Perceptual Assimilation Reflects Native Phonetic-Phonological Mapping: Perceiving and Adapting to Regional Accent Differences in Native English

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Native language attunement

- **What we know**: Native language (L1) experience:
  - exquisitely shapes perception of phonemes/contrasts
  - guides acquisition and recognition of spoken words

- **Core Questions** re: these experience-based effects

  1. **What do we learn from native speech experience?**
     
     **Premise 1**: Language-environment-specific relationships (”’mappings’”) between surface *phonetic* patterns and more abstract *phonological* forms: words, phonemes

  2. **How do we learn those relationships?**
     
     **Premise 2**: Naturally-occurring *phonetic variation* in spoken language input is essential to perceivers’ discovery of native *phonetic-phonological relationships*
First core reason phonetic variation is central to perceptual learning:

1. **Necessity**: variability inherent to natural language
   - **Ubiquitous**
     - pervasive across all levels of spoken utterances
   - **Multiple sources** of structured variation in 2 domains
     - *linguistic* (contrasts; phonetic contexts; phonological processes)
     - *indexical* (talkers, regions of origin; emotions, registers & styles)
   - **Systematic**
     - it is *not noise* that needs filtering out or normalizing
     - phonetic variation provides *information*
   - **Word identity**: *nexus of linguistic and indexical variation*
     - constant, abstract *phonological form* for a given referent
     - recognizable in the face of *indexically-important* – but *lexically-irrelevant* – phonetic variations
Second reason phonetic variation is central to perceptual learning:

2. **Logic:**
   - Two **complementary** principles identify the relationship between phonetic variants and phonological forms:
     - **Phonological Distinctiveness**
       - *Contrastive functions:* linguistic
       - Phonetic differences that *do* alter phoneme/word identity, e.g., BEES [piz] ≠ PEAS [pʰɪz] nor BUYS [pɑɪz]
     - **Phonological Constancy**
       - *Categorical functions:* indexical ∩ linguistic
       - Phonetic differences that *do not* alter word identity, e.g., American SHUTTER [ʃʌtə] = Yorkshire SHUTTER [ʃuːtə]
Word and phoneme recognition across native regional accents

- Regional accent
  - a major source of within-language variation
  - systematic phonetic realizations shared by talkers of a given socio-geographically defined community
  - adults quite sensitive to accent as *indexical* info re: talkers
  - yet they also recognize *words* across regional accents

☞ phonological constancy & phonological distinctiveness

phonological constancy

\[
[eɪt] \quad [æɪt] = \text{“eight”}
\]

phonological distinctiveness

\[
[æət] \quad [ɪət] = \text{“eight”}
\]
Research on spoken word recognition

- **Phonological Distinctiveness** has been the focus of many studies of spoken word recognition
  - phonetic changes that turn one word to another:
    - LED vs RED or LID
  - or change a word to a nonword:
    - THANK vs *FANK or *THONK
  - ✓ Phonetic change
  - ✓ Phonological change

- **Phonological Constancy**
  - phonetic changes that don’t change word identity or phonological structure
  - ✓ Phonetic change
  - ✗ Phonological change
  - research on this examines effects of indexical information:
    - talker-specific effects: faster recog if known/same talker(s)
    - similar for the fewer studies on accent-specific effects

- **L1 adults**: rapid, automatic, robust lexical access
  - ✫ **L2**: slower, less accurate, hindered by noise, talker & accent diffs
L1 Assimilation across accent variation?

Cross-language speech perception research
- non-native phones are perceptually assimilated to native phonemes
- with some sensitivity to within-category variation (goodness of fit)
- perception of some non-native contrasts improves with L2 learning

Native speech perception and word recognition
- systematically affected by talker-specific information in speech
- talker-specific phoneme adaptation generalizes to new words
- actual or imputed regional accent affects phoneme perception
- accent adaptation should generalize across words and talkers

How does perceptual assimilation organize native speech perception across regional accent variation?
Perceptual Assimilation of accent variation when perceiving native phonemes and words

Perceptual Assimilation Model:

NATIVE PHONOLOGICAL SPACE

Assimilated as Nativelike

Assimilated as Category Shift: different phonemes in listener’s versus speaker’s accent

Assimilated as Category Goodness

Difference: same phoneme in both accents

UnCategorized Assimilation: partial assimilation to multiple phonemes

Best et al., 2014; 2015a, b; Shaw et al., 2014
Vowel spaces in two English accents: Australian (AusE) / Newcastle UK (NCL)
FLEECE and CHOICE vowels in NCL and AusE: *Nativelike (NL)*
DRESS and MOUTH vowels in NCL and AusE: *Category Goodness (CG)*
GOAT vowel in NCL vs AusE: Category Shift (CS)
Lack of FOOT-STRUT split in NCL: *Nativelike (NL) vs. Category Shift (CS)*
FACE vowel in NCL vs Aus:

UnCategorized (UC)/Category Shifting (CS)
Perceptual Assimilation to L1 accent (A1)

Perceptual assimilation task
- vowels of an unfamiliar accent will assimilate to A1 vowels
  - Nativelike: NL
  - Category Goodness assimilation: CG
  - Category Shifting assimilation: CS
  - UnCategorised assimilation: UC
- natural variation: real accents, untrained talkers, full V system
- phonetic focus: nonce words with keyword vowel choices
- accent-level focus: multiple talkers (2♀, 2♂) & tokens (2 per)

Perceptual orientation to A1: the native accent
- pre-exposure to meaningful A1 multi-talker passage should:
  - enhance A1 listening and assimilation to A1 vowels
  - yield a range of NL, CG, CS, UC assimilations
- different talkers than Perc Assim task: accent level focus
RESULTS: Vowel assimilation patterns

Australian

Newcastle UK

Uncategorized, with \textit{wrong} top choice (CS) \approx split between 2+ choices: \textit{SQUARE}, \textit{NEAR}, \textit{STRUT}, \textit{GOOSE}, \textit{SQUARE}, \textit{NEAR}, \textit{CURE}
Perceptual Assimilation index: **Accuracy’**

\[
\text{Accuracy’} = r_t \times \frac{P(c_t|s_t)}{P(c_t)} - \sum_{i=1}^{18} r_i \times \frac{P(c_i|s_t)}{P(c_i)}
\]

- conditional probability of categorizing target V correctly
- minus the sum of conditional probabilities of incorrect categorizations to each of the remaining V choices
- each weighted by observed goodness ratings
- **NOTE**: Accuracy’ can thus be negative, i.e., < 0
  - **CS** (Category Shifting)
  - **UC** (UnCategorized)

Accuracy’ simulation with idealized parameters for (left to right): Category Shifting (CS), Uncategorized (UC), Category Goodness (CG), and Native-like (NL) assimilation types
Accuracy’ for AusE listeners assimilations of AusE vs NCL vowels

- Newcastle UK (red) – 11 are Nativelike

hyper-NL hyper-NL
BORED 70% BIRD 80% (vs. 37%)

NCCL

Mean Accuracy

Lexical Set

UC/CS
BAD 20%
bad 15%, pod, bored

UC/CS
BAD 20%
bud 15%, pod, bored

UC/CS
BAD 20%
bard 30%, bud

UC/CS
BARD 42% BIRD 53% 30%
bard, saired, paid

UC/CS
BAED 55% BEOR 60%
bard, saired, paid
Vowels in other non-AusE accents: London (Cockney) & Yorkshire (York)

MONOPHTHONGS

DIPHTHONGS
Accuracy’ for AusE listeners assimilations of AusE vs London vowels

- London “Cockney” (green) – 16 Nativelike

![Graph showing accuracy comparison between Australian and London dialects for various words.]

- UN/CS: bud, bid, bed
- paired, bed, beard: 20%
- CGC/CGCG: 55% (vs. 73%)
- Boulder: 55% (vs. 67%)
- CODE: 55% (vs. 67%)
- POD: 60% (vs. 80%)
Accuracy’ for AusE listeners assimilations of AusE vs York vowels

- York UK (blue) – 14 Nativelike

*hyper-NL BIRD 52% (vs. 37%)*

- UC/CS UC/CS UC/CG UC/CG UC/CS
  - HOOD 40% BAD 40% BAD 41% PAID 30%
  - bud 13%, paid 34%, 57%, bed, bead, bird, code 12%
Word recognition across native regional accents

- Do L1 listeners engage perceptual assimilation when recognizing words spoken in another accent?
- How is word recognition modulated by:
  - assimilation differences between accents:
    - Category Goodness difference (CG)
    - Category Shifting (CS)
  - lexical competitor types
    - main accent difference in VOWEL vs CONSONANT realization
    - main accent difference in word ONSET vs OFFSET
- Do L2 learners show the same effects as L1 listeners for most familiar vs unfamiliar L2 accents?
VOWELS: Australian English (AusE) vs Jamaican Mesolect English (JaME)

Targets selected to differ across AusE & JaME
- mainly in stressed vowel
- by one of the 2 assimilation types

Example words in AusE (2) vs JaME (2):
- **CG assimilation** (Category Goodness difference)
  - 1-syllable: BIRD
  - 2-syllable: ROOKIE
- **CS assimilation** (Category Shifting)
  - 1-syllable: CASK
  - 2-syllable: CARROT

Best, Shaw & Clancy, 2013, Interspeech Proceedings
CONSONANTS: AusE (native) vs London “Cockney” English (CknE)

Targets selected to differ across AusE & CknE:
- mainly in an initial, medial or final consonant
- by one of the 2 assimilation types

Example words in AusE (2) vs CknE (2):
- CG assimilation:
  - 1-syllable: TOE MOAT
  - 2-syllable: ROWING MATTER
- CS assimilation:
  - 1-syllable: TH DRIFT
  - 2-syllable: YOGURT TRAWL

Best, Shaw & Clancy, 2013, Interspeech Proceedings
Visual World Procedure

Tobii x120

Words and central crosshair appear; participant views words and clicks on crosshair

fixation on crosshair causes red box to appear; 200 ms fixation causes audio stimulus to play.

Participant mouse clicks on the word that matches the auditory stimulus.

BEAR  BEERS

+  +

CHEER  LIKED  CHEER  LIKED  CHEER  LIKED

not there
Trial type illustrations:

**JaME**

- **Category Goodness differences (CG)**
  - **LOOK** vowel:
    - JaME [u] ~ AusE [ʊ]

- **Category Shifting differences (CS)**
  - **FAIR → FEAR** vowel:
    - JaME = [iːɹ] → AusE [iːə]

**BOOK**
**BUSH**

not there

**CROOK**
**SIDE**

**DARED**
**DEERS**

not there

**FEARED**
**TAKE**
Trial type illustrations:

CknE

- **Category Goodness differences (CG)**
  - **TEAM** consonant:
    - CknE $[t^s] \sim$ AusE $[t^h]$

- **Category Shifting differences (CS)**
  - **THINK**→**FINK** consonant:
    - CknE ‘th’ = [f] → AusE [f]
Data preparation and analysis

![Graph showing mean fixation proportion to target over time with a highlighted analysis window of 500-1500 ms.](image)
L1 listeners: Vowels

JaME accent *slowed* word recognition

JaME *CS differences* from AusE vowels more distracting than CG differences

**ONSET competitors** more distracting in JaME than OFFSET competitors
L1 listeners: Consonants

CknE accent *slowed* word recognition

CknE *CS differences* more distracting than CG differences ... for *onset* competitors

**ONSET competitors** more distracting than **OFFSET competitors**

*CG > CS* for CknE **offset competitors**
L2-English
L1-Mandarin: Vowels
JaME accent slowed word recognition: CS differences from AusE vowels were more distracting than CG differences but only for ONSET competitors not for OFFSET competitors!
L1-Mandarin: Consonants CknE accent slowed word recognition: from AusE consonants were more distracting than CG differences... but only for ONSET competitors not for OFFSET competitors!

DISTRACTOR TYPE

Mean arcsin fixation proportion

Onset

Offset

ASSIMILATION TYPE

CG

CS

ACCENT

AusE

CknE

AusE

CknE

AusE

CknE

ACCENT

ASSIMILATION TYPE

CG

CS
Perceptual assimilation and lexical competition

- **Onset competitors** displayed a reliable **CS > CG** competition bias across
  - Vowels and Consonants
  - L1 and L2 listeners

- **Offset competitors** differed by listener group:
  - Significant effects for L1 AusE group
  - Weaker and NS for L1-Mandarin/L2-AusE group
    - Phonotactic constraints on C offsets in L1-Mandarin

- **Offset competitors** differed by segment class for **L1 listeners**
  - Vowels (JaME): CS > CG
  - Consonants (CknE): **CG > CS**
Early development of Phonological Constancy in word recognition

Look at the baby

✓ Phonetic change
✗ Phonological change

Eye-tracking study

- Word identification
- 15 vs. 19 months
  - Native: Australian English (AusE)
  - Non-native: JaME
- Target/distractor ratio > .5
**Phonological Constancy: CG vs. CS differences**

- **Vowels** versus **Consonants**
- prior preference studies, each using 2 regional accent tests:
  - **Native**: Australian English (AusE)
  - **Non-native**:
    - **Vowel** differences: JaME (Jamaican English): \( CG \), \( CS \), \( CS+Cs \)
    - **Consonant** diffs: CknE (London Cockney): \( CG \), \( CS \)

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**CG vowel difference**
JaME

---

**CG consonant diff**
CknE

---

**CS consonant diff**
CknE

---

**Total fixation time (s)**

- **Familiarity main effect**
- **Familiarity** main effect

---

**15 months**

19 months
Emergence of phonological constancy

- **CS consonant** differences, like **CG consonant** or **vowel** diffs, *fail* to impair word recognition even at 15 months

- whereas **CS vowel** differences *do* impair word recognition -- at not only 15 mo but *also* 19 mo

- **Phonological constancy** for word recognition:
  - appears early for CG vowel and consonant differences
  - but later for CS vowel differences than for CS **consonant** differences

★ natural variation in vowels and consonants affects early word recognition and learning **fundamentally differently**
Conclusions

- **Perceptual assimilation** of within-language variation
  - Category Goodness vs Category Shifting differences
  - Vowels vs consonants
  - L1 vs L2 listeners

- **Phonological Constancy** and word recognition
  - detecting word identity over systematic natural variation
  - different roles for Vs and Cs in word learning/recognition

- **Further research questions**
  - do these patterns occur in other languages, e.g., where regional accents differ more in consonants than vowels?
  - will similar patterns be found in new word learning?
  - can pre-exposure to a multi-talker story in another accent yield perceptual adaptation, i.e., adjust assimilation of phonemes and words to A1/most familiar accent?
Perceptual assimilation of non-native phonetic details to native phoneme contrasts

Assimilation of Non-native \textbf{Contrasts}

NATIVE PHONOLOGICAL SPACE

Single-Category Assimilation

Two-Category Assimilation

Category Goodness Difference

Best, 1995; Best & Tyler, 2007; Best et al., 1988, 2001
Using accent variation to assess Phonological Constancy

Look at the baby

✓ Phonetic change
✗ Phonological change
Adult word recognition across accents: Converging theoretical issues

**Dynamic invariance** *(Shaw et al., 2011)*

Different phonological organizations can be distinguished because they structure phonetic variability in different ways.

Phonetic variation offers *information* - How do listeners use it?

**Spoken Word Recognition** *(Best et al., 2009)*

- *Phonological distinctiveness*: to distinguish among words
- *Phonological constancy*: to identify words across variations

*How do listeners co-achieve contrast and constancy?*

**Cross-Accent Perceptual Assimilation** *(Best et al, 2015a, b)*

We assimilate unfamiliar-accent *phonemes* to our native accent

*How do we recognize *native words* across accent variation?*
Procedure: Visual World

- Spoken target
- Click on screen to identify from among choices
- Printed choice types:
  - Target word
  - Onset competitor
  - Offset competitor:
  - Unrelated distractor
  - “not there”

Best, Shaw & Clancy, 2013, Interspeech Proceedings
Experiment 1: Native listeners

**Task:** Visual world with printed words

- **Participants:** 14 Australian English (AusE) listeners
- **Materials:** Words in native AusE accent vs unfamiliar regional English accents:
  - Condition 1: Jamaican English (JaME)
  - Condition 2: Cockney English (CknE): London working class
  - Cross-accent word differences mainly in one vowel (JaME-AusE) or one consonant (CknE-AusE)
  - 2 native female speakers of each accent

**Predicted assimilation types** for the unfamiliar accents

- **Category Goodness difference (CG)** -- perceived as deviant exemplar of same phoneme/word in AusE
- **Category Shifting (CS)** -- perceived as different phoneme/word in AusE
RESULTS:
Experiment 1
AusE Listeners
Condition 1: AusE vs JaME
\rightarrow Focus is on vowel differences
RESULTS:

Experiment 1
AusE Listeners

Condition 2: AusE vs CknE

→ Focus is on consonant differences
RESULTS:

Experiment 2
Mandarin Listeners

Condition 1:
AusE vs JaME

→ Focus is on vowel differences
RESULTS:

Experiment 2
Mandarin Listeners

Condition 2: AusE vs CknE

→ Focus is on consonant differences
Discussion 1: Role of perceptual assimilation

- Globally, **CS** differences from the native accent are more distracting than **CG** differences for competitors of non-native accented words:
  - both L1 and L2 AusE listener groups
  - both JaME and CknE accents

- Thus perceptual assimilation clearly affects cross-accent word recognition *phonologically*

- **BUT …** the effects were modulated by:
  - Segment class: Vowels vs Consonants
  - Competitor type (onset vs offset)
Experiment 2: L2 listeners

**Task:** Visual world with printed words

- **Participants:** 15 Mandarin L1/Australian English L2 listeners
- **Materials:** SAME AS BEFORE: Words in familiar AusE L2 accent vs unfamiliar regional English accents:
  - Condition 1: Jamaican English (JaME) - vowels
  - Condition 2: Cockney English (CknE) – consonants

**Predicted assimilation types** for the unfamiliar accents … IFF they’ve learned L2-AusE phonetic-phonological mapping

- Category Goodness difference (CG) -- perceived as deviant exemplar of same phoneme/word in AusE
- Category Shifting (CS) -- perceived as different phoneme/word in AusE
- Onset competitor: CS>CG for other accents, like AusEs
- Offset competitor: even less competition than w/ AusEs

Best, Shaw & Clancy, 2013, Interspeech Proceedings
Recognition of words in which a consonant differs categorically from the native accent

The present study:

- **Cross-accent assimilation**: CS consonant differences
- **Accents**: AusE (native) vs CknE (non-native)
- **Preference tests**: FAMILIAR vs UNFAMILIAR words
- **Examples of target words in AusE (2) vs CknE (2):**
  - 1-syllable FAMILIAR (toddler)  **HAT**
  - 1-syllable UNFAMILIAR (adult)  **BOLT**
  - 2-syllable FAMILIAR (toddler)  **THANK YOU**
  - 2-syllable UNFAMILIAR (adult)  **PATTER**