Phonological underspecification: Evidence from neural responses

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1. Introduction

- Underspecification models claim that the featural properties of segments may differ in the underlying representation (UR) from the surface representation (SR), such that some surface specifications may not be present underlyingly.
- If this is the case, a difference is predicted for UR-SR comparisons between underspecified segments versus fully-specified segments.
- Previous work suggests that such a perceptual difference does appear neurobiologically (Eulitz and Lahiri 2004).
- We test the prediction with the same neural response and consonantal English segment pairs differing in place of articulation.
- Our results also validate the prediction – manipulating the representation accessed by the listener results in asymmetrical perceptual distance.
- We conclude that differences in degree of phonological specification exist and are relevant in speech processing.

1.1 (Coronal) Underspecification

Featurally Underspecified Lexicon: Features that are redundant, or contrastive but nonactive, in the phonology of a language are not specified in the underlying representation.

Coronal segments are commonly held to be underspecified for place (for other views, see Trigo 1988, Rice 1996, Hume and Tserdanelis; for arguments contra coronal underspecification in English specifically, McCarthy and Taub 1992).

Standard argument: (In)vulnerability to assimilation (Mascaro 1976)

**Coronal**

| ten apples ~ ten apples | trim towers * trin towers |
| ten towers ~ ten towers | trim girls * tring girls |
| ten bells ~ ten bells | flung bells * flum bells |
| ten girls ~ ten girls | flung towers * flun towers |

**Labial/Velar**

Standard solution: Assimilation applies to underlyingly placeless segments.

Directionality of featural conflict:

| UR /b/ [LABIAL] | conflicts with SR [d] [CORONAL] |
| UR /d/ [ ] | does not conflict with SR [b] [LABIAL] |

1.2 Neural responses to spoken language: The MMN/F

MMN/F: nonattentive auditory response indexing perceived (dis)similarity

- For nonspeech sounds, response strength correlates with acoustic distance.
- For speech, language-specific categories outweigh it
1.2.1 Voicing (Sharma & Dorman 1999)

MMF significant for both pairs, but greater for cross-category pair despite equal acoustic distance.

1.2.2 Vowel backness (Näätänen et al. 1997)

In general, response strength correlates with F2 difference.

For Finns, the non-Finnish vowel /õ/ elicits a smaller response relative to standard /e/ than the acoustically closer vowel /ö/.

1.3. Testing the FUL model with neural responses 1: German vowels (Eulitz and Lahiri 2004).

By hypothesis, the multiple tokens of standard bias the listener towards a representation which is “more abstract than the sum of perceived acoustic elements,” especially as compared to the single-token and more recent deviant, which therefore corresponds more closely to the surface form.

<table>
<thead>
<tr>
<th>Test pairs</th>
<th>MMN peak</th>
<th>MMN amplitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>e ø</td>
<td>earlier</td>
<td>greater</td>
</tr>
<tr>
<td>ø o</td>
<td>No conflict</td>
<td></td>
</tr>
<tr>
<td>ø e</td>
<td>No conflict</td>
<td></td>
</tr>
<tr>
<td>o ø</td>
<td>Conflict</td>
<td></td>
</tr>
</tbody>
</table>

MMN peak is earlier for conflicting pair (F(1,11)=10.53; p<.01)
MMN amplitude is greater for conflicting pair (F(1,11)=5.21; p<.05)

Fully-specified coronal vowels conflict with labials;
Underspecified ones do not

Pairs involving feature conflict are perceived as less similar to each other than the same pairs without such a conflict.

This conflict (or lack thereof) may be due to differential extent of specification.
4. Testing the FUL model with neural responses 2: English consonants

4.1 Method

30 trials per condition, randomized order. Same/different judgment task for 5th stimulus in set.

4.2 Predictions

Deviant SR [d] conflicts with standard UR /b/ [CORONAL][LABIAL]
Deviant SR [b] does not conflict with standard UR /d/ [LABIAL][ ]

For consistency with German results and underspecification models: Deviant coronals should elicit earlier/stronger MMF responses than labials.

4.3 Results: Latency

Labial – coronal peak latency
By subject
Mean peak latency
Group, by place
MMF peak latency: (F(1,11)=2.72, p=.13).
→ Earlier for coronal deviants (trend).

4.4 Results: Amplitude

Coronal-deviant MMF – labial-deviant MMF, by subject

MMF time window
Pre-MMF time window
1. Way RM ANOVA:
MMF (200-300 ms pso): Significant difference (F(1,11)=7.22, p=.02)
Pre-MMF (0-199 ms): No significant difference (F(1,11)=.57, p=.47)

Æ  As predicted, coronal deviants elicit a mismatch response that is earlier and significantly greater than that of labial deviants.

5. Alternative explanations for perceptual asymmetries
Don’t work for the German and English cases discussed above.

5.1 Superset/subset 1: Acoustic cues
“The perceiver is more likely to miss a distinctive part of the stimulus array than she is to imagine its presence when it is not actually there.”
(Chang, Plauche and Ohala 2001; henceforth CPO)

In visual perception:
E > F  R > P  Q > O  W > V

Notation: x > y = x is more likely to be misperceived as y than vice versa.
Æ  x is more confusable with/similar to y than y is to x.

Same conceptual explanation applies to consonant confusion.

ki > ti:
Vowel neutralizes formant transition differences, so that mid-frequency (F3) peak of velar burst is only remaining cue. When missed, leads to misperception of ki as ti.

Æ  Generally, cues for coronality exist to an equal or greater extent than for labiality.
Prediction: Finding:
da > ba  \( \Rightarrow \) ba > da

This is the opposite of our findings.

5.2 Superset/subset 2: Feature specifications

Predictions:
If computed over SR  If computed over UR
1) \( ba = da \)  \( ba > da \)  \( ba > da \)
2) with secondary articulations
\( o = \phi \)  \( o > \phi \)  \( o > \phi \)
\( \phi > e \)  \( \phi > e \)  \( \phi = e \)
3) without secondary articulations
\( o = \phi \)  \( o > \phi \)  \( o > \phi \)
\( \phi = e \)  \( \phi = e \)  \( \phi = e \)

If sets are computed over underlying representations without taking secondary articulations into account, the predictions match our findings.

Corollary (with same predictions):
Greater exposure to more frequent segments makes us better at identifying them (less likely to think that they’re something else).

English: coronal consonants much more frequent than labial ones
German: Classes below based on orthographic frequency (Pratt 1942)

<table>
<thead>
<tr>
<th>Least frequent</th>
<th>Most frequent</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \ddot{o} ) ( \ddot{a} ) ( \ddot{u} ) ( \ddot{u} ) ( \ddot{j} ) ( w ) ( v ) ( z ) ( \dddot{p} ) ( \dddot{f} ) ( \dddot{k} ) ( \dddot{m} ) ( \dddot{c} ) ( \dddot{l} ) ( \dddot{b} ) ( \dddot{u} ) ( \dddot{h} ) ( \dddot{g} ) ( \dddot{s} ) ( \dddot{t} ) ( \dddot{r} ) ( \dddot{a} ) ( \dddot{d} )</td>
<td></td>
</tr>
<tr>
<td>( \dddot{e} )</td>
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Predictions:      Findings:
\( ba > da \)  \( ba > da \)
\( o > \phi \)  \( o > \phi \)  \( o = \phi \)
\( \phi >> e \)  \( \phi = e \)

For CPO, outweighed (if present at all) by acoustics: found misperception effect only before /i/ vowel, whereas frequency theory predicts it everywhere equally.

6. Conclusions

- Order of stimulus presentation affects similarity perception of one segment relative to another.
- The observed asymmetries occur with segment pairs which, according to underspecification models, differ in degree of specification as well as in kind.
- Alternative explanations of perceptual asymmetries fail to capture these facts:
  - The nature of acoustic cues makes an incorrect prediction for the English data, and no clear prediction for the German data
  - Frequency accounts for the English data, but not for German
- This study supports a representational model in which at least two degrees of featural specification exist
**Selected References**


Näätänen R. The perception of speech sounds by the human brain as reflected by the mismatch negativity (MMN) and its magnetic equivalent (MMNm). Psychophysiology 2001;38:1-21.


