productive in the experiment and is the most common option, yet saltation repair ([ʃ]) is also common.

- 6.6 Masc-to-Fem Results
 - Sample outputs for the wug form: [bis'trɛ]
 - n: [bis'trɛ.nə]
 - r: [bis'trɛ.rə]
 - hiatus: [bis'trɛ.ə]

(p) Masc-to-Fem Experimental results



- Recall from (i) that, in the lexicon, ['ɛ]-final stems exceptionally have [n] in the feminine, ['o]-final stems strongly prefer [r], and ['u]-final stems exhibit mixed behaviour but generally prefer [r].
- However, in the experimental results, [n] is equally preferred across all conditions.
 - This is so even in the ['o] and ['u] conditions where [r] is preferred in the lexicon.

(7) Summary of Findings

- /n/-deletion
 - Productive and speakers frequency match lexicon
- /r/-deletion
 - Productive and speakers qualitatively frequency match but at a lower rate than the lexicon
- /nt/ cluster simplification
 - Productive
 - Exceptionless in input but variable behaviour in experiment
- Saltation
 - Productive but many speakers repair saltation ([ʒ] ~ [ʃ])
- Masc-to-fem
 - /n/ is overwhelmingly preferred in the UR despite it only being marginally more frequent than /r/

MODELLING

(8) Modelling

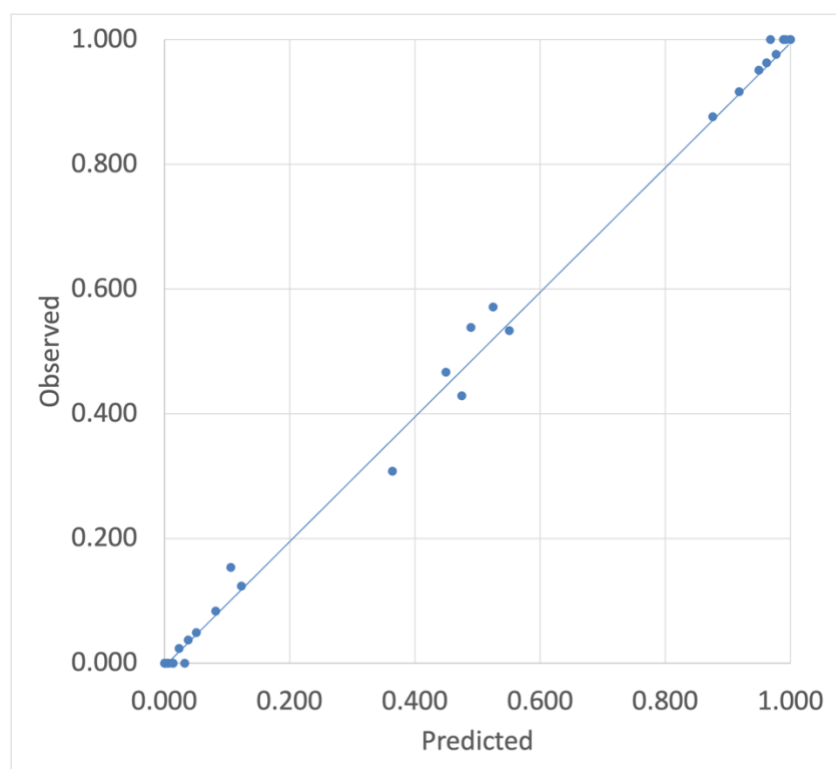
- We employed MaxEnt modelling (Goldwater & Johnson, 2003) with constraints of types (Markedness, Faithfulness) familiar from the literature in Optimality Theory (Prince & Smolensky, 1993 et seq.).
- Two models were created to:
 - (a) match the lexicon
 - (b) match the experimental results
- Both models can capture their respective data (r and s).
- The constraints used to create these models and their associated weights are shown in (q).

(q) Lexical and experimental model constraints and weights

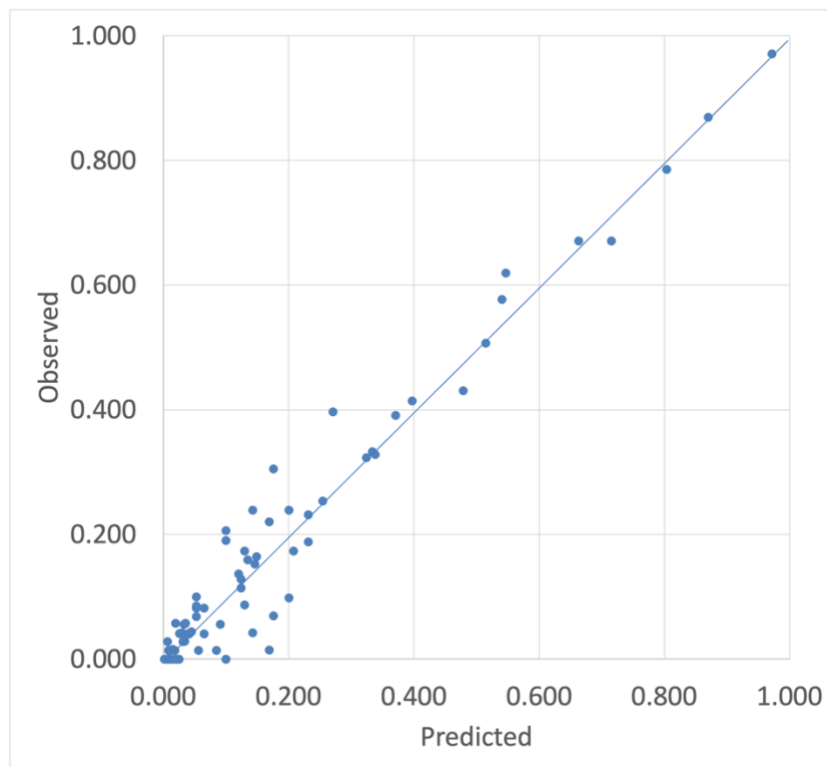
| Constraint | Meaning | Lexicon Weight | Experimental Weight |
|------------------|-----------------------------------------------------------------------------------------------|----------------|---------------------|
| *A-THEMEVOWEL | Avoid final [ə] in masculine forms | 2.35 | 12.45 |
| *U-THEMEVOWEL | Avoid final [u] in masculine forms | 4.62 | 12.45 |
| *CREATIVEDESPAIR | Avoid random, unmotivated responses (ad hoc constraint employed to treat these unusual cases) | 3.18 | 12.49 |
| [-do] for masc. | Select the allomorph [-do] for masculine forms | 2.43 | 6.87 |
| [-i] for masc. | Select the allomorph [-i] for masculine forms | 0.54 | 4.09 |
| *CODA-[r] | Avoid [r] in coda position | 1.67 | 4.19 |
| *CODA-[n] | Avoid [n] in coda position | 2.21 | 2.97 |
| *nt] | Avoid word-final [nt] | 2.03 | 8.62 |
| *HIATUS | Avoid two adjacent vowels | 2.61 | 1.60 |

| | | | |
|----------------------------|----------------------------------------------------|-------|------|
| FINALDEVOICING | Avoid final voiced obstruents | 15.96 | 0.00 |
| MAX(r) | Retain /r/ | 1.53 | 0.47 |
| MAX(n) | Retain /n/ | 0.00 | 0.03 |
| MAX-MONO | Retain segments in monosyllables | 1.31 | 2.74 |
| MAX(r)-MONO | Retain /r/ in monosyllables | 0.00 | 1.33 |
| MAX-POSTATONIC | Retain segments postatonically | 3.23 | 6.06 |
| DEP(n) | Avoid inserting [n] | 0.00 | 0.00 |
| DEP(r) | Avoid inserting [r] | 0.29 | 1.26 |
| DEP(z) | Avoid inserting [z] | 1.34 | 4.41 |
| [XV] is derived from /XVn/ | Surface [XV] should have the underlying form /XVn/ | 1.52 | 3.66 |
| [Xo] is derived from /Xor/ | Surface [Xo] should have the underlying form /Xor/ | 0.33 | 6.85 |
| [Xu] is derived from /Xur/ | Surface [Xu] should have the underlying form /Xur/ | 0.00 | 5.22 |
| [Xu] is derived from /Xu/ | Surface [Xu] should have the underlying form /Xu/ | 1.33 | 3.84 |
| MAX(CC) | Retain two consonant sequences | 4.02 | 8.00 |
| *MAP(ʒ-f) | Avoid correspondence between [ʒ] and [f] | 0.27 | 3.02 |
| IDENT(voice) | Avoid alteration to the feature [voice] | 1.68 | 0.00 |

(r) Lexical model predicted vs. observed results



(s) Experimental model predicted vs. observed results



- **Upshot:** Both lexical patterning and experimental results are amenable to analysis in classical OT/MaxEnt fashion, with good fit to data.
- **Still lacking:** Biased model that takes the lexicon as the input and learns a grammar that matches the experimental results (cf. Wilson, 2006; Hayes et al., 2009)
 - This currently eludes us.
 - For challenges in creating such a model, see the general discussion below.

DISCUSSION AND INTERPRETATION

(9) Discussion

- *9.1 Frequency matching*
 - These results further support the hypothesis frequency matching (Zuraw, 2000; Ernestus & Baayen, 2003).
 - The four types of /n/-deletion pattern similarly in the lexicon and experiment in (l).
 - The four types of /r/-deletion have similar relative frequencies in the lexicon and experiment in (m).
 - There is a near-complete absence of feeding derivations of /nt/ (i.e., /nt/ does not alternate with \emptyset).
 - The *deviations* are of greater interest – what causes speakers not to frequency match?
 - We cover these deviations below with speculation about the causes.

- 9.2 *Deviation 1: Saltation repair*
 - Almost half the participants gave [ʃ], not [tʃ], for /ʒ#/ (o).
 - /ʒ/ ~ [tʃ] is exceptionless in the input.
 - /ʒ/ never alternates with [ʃ] in the input.
 - This supports the suggestion (e.g. Hayes and White 2015) that Saltation is a form of unnatural phonology, which only arises from an aberrant diachronic origin and is liable to be “repaired”.
 - Existing theoretical principles predict the [ʃ] response:
 - P-map (Steriade, 2001)
 - *Map constraints and P-map based a priori weightings (Zuraw, 2000)
 - Earlier experimental evidence has also suggested a bias against Saltation:
 - White & Sundara (2014) in 12-month-olds
 - White (2014) in adult English-speakers
 - On the other hand, a slight majority of speakers *do* productively extend Saltation.
 - This is especially surprising given the limited number of types that undergo Saltation in the lexicon.
 - Across all Catalan CHILDES transcripts (Aparici, Tolchinsky, & Rosado, 2000; Bel, 1999; Esteve-Gibert & Prieto, 2013; Llinàs i Grau, 1998; Llinàs i Grau, 2000):
 - 145528 word corpus of infant-directed speech
 - 7 stems attested where [ʒ] could alternate with [tʃ]
 - 5 stems where [ʒ] actually alternates with [tʃ]
 - Alternation frequency: token – 315 (0.2%), type – 5
 - This limited amount of data is apparently enough for the learner to (at least partially) overcome any pre-existing bias against saltation.
- 9.3 *Deviation 2: Non-application of /nt/ simplification*
 - /nt/ cluster simplification is exceptionless in the input (no SR contains word-final [nt]) yet >30% of our datapoints had a faithful output.
 - Potential L2 influence
 - All participants also spoke Spanish which (at least in some varieties) permits word-final [nt] in loanwords (e.g., [es'prĩnt] *esprint* ‘sprint’).
 - 24/37 participants also spoke English which permits word-final [nt].
 - L2 effect on L1 has been observed in the literature: native Russian speakers who also speak English often fail to apply final obstruent devoicing in Russian (Dmitrieva, Jongman, & Sereno, 2010).
 - Other varieties of Catalan (Balearic, Valencian) permit word-final [nt] clusters.
 - A totally different story: /nt/ cluster simplification and /n/-deletion are in a counterfeeding relationship.
 - Speakers avoid applying /nt/ simplification because of an aversion to opacity.

- 9.4 Deviation 3: The /n/-/r/ difference in deletion
 - /n/-deletion in the experiment comes amazingly close to the lexical frequencies (l) – hardly any alternation bias.
 - /r/-deletion only *relatively* matches the lexical frequencies (m) (-dor deletes the most followed by default, monosyllable, and paroxytone), but its overall frequency is substantially lower.
 - Why does this difference occur? We present one speculation below.
 - Wug-test intuitions may be influenced by orthography (Cena, 1978; Kawahara, 2018).
 - /n/-deletion is reflected orthographically.
 - [kətə'la] *Català* ‘Catalan-m.’ ~ [kətə'lanə] *Catalana* ‘Catalan-f.’
 - This supports alternation.
 - /ʒ/ → [tʃ] is like /n/-deletion in that it is reflected in the orthography.
 - ['bətʃ] *boig* ‘crazy-m.’ ~ ['bɔ.ʒə] *boja* ‘crazy-f.’
 - This also supports the alternation and may help in learning unnatural phonology.
 - /r/-deletion is not reflected in the orthography.
 - ['kla] *clar* ‘clear-m.’ ~ ['klarə] *clara* ‘clear-f.’
 - Perhaps this discourages alternation.
 - /nt/-simplification is like /r/-deletion (not shown in orthography).
 - [ə.lə'fan] *elefant* ‘elephant-m.’ ~ [ə.lə'fan.tə] *elefanta* ‘elephant-f.’
 - This may explain why /nt/ occurs at a lower rate in the experiment.
 - Additional work must be done to invent a theory to make this idea explicit (perhaps: phoneme-to-orthography conversion, the orthographic version of phonology, orthography-to-phoneme conversion).
- 9.5 Deviation 4: The /n/-/r/ difference in insertion
 - In (p), /n/ is overwhelmingly preferred in the UR despite it only being marginally more frequent than /r/.
 - May be due to higher productivity of /n/-deletion than /r/-deletion
 - From (l) and (m), speakers are more likely to retain /r/ than /n/ which may mean that speakers are more likely to propose a UR with underlying /n/.
 - Again, a potential orthographic effect
 - Speakers hear a form [bis'trɛ] and create the orthographic representation *bistrè*.
 - Orthographically, *bistrè* ~ *bistrera* is impossible but *bistrè* ~ *bistrena* is possible.
- 9.6 Deviation 5: Use of avoidant responses
 - Systemic pressure to avoid alternation finds its outlet in the violation of morphological constraints governing how to realize [+masculine].
 - [-ə] final masculines, [-u]-final masculines
 - These let the participant “off the hook” as far as guessing whether phonology should be applicable.

TO COME

(10) Future directions

- Testing our findings statistically (suggestions welcome)
- Speaker-specific grammars (cf. current work by Claire Moore-Cantwell and Jinyoung Jo)
 - We hope to be able to retest some of our participants in a followup multiple-choice experiment now in progress.
- More information can be extracted from the present data. For example:
 - Consistency of responses across similar wug items; is there perhaps self-priming in process application?
 - Effects of individual wug items (for example: OCP effects like ...n...n... and ...r...r...)
- Follow-up experiment:
 - Participants will be asked to rate the well-formedness of 2 or 3 inflected wug forms instead of being asked to produce their own.
 - Do the results differ substantially and might this be attributed to separate grammars for the perception and production (Boersma, 1999; Stave et al., 2013)?
 - Gradient judgements and how they are related to production probabilities.

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