

## Defining phonological rules over lexical neighbourhoods: Evidence from Canadian Raising

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## Canadian Raising (CR)

- A phonological process in which the distribution of the vowels [ai] and [ʰi] is traditionally assumed to be predictable by phonological rule.

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## Canadian Raising (CR)

**Canadian Raising: /ai/ will be realized as [ʰi] when it is followed by a tautosyllabic voiceless consonant.**

(Paradis 1980; Chambers 1989)

e.g. “tight” → [tʰit]      cf. “tide” → [taid]

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## Assumptions

Canadian Raising: /ai/ will surface as [ʰi] when it is followed by a tautosyllabic voiceless consonant.

- a. There is a categorical difference between the output of the rule when it applies ([ʰi]) and the variant that does not undergo the rule ([ai]).
- b. The rule will apply in all and only words where its phonological environment is met (in any word with /ai/ followed by a tautosyllabic voiceless consonant).

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## Goals of Study

- a. To investigate whether the observed patterns of Canadian Raising are consistent with traditional accounts;
- b. If not, to determine the ways in which they differ and how a theory of language can account for the observed patterns.

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## Structure of Talk

- a. Methods of data collection and analysis
- b. Predictions of traditional theories
- c. Actual results contradicting these predictions
- d. Proposed explanation of these results

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## Methods: A Production Study

Question: Is the pattern of Canadian Raising the same as is described in the literature?

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## Methods: A Production Study

Participants:

- a. 20 native speakers of Canadian English from Grey County, Ontario
- b. ages 20-76
- c. 3 males over 65 examined here: controlled for age and sex

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## Methods: A Production Study

Task 1: Read Narrative

- a. each speaker read a passage describing a set of pictures they had examined
- b. 78 different /ai/ words were embedded, some repeated several times

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## Methods: A Production Study

Task 2: Read Wordlist

- a. each speaker read a randomized list of 554 words: 299 /ai/ words and 255 fillers
- b. /ai/ words were controlled for context, stress, syllable structure, and frequency (based on CELEX corpus)

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## Methods: A Production Study

Task 2: Read Wordlist (cont.)

- a. wordlist also included words commonly cited in the literature on CR (e.g. write/writing/ride/riding)
- b. also included words that were related phonologically or morphologically to words already on the list (e.g. cite/sight or cite / citation)

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## Methods: A Production Study

Measurement:

- a. vowels from all /ai/ words delimited in Praat (Boersma & Weenink 2001)
- b. first two formant values used as phonetic correlates of Canadian Raising
- c. F1 and F2 values at the maximum F1 (lowest part of the vowel) automatically measured using a Perl script written by Elliott Moreton (UNC-CH)

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## Predictions and Results

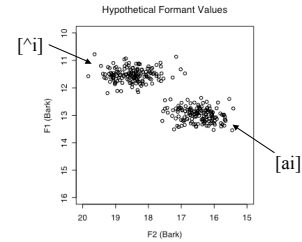
Canadian Raising: /ai/ will surface as [ʌi] when it is followed by a tautosyllabic voiceless consonant.

Prediction 1 (of traditional models):

- there is a categorical distinction between [ai] and [ʌi]
- therefore, phonetic measurements of words with /ai/ should fall into two distinct clusters
- despite variation in each cluster, the two vowels should be clearly differentiated

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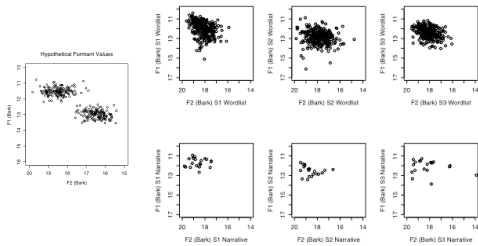
## Predicted Distribution of Two Distinct Vowels



Hypothetical graph of predicted vowel formants in 300 different tokens of /ai/, from different words, for one speaker, based on traditional categorical rules

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## Actual Distribution: Not Two Distinct Vowels



Actual graphs of vowel formants in ~300 different /ai/ words, for each speaker, separated by task (top = Wordlist, bottom = Read Narrative)

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## Predictions and Results

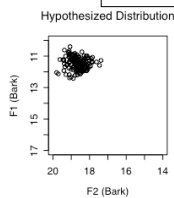
Perhaps prediction was too ambitious . . .

- do the predictions of traditional phonological models bear any resemblance to the data?
- perhaps the vowels predicted to be low ([ai]) and those predicted to be high ([ʌi]) are distinct but not separated

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## Hypothetical Distribution: Distinction of “High” and “Low” Vowels

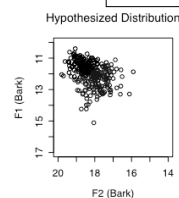
Black = predicted “high”  
Red = predicted “low”



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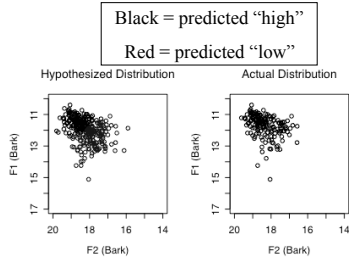
## Hypothetical Distribution: Distinction of “High” and “Low” Vowels

Black = predicted “high”  
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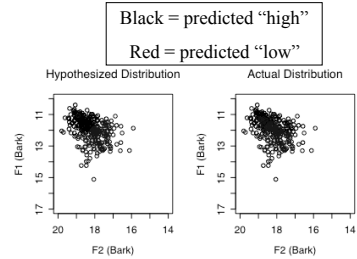
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## Actual Distribution: Overlap of Predicted “High” and “Low” Vowels



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## Actual Distribution: Overlap of Predicted “High” and “Low” Vowels



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## Predictions and Results

### PROBLEM

- there is not a categorical distinction between [ai] and [˘i]
- therefore, it is not clear which vowel (high or low) any given word contains

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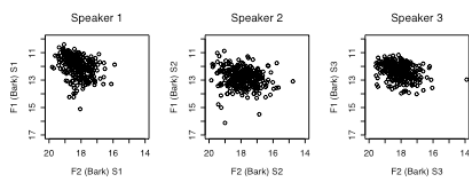
## Dividing the Data into “High” and “Low” Vowels

The current solution:

- Divide data into quartiles (determined through a principal components analysis)
- Top quartile = words with a high variant [˘i]
- Bottom quartile = words with a low variant [ai]
- Conservatively, ignore the dense middle 50% of the data as ambiguous between high and low

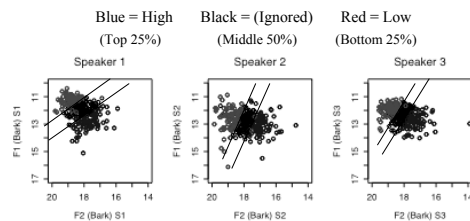
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## Upper and Lower Quartiles



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## Upper and Lower Quartiles



Upper and lower quartiles of actual data for all three speakers.

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## Observations

Interspeaker consensus -- of 268 words that all three produced:

- 37 (14%) showed agreement across all 3
- 29 of those 37 (78%) were consistent with traditional phonological predictions
  - e.g. *high* [hai], *five* [faiv], *dacey* [d^isi], *bauxite* [baks^it]
- 4 (11%) had high vowels despite being predicted to be low
  - e.g. *gigantic* [dʒ^igæntik], *Siberia* [s^ibiria]
- 4 (11%) had low vowels despite being predicted to be high
  - e.g. *like* [laik], *Michael* [maikl]

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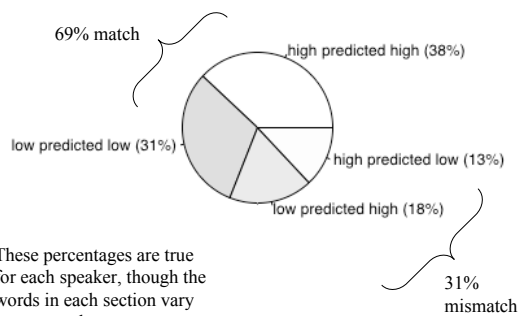
## Observations

Interspeaker variation -- of 300 words for each speaker:

- 50% were predicted to be high and 50% were predicted to be low based on traditional phonological rules
- 25% were classified as "high" and 25% were classified as "low" based on phonetics (the middle 50% were not considered in this analysis)

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## Observations



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## Observations

**On average, for each speaker, 31% of the highest and lowest phonetic tokens were in the "wrong" place according to traditional phonological rules.**

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- Traditional rules take into account: voicing of the following segment, syllabification, and stress.
- Clearly, more is going on with Canadian Raising than traditional rules can account for.
- What else needs to be included?

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## Proposal

Additional Crucial Factors:

- phonological neighbourhood**
- lexical frequency**

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### Phonological Neighbourhood

- Words that are phonologically similar to each other tend to pattern together.
- “Phonologically similar” defined over /ai/ and the segment that immediately precedes it.

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### Phonological Neighbourhood

- These pairs will be referred to as “biphones.”
  - e.g. /bai/, /tai/, /#ai/, etc.
  - e.g. tiger, enticingly, environment
- shared biphone = more similar
- different biphone = more different

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### Phonological Neighbourhood

- Independent evidence has shown the importance of the joint frequency of such pairs of sounds (“biphone frequency”) in predicting phonological processes.
- e.g. Raymond, Dautricourt, and Hume (2004) show that greater biphone frequency correlates with a higher rate of deletion of word-internal t/d in American English.

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### Phonological Neighbourhood: Results

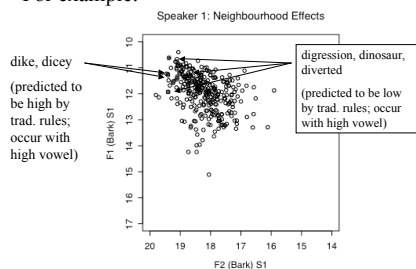
- For all speakers, almost all words with the biphones /dai/, /dʒai/, and /sai/ have a *high* vowel (or one that fell into the middle (ignored) 50%) -- regardless of the rest of the phonological predictions of these words.
- e.g. dicey, diverted, dididactically -- [d^i]
- e.g. gigantic, gigantically, angina -- [dʒ^i]
- e.g. sight, exciting, bauxite, psychological, psychology, Siberia -- [s^i]

(NB: underlined words are those that patterned unexpectedly with respect to traditional phonological rules)

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### Phonological Neighbourhood: Results

- For example:



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### Phonological Neighbourhood: Results

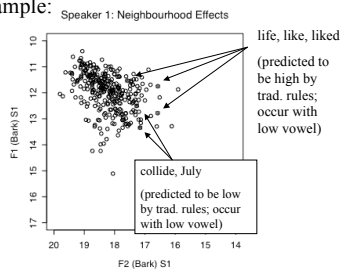
- For all speakers, almost all words with the biphone /lai/ have a *low* vowel (or one that fell into the middle (ignored) 50%) -- regardless of the rest of the phonological predictions of these words.
- e.g. collide, July, like, life -- [lai]

(NB: underlined words are those that patterned unexpectedly with respect to traditional phonological rules)

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## Phonological Neighbourhood: Results

- For example:



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## Phonological Neighbourhood: Results

- Despite variation across speakers, consistency holds within a given speaker:
- e.g. for speaker 1, almost all words with the biphone /hai/ have a *low* vowel (or one that fell into the middle (ignored) 50%) -- regardless of the rest of the phonological predictions of these words
- e.g. high, hypothesis, hype, hypercritical -- [hai]

(NB: underlined words are those that patterned unexpectedly with respect to traditional phonological rules)

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## Phonological Neighbourhood: Results

- Similarly: for speaker 2, almost all words with the biphone /nai/ have a *high* vowel (or one that fell into the middle (ignored) 50%) -- regardless of the rest of the phonological predictions of these words.
- e.g. united, nitroglycerine, nine, nineteen -- [n<sup>h</sup>i]

(NB: underlined words are those that patterned unexpectedly with respect to traditional phonological rules)

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## Phonological Neighbourhood

- Effect of adding biphone neighbourhoods as a predictor:
- Of the 31% that were “wrong” under traditional models:
- Speaker 1: 37 / 43 words (86%) accounted for
- Speaker 2: 36 / 54 words (67%) accounted for
- Speaker 3: 26 / 44 words (59%) accounted for

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## Phonological Neighbourhood: Results

- These patterns suggest that speakers are forming generalizations about subsets of words in the lexicon.
- How are these generalizations formed?

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**Proposal: A lexical neighbourhood “anchor” determines the CR pattern for all members of its biphone neighbourhood.**

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## Phonological Neighbourhood

- **Lexical neighbourhood:** defined by sets of words with the same biphone.
- **Neighbourhood anchor:** A particular chosen word from a lexical neighbourhood.
- The traditional phonological rule applies as expected to the anchor. Then, the other words in the neighbourhood follow the lead of the anchor, regardless of the expected pattern of their own phonological environment.

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## Phonological Neighbourhood

- For example: use frequency to determine anchor. In CELEX, highest frequency word with /dʒai/ biphone is *meningitis*. This is chosen as the lexical anchor for the /dʒai/ neighbourhood.
- Traditional phonological rule: predicts [ʰi] in *meningitis* because of tautosyllabic /t/.
- Other words in neighbourhood -- e.g. *gigantic*, *angina* -- have a high vowel [ʰi] by analogy with the anchor.

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## Interim Summary: Observations to Be Accounted For

- /ai/ vowels are not clearly separated into two types
- traditional phonological rules do not account for 31% of the data for each speaker
- phonological biphone similarity defines neighbourhoods that pattern together regardless of traditional predictions, and can account for 60-85% of the “aberrant” forms
- neighbourhoods are consistent within a speaker but may vary across speakers
- neighbourhoods may pattern together on the basis of a single neighbourhood “anchor”

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## Modelling Canadian Raising

| Factor                     | Effect  |
|----------------------------|---|
| Following segment          | Voiceless segment =<br><i>higher vowel</i>                                  |
| Syllabification            | Closed syllable =<br><i>higher vowel</i>                                    |
| Stress                     | Followed by lesser stress =<br><i>higher vowel</i>                          |
| Phonological neighbourhood | Shares biphone with high frequency high vowel word =<br><i>higher vowel</i> |

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## Modelling Canadian Raising

- As with variable rules (e.g. Sankoff 1988, Guy 2003), these factors can be modelled with a regression model.
- The *gradient* F1/F2 value of a particular token of /ai/ can be estimated by taking into account each factor’s contribution in a particular word.

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## Modelling Canadian Raising

- For example:  
 $(F1 \& F2) = \text{Baseline} + \text{Phonological Parameters (voicing, syllabification, stress)} + \text{Lexical Parameters (neighbourhood, frequency)} + \dots$
- these factors compete with each other but *all* contribute to actual phonetic output

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## Accounting for Canadian Raising in a Model of Grammar

- How does a regression equation fit into a model of grammar?
- Exemplar Model -- e.g. Johnson (1997), Goldinger (1997), Pierrehumbert (2001, 2003)
- All tokens of utterances encountered are stored in the lexicon; grammar is made up of generalizations over the lexicon.
- Finely grained details -- including token frequency -- are kept track of automatically.

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## An Exemplar Approach to CR

- Neighbourhood effects are easily accounted for in this approach. Grammar itself is composed of generalizations or “similarity matching” across tokens.
- Having words that share particular biphones pattern together is expected, and the frequency of these biphones can play a role in determining generalizations.
- Similarly, other patterns across lexical items (e.g. voicing of following segment, stress, syllabification) can play a role.

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## An Exemplar Approach to CR

- This model also PREDICTS variation across speakers.
- Each person’s experiences shape the frequencies with which they encounter particular words and the generalizations that they make across those words.

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## Conclusions

- Assumptions of traditional rules not always well-founded (CR: no categorical difference; not in all environments)
- CR does not always occur as predicted in literature
- Productions are generally consistent within a speaker, but may vary across speakers
- Phonological similarity as determined by biphones significantly improves the account of CR
- All of the relevant factors can be modelled in an exemplar approach to grammar
- Other factors (e.g. greater domains of phonological similarity, duration, semantic / morphological relatedness, age, sex, socioeconomic status, etc.) also easily incorporated

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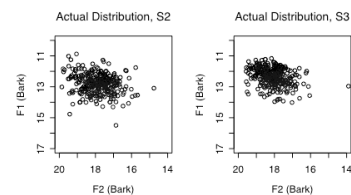
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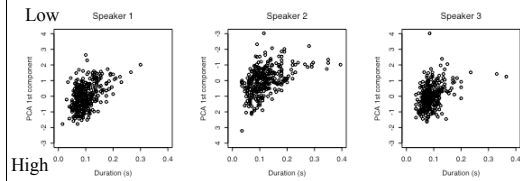
## Actual Distribution: Overlap of “High” and “Low” Vowels (S2, S3)

Black = predicted “high”  
Red = predicted “low”



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## Duration



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## Duration

- Duration may certainly play a role in distinguishing high and low vowels.
- Faster duration associated with higher vowel.
- Duration cannot serve to completely disambiguate “high” and “low” vowels; for example, there are vowels that are very clearly low in terms of formant structure and very clearly sound like low vowels, but which are shorter than any of the “high” vowels.

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## Task Differences

- Narrative tended to produce faster, more natural speech than wordlist.
- Some words were produced the same way across tasks:
  - e.g. *lifelike* [laɪf]- and *excited* [ɛks^ɪrəd]

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## Task Differences

- But -- if the quality of the vowel in a given word differed between the narrative and the wordlist, it was always higher in the narrative:
  - e.g. *ice*: [aɪs] on the wordlist, [^ɪs] in the narrative for all three speakers

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## Task Differences

- These differences could be “undershoot” in the narrative task resulting in [^ɪ] and/or “careful speech” in the wordlist resulting in [aɪ].
- Implies that phonological rule is affected by speech rate and does not apply across the board.
- Does not explain why all words are not the same: why is *ice* affected while *life* is not?

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