Discreteness and asymmetry in phonological representations: features and quantity contrasts in the mental lexicon

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**WORDS & their variants and asymmetries**

*No word is ever spoken in exactly the same way, even by the same speaker.*

- Adult speech is produced with great speed and accuracy at an average rate of **three words per second**
- Our **mental lexicon** contains **tens of thousands** of words

The problem facing a phonologist...

**Uneven pronunciation (non-linguistic)**
- Differences in vocal tract size, age and gender
- Noisy environments
- Mispronunciations

**Varying pronunciations: linguistic contexts**
- Surrounding context changes the sounds of a word

Given this variation how do listeners parse the acoustic signal, access their mental lexicons, and identify words?

Our approach attempts to address the following:

- Asymmetries: How can we identify the types of possible word variations, complexities and asymmetries in the output.
- Speaker & Listener differences: How does the speaker plan her output and how does the listener identify and recognise words despite the variation?
- Lexical representation: How are words represented in the mental lexicon? Should the output and input be identical? This goes for phonological as well as morphological variants.

We attempt to combine synchronic theoretical data (& evidence from language change which tells us what variations may or may not lead to change), with experimental evidence asking how and with what difficulties the speaker and listener resolve complexities of word variation and word formation.
Phonological Representations in Language Production & Language Comprehension

Speaker - Hearer problems and asymmetries
• The speaker is in control - knows what to say, how to say it
• The listener is dependent on the speaker
• The child is initially only a listener and then a speaker as well
But identifying words in running speech is difficult!

Languages are replete with asymmetries
• No language has equal number of vowels and consonants
• Verb final languages are more frequent than verb initial languages
• Front rounded vowels imply back rounded vowels
• Dual number implies plural number contrasts
• Retroflex consonants imply dental/alveolar consonants
• Nasal vowels occur only with oral vowels
• Interdental non-sibilant fricatives occur only with sibilant fricatives
• Etc...
Asymmetries in assimilation leading to change

Languages are replete with asymmetries:

Vowel Deletion: Vowels are usually deleted finally (apocope) or medially (syncope) — not initially
Vowel Insertion: Vowels are inserted medially (epenthes) or initially (prothesis) — not finally

Consonants affecting vowels: manner not place features; e.g. vowel nasalisation
  Sanskrit  candra > Bengali  ca)d
  Nasal vowels do not lose nasality before oral consonants

Vowels affecting vowels: place & height, not manner; raising, fronting, rounding
  Germanic  u —> ü /— i;
  English has converted all [ü]s to [i]
  Umlauted vowels do not become back rounded vowels in similar contexts

Consonants affecting consonants: place & manner, not height
  Place assimilation (eventually place can change)
Vowels affecting consonants: place & height, not manner
  Retroflexion, Palatalisation (eventually palatals & retroflexes become phonemes)

Surrounding context changes the beginning or end of a word

alveolar labial velar
n t m p b η k

alveolar > labial if labial follows
n > m if m,p,b follow

alveolar > velar if velar follows
n > η if η,k,g follow

But /m/ remains unchanged

gum drops
hand bag  ha[nd] [b]ag  —> ha[m][b]ag
hand gun  han[nd] [g]un  —> ha[ŋ][g]un

gum [m] [d]rops
cream cake  crea[m] [k]ake

* gum[n][d]rops
* crea[ŋ][k]ake
Consonants at word onset tend to be less vulnerable to change. Nevertheless, they may change - affected by the end of the preceding word.

Celtic languages: Mutation
Italian: Radoppiamento (gemination across words) - when the preceding words end in a stressed vowel, the initial consonant of the word is doubled: *caffé caldo > café *[kk]aldo

Bengali: initial [t, d] assimilate to preceding /r/ and geminate

\[
\text{didi[r][d][æor]} \rightarrow \text{didi[d][d][æor] elder-sister's brother-in-law}
\]

\[
\text{didi[r][g][æor]} \rightarrow *\text{didi[g][g][æor] elder-sister's car}
\]

The listener may ultimately reanalyse what she hears, and initial geminates can become phonemes: true for assimilations as well as gemination.

Swiss German (North) 1000 years ago the ancestor of the dialect was spoken by Notker, an Abbot of the monastery at St Gall

\[
b\quad d\quad g \quad \text{word-initial after sonorants} \quad \text{and word-final}
\]

\[
p\quad t\quad k \quad \text{word-initial after obstruents}
\]

\[
\text{ín díu óugen begínnnet} \quad \text{Íh pegínne}
\]

‘it begins in the eyes’

‘I begin’

\[
díu súmma gát \quad \text{er férrost kât}
\]

The sun goes

‘he goes the furthest’

*Martianus Capella (Codex Sangallensis 872) and dates from early 11th century.*

*Lahiri & Krahenmann 2004 Transactions of the Philological Society*
Surrounding context changes the beginning or end of a word

**Notker’s system**

<table>
<thead>
<tr>
<th>&lt;p/b&gt;</th>
<th>&lt;t/d&gt;</th>
<th>&lt;k/g&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comparing Old Swiss German to Modern Swiss German, we know that 1000 years ago:

- \(<p t k> = [p t k] /\) when obstruents precede
- \(<b d g> = [pp tt kk] /\) when sonorants precede

Modern Swiss German: \(/p t k/ \) and \(/pp tt kk/ \) occur context independently! **They are phonemes.**

French loans into Swiss German brought in new \([p t k]/\) in the environment of sonorants.

Returning to word final position: an example of assimilation \([n] > [m]\)
How do listeners cope with variation?

*Varying pronunciations: linguistic contexts*
- Surrounding context changes the sounds of a word
- Listeners may misperceive

**Berlitz English schools for Germans:**
*Message from ship in distress “Mayday, Mayday, we are sinking”*
  
  *German coastguard*
  
  What are you [s]inking about?  
  *Learn English!*

Native listeners always assume that they are hearing WORDS and not nonwords; thus they try to find the closest match. Do human listeners treat all variants in the same way?

### Assimilations: Speaker ↔ Hearer

**RECALL**

- \( n > m \) or \( n > \eta \)
  - hand bag: \( h[a][n][d] [b]ag \) ➞ \( h[a][m][b]ag \)
  - hand gun: \( h[a][n][d][g]un \) ➞ \( h[a][\eta][g]un \)

*But /m/ remains unchanged*

- gum drops: \( g[u][m][d]rops \) ➞ *\( g[u][n][d]rops \)*
- cream cake: \( c[r][e][a][m][k]ake \) ➞ *\( c[r][e][a][\eta][k]ake \)*

### Mispronunciations: Speaker ↔ Hearer

- \( n > m \)
  - *sonnet* ➞ *sommet*
  - *honey* ➞ *homey*

- \( m > n \)
  - *tummy* ➞ *tunny*
  - *summer* ➞ *sunner*
Assimilations: Speaker $\leftrightarrow$ Hearer
Mispronunciations: Speaker $\leftrightarrow$ Hearer

Do listeners tolerate all possible assimilations and mispronunciations?
Hypothesis: NO
Lexical representation of words are sparse
Some mispronunciations are accepted, some are not

Listeners tolerate  $m$ for $n$
Listeners do not accept  $n$ for $m$
* somnet is accepted as a variation of sonnet
* sonner is not accepted as a variation of summer

From Signal to Representation

What is the relevant information that should be represented?
- not the acoustic signal - too much variation
- if not the signal then some more abstract information
- how abstract is abstract?

The less specification in the lexicon, the larger the options available:
- specific enough to keep entries distinct
- abstract enough to allow for recognition

Our model — FUL (Featurally Underspecified Lexicon) makes claims on two levels:
What is represented?
How does the signal map on to the representation
Features & Segments

Vowels & Consonants share the same features
Universally, two features are underspecified, [CORONAL] and [PLOSIVE]

- **[LABIAL]** labial consonants, rounded vowels
- **[CORONAL]** front vowels, dental, palatal, palatoalveolar, retroflex consonants
- **[DORSAL]** back vowels, velar, uvular consonants
- **[RADICAL]** pharyngealized vowels, glottal, pharyngeal consonants
- **[HIGH]** high vowels, palatalized consonants, retroflex, velar, palatal, pharyngeal consonants
- **[LOW]** low vowels, dental, uvular consonants
- **[ATR]** palatoalveolar consonants
- **[RTR]** retroflex consonants

How does this work for perception? What features are extracted and how do they match to the representation?

*Lahiri & Reetz, 2002, 2010; Lahiri 2012*
The FUL model:
Lexical Phonological Representation

- Each contrastive sound (phoneme) has a set of phonological features.
- The phonological representation of each phoneme is abstract such that not all features are present. Underspecification leads to asymmetries.
- Contrasts and asymmetries in representation are reflected in language change and language processing.

Mapping from Signal to Representation

- The perceptual system analyses the signal for rough acoustic features which are transformed into phonological features and mapped directly onto the lexicon.
- A three-way matching procedure (match, mismatch, nomismatch) determines the choice of candidates activated.
- Features from the signal which conflict with the representation mismatch, and constrain activation of candidates.

Feature Representation

Asymmetry in place assimilation

\[
\begin{align*}
\text{green}[n] \ [b]ook & \quad \rightarrow \quad \text{gree}[m][b]ook \\
\text{green}[n] \ [g]lass & \quad \rightarrow \quad \text{gree}[n][g]lass
\end{align*}
\]

But

\[
\begin{align*}
\text{crea}[m] \ [d]ress & \quad \rightarrow \quad *\text{crea}[n][d]ress \\
\text{crea}[m] \ [g]lass & \quad \rightarrow \quad *\text{crea}[n][g]lass
\end{align*}
\]

How does it work?

Asymmetry in place assimilation

\[
\begin{align*}
\text{green}[n] \ [b]ook & \quad \rightarrow \quad \text{gree}[m][b]ook \\
\text{green}[n] \ [g]lass & \quad \rightarrow \quad \text{gree}[n][g]lass
\end{align*}
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But

\[
\begin{align*}
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\text{crea}[m] \ [g]lass & \quad \rightarrow \quad *\text{crea}[n][g]lass
\end{align*}
\]

signal | representation
--- | ---
/n/ /t/ /d/ | [CORONAL] underspecified
/m/ /p/ /b/ | [LABIAL] [LABIAL]
/η/ /k/ /g/ | [DORSAL] [DORSAL]

[CORONAL] extracted from the signal conflicts with the others

[LABIAL] and [DORSAL] extracted from the signal conflicts with each other, but not with unspecified [CORONAL]
Matching process

features from the signal
labial    nasal
features, stored in the lexicon

unspecified PLACE nasal

features from the signal
coronal    nasal
features, stored in the lexicon

labial    nasal

*so[m]et
*green[m] [b]ox
[m]

no mismatch

/ n/ sonnet green

/ m/ hammer cream

gree[m], so[m]et does not mismatch /n/; tolerated as a variant of green, sonnet
cree[n], ha[n]er mismatches /m/; does not activate cream, hammer.

Models of word recognition

Storage of all variants experienced by the listeners (exemplars?)
Connine et al; Johnson, Pierrehumbert
Feature Parsing model: no assimilation is complete; partial assimilated cues help retrieve the intended articulation Gow
Context dependent activation - assimilation may be complete; the following context helps retrieve intended articulation Gaskell et al
Abstract representation; under-specification is not based on assimilation alone; contrasts determine representations FUL
Models of word recognition

What variations can be tolerated or accepted?
Can variations out of context be accepted?

<table>
<thead>
<tr>
<th>real word</th>
<th>variant</th>
<th>Existing Variants</th>
<th>Context dependent</th>
<th>Feature parsing</th>
<th>FUL</th>
</tr>
</thead>
<tbody>
<tr>
<td>green</td>
<td>gree[m]</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>✅ gree[n]</td>
</tr>
<tr>
<td>sonnet</td>
<td>so[n]net</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>✅ so[n]net</td>
</tr>
<tr>
<td>neck</td>
<td>[m]eck</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>✅ [n]eck</td>
</tr>
<tr>
<td>cream</td>
<td>crea[n]</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x crea[m]</td>
</tr>
<tr>
<td>hammer</td>
<td>ha[n]ner</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x ha[m]mer</td>
</tr>
<tr>
<td>mouse</td>
<td>[n]ouse</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x mouse</td>
</tr>
</tbody>
</table>

Lexicon

- Auditory: sonnet, *sommet
- Visual: hammer, *hanner

**Lexical decision - word/nonword**
sonnet - *sommet; hammer - *hanner

**SEMANTIC PRIMING**

<table>
<thead>
<tr>
<th>auditory</th>
<th>visual</th>
<th>REACTION TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRIME</td>
<td>TARGET</td>
<td></td>
</tr>
</tbody>
</table>

**TEST**
- sonnet: POEM ➔ RT 1 FAST
- *sommet: CONTROL ➔ RT 2 SLOW

**TEST**
- hammer: MALLET ➔ RT 1 FAST
- *hanner: CONTROL ➔ RT 2 SLOW

billet
**Word final /-m/**
Prime **Baum** ‘tree’
Target **Strauch** ‘bush’

**word final /-n/**
Prime **Bahn** ‘rail’
Target **Zug** ‘train’

---

**Word medial : Degree of priming (Control-Test)**

<table>
<thead>
<tr>
<th>Auditory Primes</th>
<th>Coronal Word</th>
<th>Coronal Pseudoword</th>
<th>Noncoronal Word</th>
<th>Noncoronal Pseudoword</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>sonnet</strong></td>
<td><strong>sommet</strong></td>
<td><strong>hammer</strong></td>
<td><strong>hanmer</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Maus</strong></td>
<td><strong>Bahn</strong></td>
<td><strong>Bahn</strong></td>
<td><strong>Bahn</strong></td>
</tr>
<tr>
<td></td>
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</tbody>
</table>

**SEMANTICALLY RELATED TARGETS**

**POEM**
Roberts, Wetterlin, Lahiri 2013

**MALLET**
Roberts, Wetterlin, Lahiri 2013

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**Lahiri & Reetz 2002**
Semantic priming: English mispronounced words (ERP of targets)

**Difference of differences:**
- sonnet & *sommet
- POEM
- hammer & *hanner
- MALLE
- razor & *raver
- billet & *birret

\[((\text{cntrl-ident corword}) - (\text{cntrlnw-cornw})) = \text{expect “flat”}\]

\[((\text{cntrl-noncorword}) - (\text{cntrlnw-noncorword}) = \text{enhanced N400}\]

\[\text{sonnet & *sommet both accepted as words}\]
\[\text{The brain rejects *hammer as a variant of hammer}\]

**Word onset asymmetries and lexical activation**

**CORONAL SETS**
- matching onset fragment
  - non-NONNE
  - dich-DICHTER
  - dam-DAMPFER
  - trau-TRAUBE
  - trich-TRICHTER

**NON-CORONAL SETS**
- matching onset fragment
  - mons-MONSTER
  - gar-GARTEN
  - bru-BRUDER
  - kum-KUMMER
  - pin-PINSEL

**non-conflicting onset fragments**
- mon-Nonne
- bich-DICHTER
- gam-DAMPFER
- krau-TRAUBE
- prich-TRICHTER

**mismatching onset fragment**
- nons-MONSTER
- dar-GARTEN
- dru-BRUDER
- tum-KUMMER
- tin-PINSEL

Change initial consonant of fragment
Word onset asymmetries and lexical activation

**Word fragment priming**

*P350 lexical activation effect*

**Match**
(e.g., kro - KROKUS)

**Unrelated**
(e.g., kro - LASTER)

P350 = left-hemispheric correlate of lexical activation for matching words

Friedrich, 2005

---

Task: cross modal lexical decision with *fragment* priming

- **mon-** → MONSTER
- **non-** → NONNE
- **mon-** → NONNE
- **non-** → MONSTER
Asymmetries in representation is also reflected for word initial stops and nasals

Consonant & Vowel alternations

Mismatch Negativity: Basic assumptions

(i) Mismatch Negativity is sensitive to language-specific phoneme representations

(ii) *standard stimuli* create a central sound representation > taps the phonological representation in the mental lexicon (*underlying representation*)

(iii) percept created by the *deviant stimulus* corresponds in part to the set of phonological features extracted from the *speech signal*
Mismatch Negativity - MMN

Oddball Paradigm

Series of Standards build a “central sound representation” → underlying representation (UR)

Features from Deviants are extracted from the signal

Automatic change detection
Different stages in the extraction and processing of Acoustic signal

Acoustic/phonological features

- Creating a Central Sound Representation (CSR)
- Detecting changes in the feature set and updating the CSR
- Top-down influence of the mental lexicon

Extraction of phonological features from the speech signal
- N100-Component in MEG and EEG

Representation of phonological features in the CSR and the mental lexicon
- Mismatch Negativity (MMN)

Manner Features: mismatch & tolerance

<table>
<thead>
<tr>
<th>Stimuli</th>
<th>[g]</th>
<th>[d]</th>
<th>[n]</th>
<th>[z]</th>
</tr>
</thead>
<tbody>
<tr>
<td>place features</td>
<td>[DORSAL]</td>
<td>[CORONAL]</td>
<td>[CORONAL]</td>
<td>[CORONAL]</td>
</tr>
<tr>
<td>manner features</td>
<td>[PLOSIVE]</td>
<td>[PLOSIVE]</td>
<td>[NASAL]</td>
<td>[STRIDENT]</td>
</tr>
</tbody>
</table>

Features in the acoustic signal (activated from Deviant)

Features in the mental representation (activated from Standard)

Hypothesis

Cornell, Lahiri, Eulitz 2012
Journal of Experimental Psychology, General

asymmetric MMNs

symmetric MMNs
Manner Features: conflict & tolerance

Place contrast: [DORSAL] ~ [CORONAL]: [d]_{gl} ~ [g]_{dl}

Manner contrast: [NASAL] ~ [STRIDENT]: [n]_{rl} ~ [z]_{nl}

Cornell, Lahiri, Eulitz 2012, *Journal of Experimental Psychology, General*
Manner Features within Coronal

Features from the acoustic signal (from the Deviant)

<table>
<thead>
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<th>Stimuli</th>
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<td>[PLOSIVE]</td>
<td>[NASAL]</td>
<td>[STRIDENT]</td>
</tr>
</tbody>
</table>

Features in the mental representation (activated from the Standard)

| place features | [DORSAL] | [ ] | [ ] | [ ] |
| manner features | [ ] | [ ] | [NASAL] | [STRIDENT] |

Hypothesis

Manner Contrast

[NASAL] ~ [PLOSIVE]

[ŋ]_d/ < [d]_n/

Manner Contrast

[NASAL] ~ [STRIDENT]

[ŋ]_d/ = [z]_n/

Manner contrast: [NASAL] ~ [PLOSIVE]: [ŋ]_d/ ~ [d]_n/

MMN

Conflict [nasal] non-conflict [ ]

[d]_n/ ~ [ŋ]_d/

(t (25) = 3.05; p < .05)

Cornell, Lahiri, Eulitz 2012, JEP General
Manner Features within Coronal

Manner contrast: [NASAL] ~ [PLOSIVE]: [n][d] ~ [d][n]

Manner contrast: [NASAL] ~ [STRIDENT]: [n][z] ~ [z][n]

Weighted for word frequency, based on token counts of the CELEX corpus.

V[C]V: the individual frequency counts for the four consonants in medial position
[eC]V: the phonotactic probability counts for [en], [ez], [ed] with a following V
CV[C]VC: the frequency counts for /n/, /z/, /d/ and /g/ in an intervocalic position

<table>
<thead>
<tr>
<th>nonword stimuli</th>
<th>V[C]V</th>
<th>[eC]V</th>
<th>CV[C]VC</th>
</tr>
</thead>
<tbody>
<tr>
<td>eni</td>
<td>2.97</td>
<td>3.12</td>
<td>4.48</td>
</tr>
<tr>
<td>edi</td>
<td>0.37</td>
<td>1.12</td>
<td>4.03</td>
</tr>
<tr>
<td>ezi</td>
<td>0.91</td>
<td>1.48</td>
<td>4.02</td>
</tr>
<tr>
<td>egi</td>
<td>2.48</td>
<td>0.26</td>
<td>4.26</td>
</tr>
</tbody>
</table>

Our results

MMN predictions based on frequencies

- [n][d] < [d][n]
- [n][z] > [z][n]
- [n][g] < [g][n]
- [n][d] > [d][n]
- [n][z] > [z][n]
- [n][g] > [g][n]
Sound frequencies

Our findings cannot be explained by individual sound frequency effects of our stimuli.

The intervocalic frequency (V[C]V) turns out to be highest for [n], slightly lower for [g] and lowest for [z]. Again, one could argue that a high frequency deviant would elicit a higher MMN response; however, in our results the MMN amplitude of the deviant [d] compared to the standard /n/ is increased compared to the reversed condition.

Additionally, the largest sound frequency difference is between [n] and [z], but here we find equal MMN amplitudes. These results show a pattern which cannot be explained by frequency effects, nor phonotactic probability influences.

Vowel alternations

German vowels acoustics & representation

features in the signal [DORSAL] [CORONAL] [LABIAL] [COR]

features in the mental representation [LABIAL] [LAB]
Vowel alternations

Lexicon

‘Deviant’ = signal

‘standard’ stimuli (repeated) = TAPS LEXICAL REPRESENTATION

[DORSAL] [o] \[-----] /e//ø/

[CORONAL] [e] [Ø] [DORSAL] /o/

Grand Average MMN Waveforms for all Pairs of Inversion

deviant/standard/ symmetry

Grand Average MMN Waveforms for all Pairs of Inversion

[ø]/o/ has higher MMN and earlier peak latency than [o]/ø/
**WORDS & their variants and asymmetries**

**LONG vs. SHORT**

- Half of the world’s languages have a long-short consonantal contrast
- The timing contrast in languages is usually binary - long vs. short
- Underlying geminates are represented by a single set of features and a single release
- Medial geminates invariably belong to two syllables;

  \[
  \sigma \sigma \sigma \sigma
  \]

  \[
  \begin{array}{c|c}
  l & / \\
  \hline
  p a t : a & p a t a \\
  \end{array}
  \]

- Lexical geminates cannot be separated by vowels and are never treated as two separate entities which undergo separate phonological processes
- Primary acoustic cue is closure/consonant duration (cf. for a summary Ridouane 2010)

**Questions & Hypotheses**

How do we distinguish between long an short?

Is a mispronunciation based on durational information still accepted as the corresponding real word?

(A) No mispronunciations with durational changes are accepted

(B) All mispronunciations are accepted provided only durational information is changed

(C) We can see a difference between long > short and short > long changes in terms of lexical access

Hypothesis: Long subsumes short (when you hear a long consonant, the short is already activated); short is not enough to identify long.
Length distinctions in Bengali

- Extensive consonantal inventory:
  - 16 stops, 4 affricates, 3 nasals & 2 liquids over 5 places of articulation
  - all consonants contrast in length word medially
- Examples
  - *pata* ‘leaf’ vs. *pat:a* ‘whereabouts, location’
  - *kana* ‘blind’ vs. *kan:a* ‘tears’
  - *kor-to* ‘do.3p.past’ > *kot:o* = geminate through assimilation
- Predominant acoustic cue for gemination is consonant (closure) duration (Lahiri & Hankamer 1988; Hankamer et al. 1989, Ridouane 2010)

Gemination in Bengali

- Gemination occurs naturally in Bengali in assimilation and other phenomena

  **Assimilation:**
  - *mar-tam* > *mat:am* (beat-1P.PAST) – *mar-a* (beat-INF)
  - *bor-di* (*boro* ‘big’ & *didi* ‘sister’) > *bod:i*

  **Concatenation:**
  - *kʰel-lam* > *kʰel:am* (play-1P.PAST) *kʰelam* (*kʰe-lam* > *kʰelam*)

  ➔ no degemination processes
  ➔ short > long is a common feature of the language
Stimuli

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Prime</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Semantic Priming</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(short – long)</td>
<td>*sona ‘gold’</td>
<td>*rupa ‘silver’</td>
</tr>
<tr>
<td>Semantic Priming</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(long – short)</td>
<td>*sun: ‘zero’</td>
<td>*khali ‘nothing’</td>
</tr>
</tbody>
</table>

- Average length for singleton (89ms) & geminate (207ms)
- Difference in length between CVC & CVC<sub>V</sub> fragments: 17ms

Semantic Priming results

**SHORT - LONG**
Same amount of facilitation for both singleton (W) and geminate (NW) primes
- Geminate (NW) prime leads to lexical access

**LONG - SHORT**
Facilitation effect only for geminate (W) primes
- Singleton (NW) prime does not activate geminate word
Semantic Priming results

**Semantic Priming ERPs**

**SHORT - LONG**
Equal N400 response for singleton (W) and geminate (NW) primes

- Geminate (NW) prime leads to lexical access

**LONG - SHORT**
Singleton (NW) prime has significantly higher N400 than geminate (W) prime

- Singleton (NW) prime behaves like the controls
Summing up

• Facilitation of lexical access occurs when singletons are replaced with geminates but not when geminates are shortened to singletons
• Longer (mispronounced) geminates subsume singleton words, but not the other way around.

Cutting the cake differently... asymmetry in representation, symmetry in acoustics

same sound, different phonological representation

• One candidate for comparison is Bengali vs. German [ɔ].
Specification for HEIGHT

F2

~400 Hz

[u]

[LOW]

~850 Hz

[a]

[Bengali] [German]

[HI] [HI]

[LOW] [ ]

? [ɔ] or [Low]

Bengali Vowels

<table>
<thead>
<tr>
<th>3 PERS</th>
<th>1 PERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>pʰæl-e</td>
<td>pʰel-i</td>
</tr>
<tr>
<td>pʰer-e</td>
<td>pʰir-i</td>
</tr>
<tr>
<td>bol-e</td>
<td>bol-i</td>
</tr>
<tr>
<td>gol-e</td>
<td>gul-i</td>
</tr>
</tbody>
</table>

throw
return
say
stir

imperative participle

pʰæl
pʰer
bol
gol
mar

DORSAL
CORONAL

HIGH

u
i

0
e

LOW

ɔ
æ

German (relevant vowels)

DORSAL
CORONAL

HIGH

u
i

0
ɔ

LOW

ɑ

/ɔ/ patterns with /æ/ which groups with /a/: a piece of evidence for specifying both [LOW]

Lahiri 2000
Summary of predictions

Bengali
- 4 exemplars of naturally spoken vowels
- order of runs counterbalanced
- 21-channel EEG (ANT)
- 14 German & 14 Bengali subjects

MMN-Latency for [ɔ]/ʊ/ and [u]/ʊ/; Bengali < German
MMN-waveforms (Bengali and German)

Eulitz, Lahiri (2004); in preparation

Eulitz et al. in preparation
Comparing acoustically equidistant conditions, the MMN revealed an earlier peak latency when the phonological feature sets in the standard and deviant stimuli were conflicting, i.e. [ɔ] is specified for [low] in Bengali and underspecified for height in German.

Surface and underlying representations are not necessarily isomorphic; nor are the interfaces straightforward, between phonology-syntax
morphology-phonology
phonology-phonetics

Despite this human brains are able to deal with the variation, complexity and asymmetry very efficiently.

Our research attempts to use different techniques and takes into account different pieces of evidence to understand how variation can be resolved.

We hope to have shown that not all surface complexities are directly represented in the brain for comprehension.