

Weighing Phonetic Patterns in Non-Native English Speech

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Dissertation Defense 2019

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Everyone has an “accent”.

Non-native speakers have a “*Foreign Accent*”.

We want to know:

- what makes a non-native speech foreign-accented.
- and Why

❶ Foreign Accent

*The **perceivable** deviation of non-native speech from the native speech norm .*

(Munro & Derwing, 1998, pp.66)

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❷ Accentedness Perception

Native (L1) listeners can detect foreign accent even in very short non-native (L2) speech samples

30ms-long stimuli (Flege, 1984), ERP N100 (Steinschneider et. al., 1999)

Research Questions

We focus specifically on segmental and structural aspects of L2 speech.

We ask:

- 1 Do some phonetic/phonological patterns in L2 speech contribute more to **foreign accent** than others?

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- 1 Do some phonetic/phonological patterns in L2 speech contribute more to **foreign accent** than others?
- 2 Why some phonetic/phonological patterns are more accented than others?

Theoretical and Practical Importance

The “So What?” question

- ① The nature of foreign accent and its relationship with L1 grammar

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- ② Help English teachers/learners
- ③ Help design improved speech analysis algorithm

Background: Findings in Previous Research

- Consonant errors affect accentedness

VOT, Liquids

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- Vowels are complicated

Duration, Formants, Vowel space

(Major, 1987;McCullough,2013;Chan, Hall, and Assgari,2016)

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(Major, 1987; McCullough, 2013; Chan, Hall, and Assgari, 2016)

- What about syllables?

Segment Insertion, Segment Deletion

(Magen, 1998; Van Den Doel, 2006)

Background: the Ranking of “Errors”

Magen (1998):speaker 1

Epenthetic schwa, -ed ending, **tense-lax**, final/s/, tʃ to ʃ, lexical and phrasal stress

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Stop voicing,/s/ to /z/, vowel reduction

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Magen (1998):speaker 2

Epenthetic schwa, final/s/, tʃ to ʃ, lexical and phrasal stress

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Stop voicing,/s/ to /z/, vowel reduction, **tense-lax**

Background: the Ranking of “Errors”

Van Den Doel (2006): 222 American Listeners

Lexical Stress, Uvular-r >>

Voicing, Epenthesis in /lm/, /w/ to /v/, /æ/ to /e/ >>

Coda deletion in ”off” and ”that” >>

VOT shortening on /t^h/, /ʌ/ to /ɑ/, intonation >>

yod-insertion in ”news”

Background: Limitations

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We are going to fix (avoid) these problems!

Previous research has found that

- Some patterns are more accented than others.

But Why?

3 potential reasons:

① Occurrences in L1 Speech

L1 dialectal variations vs. non-dialectal variations

”ask”/æsk/ vs. /æks/ vs. /æskə/; ”five”/faɪv/ vs. /fa:v/ vs. /fav/

② Perceptual Categorizability

The perception of consonants, especially obstruent consonants, is relatively more categorical while the perception of vowels is relatively more continuous.

(Altmann et al., 2014; Kronrod et al., 2012)

③ Lexical Identification

Consonants are more important than vowels in lexical identification (Nespor et al., 2003)

- Does **Frequency of Occurrences** of a pattern in L1 speech affect accentedness?

Word	Pronunciations	Frequency
thick	[θɪk]	91%
	[θɪkʰ]	5%
	[θɪk]	2%
	[tɪk]	2%

Table 1: L1 Pronunciations for “thick” (SAA)

Background: Rationale

- Does the **Categorizability of Segments** affect accentedness?

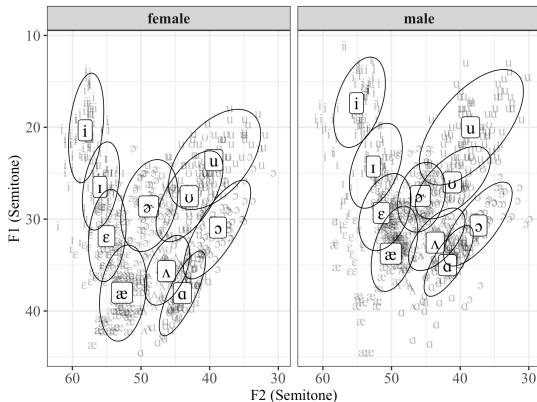


Figure 1: L1 Vowel Space (Peterson & Barney, 1952)

- Does **Lexical Identification** play a role?

Pronunciation	Consonant Change	Vowel Change
['ʒ.mi]	early	army
['ɛltəmət]	estimate	ultimate
[dɪ 'zɔɪt]	resort	dessert
['kʰibrə]	zebra	cobra

Table 2: Word Reconstruction Test (van Ooijen, 1996)

['ʒ.mi] → Early or Army?

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Table 2: Word Reconstruction Test (van Ooijen, 1996)

- 1 **Vowel Changes** are preferred (van Ooijen, 1996)
-> Vowel changes are more tolerable ?
- 2 Vowel changes are less accented?

Background: Summary

- ① L1 speech exhibits variations (Dialectal and Contextual)
(e.g., coda-deletion, /θ/ -> /t/, /faɪv/ -> /fa:v/)
-> Are they less accented?

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- ① L1 speech exhibits variations (Dialectal and Contextual)
(e.g., coda-deletion, /θ/ -> /t/, /faɪv/ -> /fa:v/)
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- ② Vowel changes are less likely to be perceived as a categorical change
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-> Are they less accented?
- ② Vowel changes are less likely to be perceived as a categorical change
-> Vowel changes could be less accented?
- ③ Consonants are more important in lexical identification.
-> Consonant changes could be more accented?

- ① Experiment 1:
a pilot study, collecting accentedness ratings on 100 L2 stimuli

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a pilot study, collecting accentedness ratings on 100 L2 stimuli
- ② Experiment 2:
(1) added a training phase, controlled for intelligibility, (2) provided accentedness rankings, (3) hypothesized potential reasons for accentedness judgement
- ③ Experiment 3:
(1) modelled L1 phonetic/phonological knowledge, (2) investigated potential reasons for accentedness judgment

Experiment 1: Tasks

- ① Design a perception study to obtain accentedness ratings;
- ② Rank the phonetic/phonological patterns by accentedness;

Experiment 1: Stimuli Design

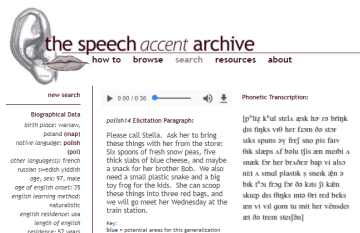
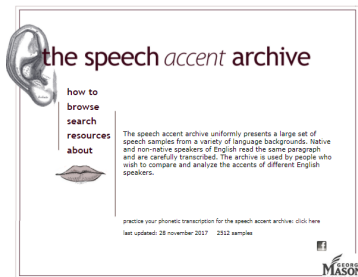
Stimuli:

- One potential “error” per stimulus
- A larger variety of potential “errors”
- No prosody manipulation

Experiment 1: Corpus

Stimuli collection:

Natural speech samples from the Speech Accent Achieve (Weinberger, 2019)



accent.gmu.edu

Experiment 1: Stimuli Classification

Stimuli Classification:

- **References:** The most common L1 productions (L1 targets)
(e.g., [θɪk] for “thick”)

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- **Match:** L2 Stimuli that **match** the L1 targets (i.e., [θɪk])

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Stimuli Classification:

- **References:** The most common L1 productions (L1 targets)
(e.g., [θɪk] for “thick”)
- **Match:** L2 Stimuli that **match** the L1 targets (i.e., [θɪk])
- **Mismatch:** L1 stimuli that **differ** from the L1 targets by **only one** element
 - ① Consonant Mismatch (e.g., [tɪk])
 - ② Vowel Mismatch (e.g., [θik])
 - ③ Syllable Mismatch (e.g., [æskə])

Experiment 1: Stimuli Examples

Stimuli Illustration:

Table 3: Types of Stimuli

Contexts	Match	Consonant	Vowel	Syllable
please call	[p ^h liz k ^h al]	[p ^h liz k ^h al]	[p ^h liz k ^h oɪ]	[p ^h əliz k ^h al]
ask her	[æsk (h)əɪ]	[æsk həɪ]	[a ^h sk həɪ]	[æs_ həɪ]
six spoons	[sɪks spunz]	[sɪks spun ^h]	[sɪks spunz]	[sɪks əspunz]
five thick	[faɪv θɪk]	[faɪv tɪk]	[fa ^h v θɪk]	[faɪvə θɪk]
small plastic	[smal p ^h læstɪk]	[smal ^h p ^h læstɪk]	[smal p ^h læstɪk]	[smal p ^h læs_ɪk]

All transcriptions were verified via acoustic analysis of the sound files

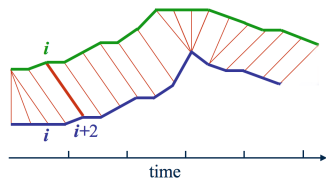
Experiment 1: Prosody

Control prosody in the least intrusive manner.

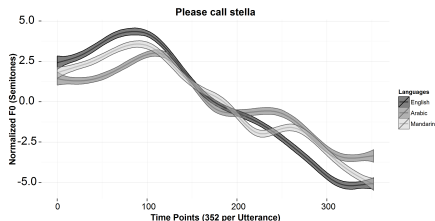
Prosody is a **CONTROLLING** variable.

Method: Dynamic Time Warping (DTW)

- No acoustic manipulation required
- Align F0 contours of two utterances
- Produce a DTW score which represents alignment cost
- The bigger the DTW score, bigger the intonational difference



(Tsiporkova, 2007)



(Morrill & Gao, 2016)

Experiment 1: Procedure

- Platform: Amazon Mechanical Turk
- Requirements for participants: US IPs, at least 95% acceptance rate.
- Procedure:

Introduction

This experiment will ask you to listen to samples of sound snippets. You'll be asked to judge whether the snippets are foreign-accented. It will take about 15 minutes to complete and you will be paid \$0.50 for your time. This experiment is part of a series of studies being conducted by Dr. Steven Weinberger at George Mason University. The elicitation of speech samples has been approved by the George Mason Institutional Review Board.

Clicking on the **agree** button below indicates that:

- you voluntarily agree to participate
- you are at least 18 years of age
- you are a native speaker of English
- you will use headphones/earbuds to listen to the sound files

If you do not agree to all of these, please close this window in your browser now.

This experiment requires you to listen to AUDIO. If your browser does not support audio, or you are not in a quiet place, please do not agree to participate in this HIT. Also, PLEASE DO NOT PARTICIPATE IN THIS HIT MORE THAN ONCE -- we cannot pay duplicate HITs!

Agree

Experiment 1: Procedure

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Instruction

Welcome!

In this experiment, you will hear samples of audio snippets.
The snippets were spoken by people with various language backgrounds.

Your task is to identify whether the speech has a foreign accent and the degree of the speaker's accent.
Click Continue to start the experiment.

Continue

Experiment 1: Procedure

- Platform: Amazon Mechanical Turk
- Requirements for participants: US IPs, at least 95% acceptance rate.
- Procedure:

Trials: Listen to snippets (Block Randomization)

Click on the button to listen to the audio file.
After that, you will be able to enter your response.

You'll be asked to judge the degree of the speaker's foreign accent.

- 1 means the speaker has "no foreign accent at all";
- 9 means the speaker has a "very heavy foreign accent".

You can only listen to each audio once.

Click to Listen

Experiment 1: Procedure

- Platform: Amazon Mechanical Turk
- Requirements for participants: US IPs, at least 95% acceptance rate.
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Trials: Make accentedness judgment

Click on the button to listen to the audio file.
After that, you will be able to enter your response.

You'll be asked to judge the degree of the speaker's foreign accent.

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1 2 3 4 5 6 7 8 9

no foreign accent at all very heavy foreign accent

next

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Demographics

Please provide us with some information about you and how you did the experiment. We will keep this information private (it will not be associated with your worker id), and it will help us very much when we analyze the data.

Gender

☐ female ☐ male

Age

Language background

List your native language

List any other languages you speak

Please tell us your occupation.

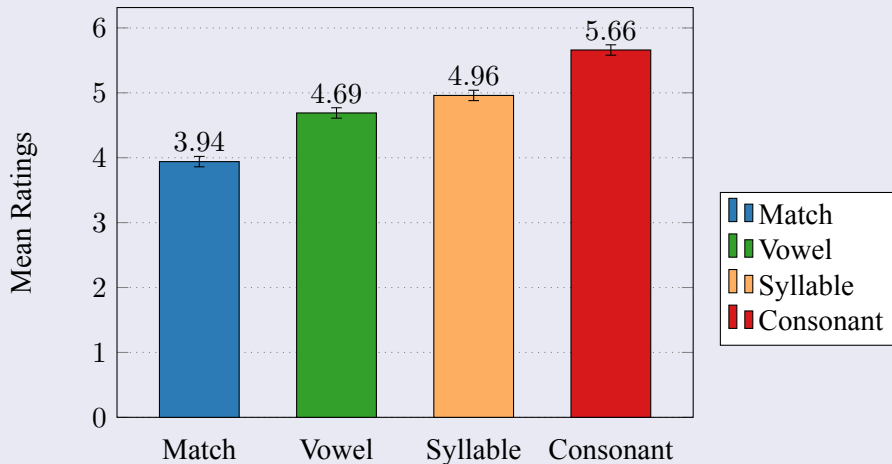
Please tell us your birth place (city/state/country).

Experiment 1: Rater Demographics

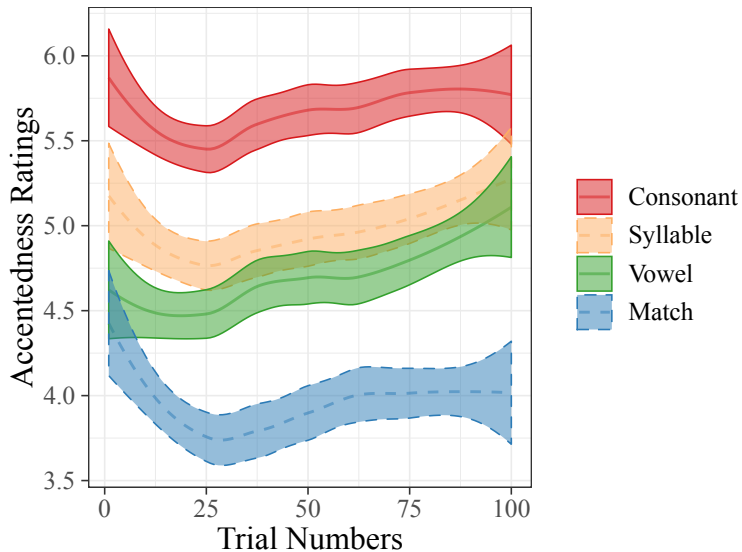
- 108 Participants (L1 American English Speakers)
- Male:61, Female:45, 2 did not report
- Age: range 20-66 (M=33.50, SD=12.51)
- Completion Time: M=12.33 min, SD=3.2 min;
Maximum time allowed:30 min

Experiment 1: Results

Mean Ratings by Type



Experiment 1: Ratings across Time



Experiment 1: General Findings

Mixed-effects linear model:

Fixed effects: Types of stimuli (contrast-coded), DTW, Trial Number;

Random effects: (Type of stimuli) Subjects, Stimuli

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($\chi^2=6.35$, $p < .05$)

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- 4 Ratings increased over time. ($\chi^2=46.80$, $p < .001$)

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- 5 DTW and the interactions between trial and type of stimuli did not contribute significantly to model fit.

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Problems

- No training phase
- Intelligibility/Comprehensibility (e.g., six spoons vs. seeks spoons)
- Chances for a “mismatch” to exist in L1 speech (e.g., “thick” /tɪk/ vs. /stɪk/)

Experiment 2: Research Design

Aim: fix methodological problems in Experiment 1

- No training phase → add a training phase with 10 stimuli

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- Chances for a “mismatch” to exist in L1 speech → deal with this in **Experiment 3**

Experiment 2: Procedure

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You'll be asked to judge the degree of the speaker's foreign accent.

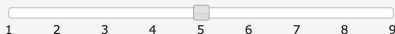
- 1 means the speaker has "no foreign accent at all";
- 9 means the speaker has a "very heavy foreign accent".

You can listen to each audio **only once**. You are going to hear:

ask her

Click to Listen

No foreign accent at all



Very heavy foreign accent

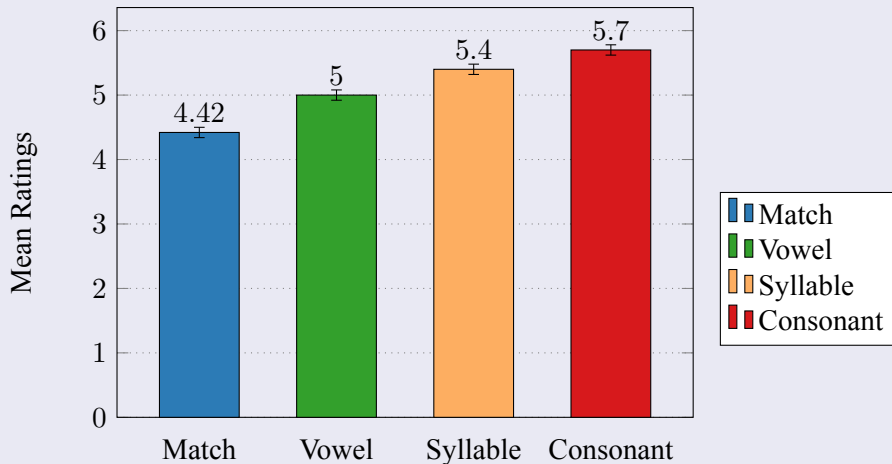
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Experiment 2: Rater Demographics

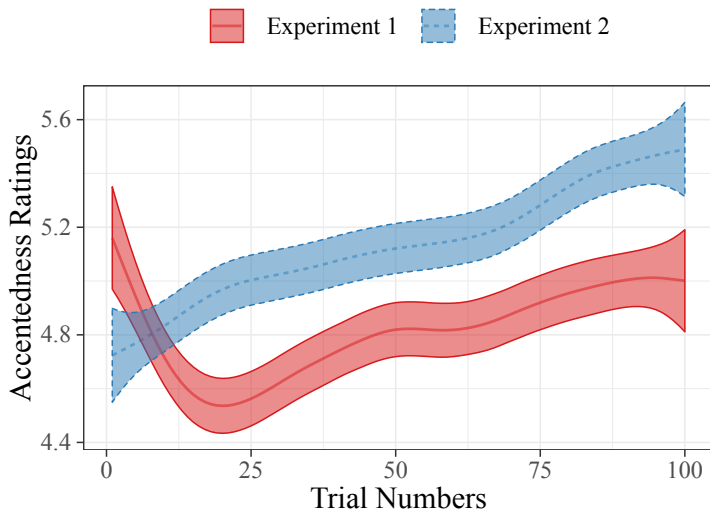
- 133 participants (L1 American English speakers)
- Male:68, Female:58, 7 did not report
- Age: range 19-69 (M=38.42, SD=11.84)
- Completion Time: M=15.96 min, SD=5.47 min;
Maximum time allowed:40 min

Experiment 2: Results

Meaning Ratings by Type



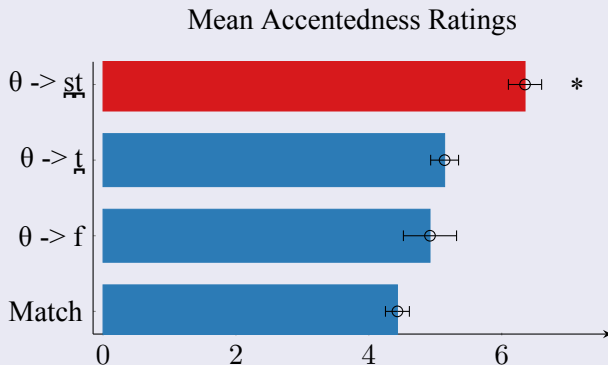
Experiment 2: Ratings across Time (SSANOVA)



Experiment 2: L1 Dialectal vs. Non-dialectal

$\theta \rightarrow$ st is more accented than $\theta \rightarrow$ t and $\theta \rightarrow$ f

/θ/ changes in “five thick”

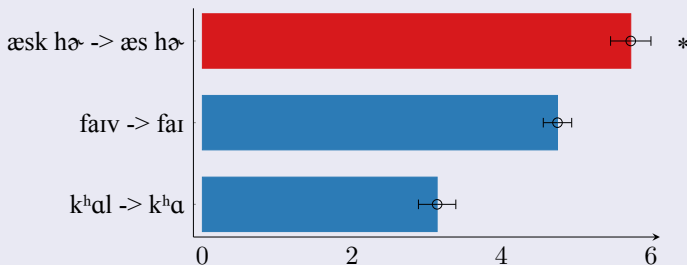


Experiment 2: Phonological Environment

/k/-deletion in “ask her” vs. other coda deletions

Coda Deletions

Mean Accentedness Ratings

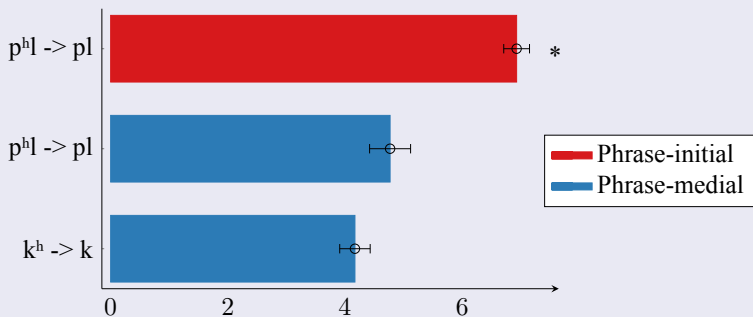


Experiment 2: Phonological Environment

Phrase-Initial vs. Phrase-Medial VOT-shortening

VOT-shortenings

Mean Accentedness Ratings



What affects accentedness judgment?

1 Lexical Information

Ratings became higher when the intended meanings were known.

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3 Phonological environment

e.g., /k/-deletion in “ask her”,

Phrase-initial vs. phrase-medial VOT-shortening

Experiment 3: Introduction

Hypothesis:

(1) Lexical information
(2) Occurrences in L1 speech
(3) Phonological environment

} L1 Knowledge → Accent judgment

Aim:

Build a computational model to verify that L1 knowledge affects accentedness judgment.

Experiment 3: Method

The Naïve Discriminative Learning Model (**NDL Model**)

(Wieling et al. 2014; Bayaan, 2011)

Rescorla-Wagner learning theory (1972): learners attempt to predict an outcome based on available cues.

Cue: Four-legged

Outcomes: Puppy, Kitten, Table, Chair etc.

Association Strength (Weight):

How probably the cue “Four-legged” can predict outcome “Puppy”.

Experiment 3: Method

Data: Productions from 100 L1 American English Speakers

Cues: Trigram sequences

Outcomes: Words

Table 4: Association Strengths

Cues	Outcomes	Association Strengths
#æs	ask	0.166
æsk	ask	0.167
sk#	ask	0.667
#æ̩s	ask	0.147
æ̩sk	ask	0.147
#ə#	her	1.000
#hə	her	0.500
hə#	her	0.500

Experiment 3: Method

Reasons for using Trigram cues:

- 1 **Three-member sequence:** English phonotactics, sound changes in continuous speech
- 2 **Include diacritics:** Sub-phonemic information ([æ] and [ɤ] are two independent segments)
- 3 **Lexical outcomes:** Lexical information

Experiment 3: Method

Pronunciation	Association Strength	NDL-distance
[æsk.ə]	$(0.166 + 0.167 + 0.667 + 1.000) \div 2 = 1.000$	$1 - 1.000 = 0.000$
[æsk.ə]	$(0.147 + 0.147 + 0.667 + 1.000) \div 2 = 0.980$	$1 - 0.980 = 0.020$
[ask.hə]	$(0 + 0 + 0.667 + 0.500 + 0.500) \div 2 = 0.834$	$1 - 0.834 = 0.166$

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Cues	Outcomes	Association Strengths
#æs	ask	0.166
æsk	ask	0.167
sk#	ask	0.667
#æsk	ask	0.147
æsk	ask	0.147
#ə#	her	1.000
#hə	her	0.500
hə#	her	0.500

Experiment 3: The NDL model

Try out the NDL model at

https://gaozhiyan.shinyapps.io/ndl_calculator/

A Web Application

NDL-Calculator

Phonological Similarity Estimation

By [Zhiyan Gao](#) • Data Available on [the Speech Accent Archive](#)

[About](#) [Calculator](#) [User Guide](#) [References](#)

Calculator:

Words (e.g. Please call Stella)

Pronunciations (e.g. pʰlɪs kɔl ɪstɛlə)

Iterations

RUN

NDL Phonological Similarity:

99%

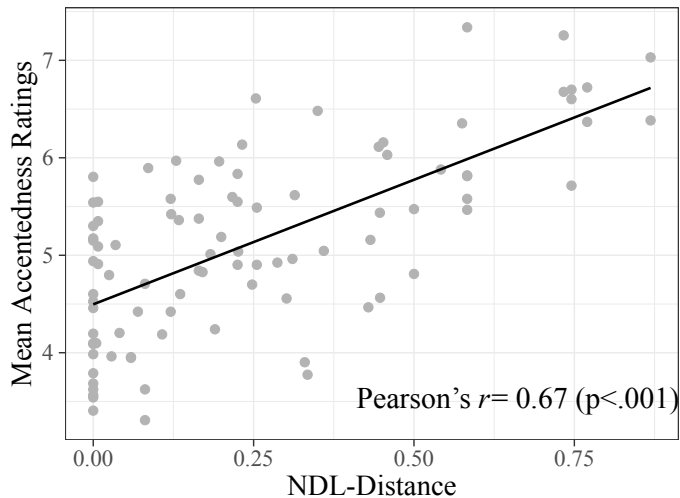
Top 5 Native Variations of American English

Show entries Search:

Words	Pronunciation	Percentage
five	faɪv	49%
five	fa:v	12%
five	faiy	10%
five	faɪf	5%
five	fa:y	4%

Showing 1 to 5 of 5 entries Previous Next

Experiment 3: Results



Experiment 3: Results

Linear Mixed-effects model:

- fixed effects: NDL-distance, Type of Stimuli (Contrast-coded), Trial Number, DTW scores
- Random effects: (Type of Stimuli) Raters, stimuli

Experiment 3: Results

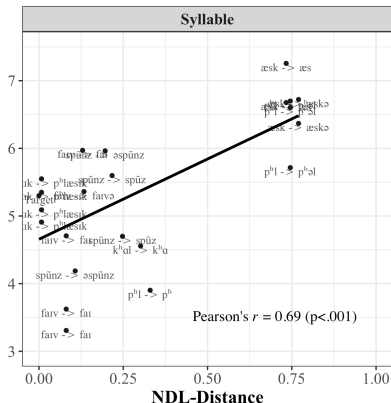
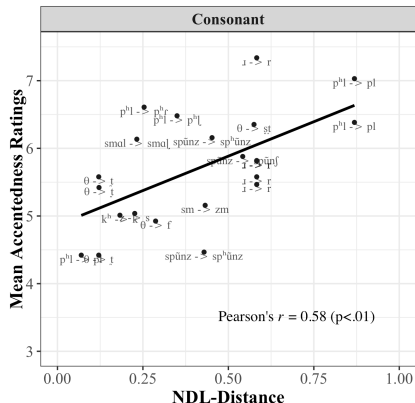
Linear Mixed-effects model:

- fixed effects: NDL-distance, Type of Stimuli (Contrast-coded), Trial Number, DTW scores
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Results:

- NDL-distances significantly contributed to model fit ($\beta = 1.74$, $\chi^2 = 8.79$, $p < .01$)
- The three stimuli contrasts did not contribute significantly to model fit.
- Trial number contributed significantly to model fit ($\beta = 0.6$, $\chi^2 = 72.24$, $p < .001$),

Experiment 3: Consonants & Syllable

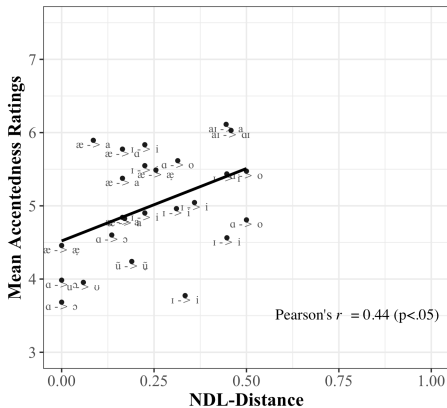


Observations:

Clear positive correlation.

Not that good for non-English sounds (e.g., retroflex [ɭ])

Experiment 3: Vowels



Observations:
Positive correlation.
Restricted Range

Experiment 3: Variability of Segments

Words	Pronunciations	Frequency	Outcomes	Cues	Strengths
small	[smal ^v]	41%	small	#sm	0.712
small	[smɔl]	16%	small	sma	0.078
small	[smɔl ^v]	14%	small	mal ^v	0.094
small	[smaʊl]	4%	small	al ^v #	0.094
small	[sma:l ^v]	4%			

- Vowels are more variable in L1 speech than consonants
- Trigrams involving vowels have smaller association strengths

Vowel changes affect association strength **less**;

Consonant changes affect association strength **more**

The effect of syllable changes depends on whether consonants are affected

Experiment 3: Summary

- Experiment 3 modeled raters' L1 phonetic and phonological knowledge of the 5 contexts.

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- Experiment 3 modeled raters' L1 phonetic and phonological knowledge of the 5 contexts.
- The model achieved moderate success in approximating raters' accentedness judgments.
- Consonant changes are not necessarily more accented than syllable or vowel changes.

Research Questions:

- 1 Do some phonetic/phonological patterns contribute more to accent than others?
- 2 Why some phonetic/phonological patterns are more accented than others?

The Current Study: Conclusions

Experiment 1 & 2:

- 1 Do some phonetic/phonological patterns contribute more to accent than others? **YES!**
 - 2 Why some phonetic/phonological patterns are more accented than others?
 - (1) Lexical information
 - (2) Occurrences in L1 speech
 - (3) Phonological environment
- } L1 Knowledge

The Current Study: Conclusions

Experiment 3:

Modeled L1 knowledge based on

1 lexical outcome:

(lexical information)

2 Trigram cues:

(occurrences & phonological/phonetic constraints)

3 Diacritics:

(sub-phonemic information)

Conclusion:

L1 knowledge, as modeled by the NDL model, potentially governs foreign accent perception.

The Current Study: Limitations & Future Directions

Acoustic information:

1 Reliability of the IPA transcriptions

(We measured benchmark acoustic signals, but that is not enough)

2 Effects of sub-phonemic acoustic information on accentedness

(We conducted some analyses, results are not conclusive)

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Sociolinguistic issues

4 Raters' own L1 dialects and familiarity of certain L2 accents

5 Other factors: age, gender, educational attainment, etc

6 Reliability of online experiments.

This dissertation contributes to the field of foreign accent by providing accentedness rankings of various phonetic patterns in L2 speech.

In lieu of ad hoc explanations for why some phonetic patterns are more accented than others, this dissertation directly examines how raters' L1 knowledge affected their accentedness judgment on L2 speech, providing insights into the nature of foreign accent perception.

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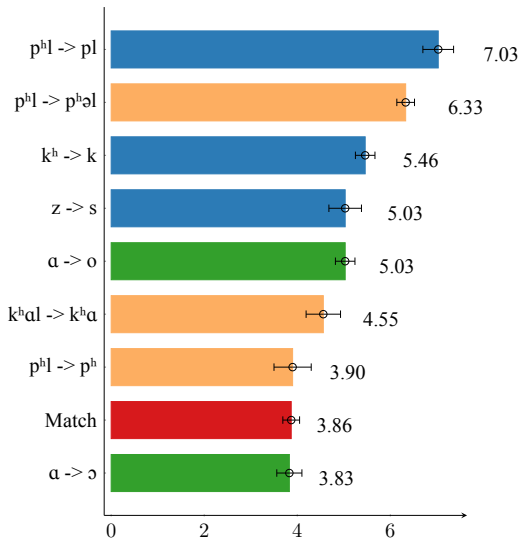
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Thank You!

Acoustic Verification

Experiment 2: Rankings

Mean Accentedness Ratings



Ranking 1:

$p^{hl} \rightarrow pl$; $p^{hl} \rightarrow p^{həl}$

↓

$z \rightarrow s$; $a \rightarrow ɔ$

↓

$a \rightarrow ɔ$; Match

Ranking 2:

$p^{hl} \rightarrow pl$

↓

$k^h \rightarrow k$

↓

$a \rightarrow ɔ$; Match; $p^{hl} \rightarrow p^h$; $k^{həl} \rightarrow k^hɑ$

Ranking 3:

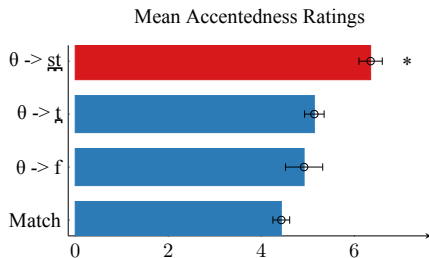
$p^{hl} \rightarrow p^{həl}$; $k^h \rightarrow k$

↓

$a \rightarrow ɔ$; Match; $p^{hl} \rightarrow p^h$; $k^{həl} \rightarrow k^hɑ$

$z \rightarrow s$; $a \rightarrow ɔ$; $k^h \rightarrow k$ (No significant difference)

Experiment 2: Rankings



Ranking 1:

θ -> st
↓
farv -> farvə; θɪk -> θɪk
↓
farv -> far; Match

Ranking 2:

θ -> st
↓
farv -> far; Match; θ -> f; θ -> t

Ranking 3:

aɪ -> aɪ; aɪ -> a
↓
farv -> far; Match; θ -> f

aɪ -> aɪ; aɪ -> a; farv -> farvə; θɪk -> θɪk (no significant difference)

Ratings across the US