Intermediacy, Ambiguity and Categorization at the Phonetics-Phonology Interface

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Phonetics vs. Phonology

Phonetics: The study of sounds as physical entities

The study of the production, realization and perception of speech sounds by humans.

- articulation
- perception
- acoustics
- aerodynamics

Phonology: The study of sound patterns

What does it mean for sounds to “pattern”?

1. **Distribution**: What is a licit sound sequence?
2. **Contrast**: What sounds contrast to give different meanings?
3. **Systems of relations**: What are the relationships between different classes of sounds?
Phonology: Distribution

Cross-linguistically, sounds differ in their distribution:

Where in the word or syllable:
- English *[#ŋ] vs. Vietnamese [#ŋ]
- thi[#ŋ], ti[#ŋ]ker vs. Nguyen

What sound sequences are licit:
- English *[#zɡ] vs. Czech [#zɡ]
- Note: a[z ɡ]ood
Phonology: Distribution

Cross-linguistically, sounds differ in their **distribution**:

Where in the word or syllable:
- English *[#θ̚] vs. Vietnamese [#ŋ]
- English *[#z̚θ̚] vs. Czech [#z̚g]
  - thi[ŋ], ti[ŋ]ker vs. Nguyen

What sound sequences are licit:
- English *[#z̚g̚] vs. Czech [#z̚g]
  - Note: a[z̚ g̚]ood

**Figure**: Nonword /zgano/: Czech (left) and English (right)

Spectrograms from Davidson (2006)
Phonology: Contrast

Cross-linguistically, sounds differ in their contrastiveness:

- English and Hawaiian both have glottal stop [ʔ] (uh oh!)
- English: not contrastive
  - Word-initially occurs as a way to begin vowels
  - Word-medially or word-finally a possible pronunciation of /t/:
    - *button*: bu[ʔ]on; *pat*: pa[ʔ]
- Hawaiian: contrastive
  - **minimal pair**: [alo] front, face vs. [ʔalo] to dodge, evade
Sounds in languages do not exist in isolation. Sounds are grouped into (natural) classes, grounded phonetically and manifested phonologically.

**Phonetic grounding: classes defined phonetically**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Sounds</th>
<th>Phonetic definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>[nasal]</td>
<td>[m, n, ŋ]</td>
<td>lowered velum</td>
</tr>
<tr>
<td>[+continuant]</td>
<td>[f, v, s, z]</td>
<td>continuous airflow (oral)</td>
</tr>
<tr>
<td>[−continuant]</td>
<td>[p, b, t, d, k, ɡ]</td>
<td>airflow blocked</td>
</tr>
<tr>
<td>[+voice]</td>
<td>[b, d, ɡ, v, z, m, ʟ]</td>
<td>vocal folds vibrate</td>
</tr>
<tr>
<td>[−voice]</td>
<td>[p, t, k, ɡ, f, s]</td>
<td>vocal folds do not vibrate</td>
</tr>
</tbody>
</table>
Phonology: Sounds pattern together in the phonology

Sounds that are classified together undergo systematic changes in their pronunciation depending on the environment, or condition different pronunciations of other sounds.
Phonology: Sounds pattern together in the phonology

Sounds that are classified together undergo systematic changes in their pronunciation depending on the environment, or condition different pronunciations of other sounds.

**Canadian Raising**

Low diphthongs are raised before voiceless consonants
(*i.e., why Americans think I say “hoose” for “house”*)

- He’s got icy eyes
- The lout was loud
- I’m happy to house you in my house
- The tribe ate tripe
- She lies about her lice
The sound **inventory** of a language is partitioned by the classes; typically captured with (binary) features.

Recap:

- Sounds can differ in **distribution**, **contrast** and **patterning**.
- Sounds do not exist in isolation, but are grouped into classes.
- Classes are phonetically grounded.
- Some classes are phonologically active $\Rightarrow$ features.
Phonology: Classes vs. Features

Recap:
- Sounds can differ in **distribution**, **contrast** and **patterning**.
- Sounds do not exist in isolation, but are grouped into classes.
- Classes are phonetically grounded.
- Some classes are phonologically active → features.

Class vs. feature

I will use the term **class** to refer to a group of sounds that shares a phonetic parameter, “the **voiceless** sounds”; the term **feature** will be restricted to a group of sounds that displays active phonological unity, “the [−voice] sounds”
Phonology: Where do features come from?

1. To what extent does phonetics determine phonological classification?
2. To what extent are other cognitive principles responsible for classification?
Phonology: Where do features come from?

1. To what extent does phonetics determine phonological classification?

2. To what extent are other cognitive principles responsible for classification?

3. What are the possible features? What features do segments get?
Russian /v/
## Russian: Consonant Inventory

<table>
<thead>
<tr>
<th>Consonant</th>
<th>Labial</th>
<th>Dental</th>
<th>Palato-Alveolar</th>
<th>Velar</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stop</strong></td>
<td>p (p^j) b (b^j)</td>
<td>t (t^j) d (d^j)</td>
<td></td>
<td>k ((k^j)) g ((g^j))</td>
</tr>
<tr>
<td><strong>Affricates</strong></td>
<td></td>
<td>ts</td>
<td>t(j^j)</td>
<td></td>
</tr>
<tr>
<td><strong>Fricative</strong></td>
<td>f (f^j) v (v^j)</td>
<td>s (s^j) z (z^j)</td>
<td>j (j^j) 3</td>
<td>x ((x^j))</td>
</tr>
<tr>
<td><strong>Nasal</strong></td>
<td>m (m^j)</td>
<td>n (n^j)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Lateral</strong></td>
<td>l (l^j)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Rhotic</strong></td>
<td>r (r^j)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Approximant</strong></td>
<td></td>
<td></td>
<td>j</td>
<td></td>
</tr>
</tbody>
</table>
## Russian: Consonant Inventory (Abridged)

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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Intermission: Voicing

How does voicing work?

- Not muscular!
- Control vocal fold position and tension...
- Expel air from lungs...
- Let aerodynamics do the rest!
Intermission: Obstruent vs. Sonorant Voicing

Voicing: continuous airflow & trans-glottal pressure drop
⇒ sonorant voicing good, obstruent voicing bad

Sonorants: nasals [m, n, ɳ], laterals [l], rhotics [r], glides [w, j], vowels [a, e, i, o, u]

Since sonorants do not impede airflow, voicing is unaffected

Obstruents: stops [p, b, t, d, k, ɡ], fricatives [f, v, s, z, ʃ, ʒ]

Obstruents impede airflow by causing a narrow constriction / stoppage of air flow, compromising voicing.
Typological implications

**Sonorants**
- Sonorants found in every* language
- Voiceless sonorants not contrastive in any* language
- If voiceless sonorant present, voiced sonorant present (exceptionless)

**Obstruents**
- Voiceless obstruents found in every* language
- Voiced obstruents often undergo changes to relieve pressure
- If voiced member present, voiceless member present
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**Relations in voicing: (disunity of voice)**

- Voiced obstruents stand in relation to the voiceless obstruents (contrastive along the parameter of voicing) ⇒ [± voice]
- Sonorants are voiced, but they are unpaired on this parameter
- We might expect different phonological behaviour from the sonorants and voiced obstruents...
Voiced obstruents devoice to voiceless counterparts in word-final position

/ʋ/ devoices to [f] in word-final position

Sonorants do not devoice

**Final Devoicing:** /ʋ/ → [f] / __# /

1) [sleda] [slet] track (gen./nom.sg)
2) [soka] [sok] juice (gen./nom.sg)
3) [prava] [praf] right (fem./masc.)
4) [mil] *[mil] dear
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4) [mil] *[mil] dear

Phonological manifestation of distinction in voicing between obstruents and sonorants
Russian /v/: Regressive Voicing Assimilation

- Voiced obstruents devoice to voiceless counterparts before voiceless obstruents
- /v/ devoices to [f] before voiceless obstruents
- Sonorants do not devoice

<table>
<thead>
<tr>
<th>Regressive Voicing Assimilation: D → T / __T</th>
</tr>
</thead>
<tbody>
<tr>
<td>5) /pod-nesti/ [podnesti] to bring (to)</td>
</tr>
<tr>
<td>6) /pod-pisatʲ/ [potpisatʲ] to sign</td>
</tr>
<tr>
<td>7) /pod-ʒetʃ/ [podʒetʃ] to set fire to</td>
</tr>
<tr>
<td>8) [volk] *[volk] wolf</td>
</tr>
</tbody>
</table>
Russian /v/: Regressive Voicing Assimilation

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### Regressive Voicing Assimilation: D → T / ___T

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<tbody>
<tr>
<td>5)</td>
<td>/pod-nesti/</td>
<td>[podnesti]</td>
</tr>
<tr>
<td>6)</td>
<td>/pod-pisatʲ/</td>
<td>[potpisatʲ]</td>
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<tr>
<td>7)</td>
<td>/podʒetʃ/</td>
<td>[podʒetʃ]</td>
</tr>
<tr>
<td>8)</td>
<td>[volk]</td>
<td>*[volk]</td>
</tr>
</tbody>
</table>

### Regressive Voicing Assimilation: /v/ → [f] / ___T

<p>| | | |</p>
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<thead>
<tr>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>9)</td>
<td>/v ruke/</td>
<td>[v ruke]</td>
</tr>
<tr>
<td>10)</td>
<td>/v gorode/</td>
<td>[v gorode]</td>
</tr>
<tr>
<td>11)</td>
<td>/v supe/</td>
<td>[f supe]</td>
</tr>
</tbody>
</table>
Voiceless obstruents become voiced before voiced obstruents
Voiceless obstruents do not become voiced before sonorants

<table>
<thead>
<tr>
<th>12) /ot-jexatʃ/</th>
<th>[otjexatʃ]</th>
<th>to ride off</th>
</tr>
</thead>
<tbody>
<tr>
<td>13) /ot-stupitʃ/</td>
<td>[otstupitʃ]</td>
<td>to step back</td>
</tr>
<tr>
<td>14) /ot-brositʃ/</td>
<td>[odbrositʃ]</td>
<td>to throw aside</td>
</tr>
</tbody>
</table>
Russian /v/: Regressive Voicing Assimilation

- Voiceless obstruents become voiced before voiced obstruents
- Voiceless obstruents do not become voiced before sonorants
- Voiceless obstruents do not become voiced before /v/

### Regressive Voicing Assimilation: $T \rightarrow D / ___D$

<table>
<thead>
<tr>
<th>Example</th>
<th>Pronunciation</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>12)</td>
<td>/ot-jexat^j/</td>
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</tr>
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</table>

### Regressive Voicing Assimilation: $/T/ \rightarrow [D] / ___v$

<table>
<thead>
<tr>
<th>Example</th>
<th>Pronunciation</th>
<th>Meaning</th>
</tr>
</thead>
</table>
| 15)     | /ot-vesti/    | [otvesti]        | lead away        | *[odvesti]
Summary: Russian /v/ patterns anomalously

Like voiced obstruents, unlike sonorants:

/\v/ \rightarrow [f] / {___#, ___T}

- A target for final devoicing
  [prav-a] \sim [praf], right (fem./masc.)

- A target for regressive voicing assimilation
  /\v\ supe/ > [f supe], in the soup

Unlike voiced obstruents, like sonorants:

/\T/ \rightarrow [D] / ___v

- Does not trigger regressive voicing assimilation
  /ot-vesti/ > [otvesti], lead away * [odvesti]

Phonological classification of Russian /\v/ is ambiguous.
### Linguists on /v/ (non-exhaustive)

<table>
<thead>
<tr>
<th>Year</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1959</td>
<td>Halle</td>
</tr>
<tr>
<td>1965</td>
<td>Lightner</td>
</tr>
<tr>
<td>1969</td>
<td>Andersen</td>
</tr>
<tr>
<td>1971</td>
<td>Coats and Harshenin</td>
</tr>
<tr>
<td>1972</td>
<td>Daniels</td>
</tr>
<tr>
<td>1978</td>
<td>Barkai and Horvath</td>
</tr>
<tr>
<td>1978</td>
<td>Jakobson</td>
</tr>
<tr>
<td>1980</td>
<td>Vago</td>
</tr>
<tr>
<td>1984</td>
<td>Hayes</td>
</tr>
<tr>
<td>1997</td>
<td>Burton and Robblee</td>
</tr>
<tr>
<td>1999</td>
<td>Kavitskaya</td>
</tr>
<tr>
<td>2002</td>
<td>Padgett</td>
</tr>
<tr>
<td>2004</td>
<td>Petrova and Szentgyörgyi</td>
</tr>
<tr>
<td>2004</td>
<td>Lulich</td>
</tr>
<tr>
<td>2006</td>
<td>Kiss and Bárányi</td>
</tr>
</tbody>
</table>

...and many others...
Russian /v/ in a (cross-)linguistic context

Linguists on /v/ (non-exhaustive)


Languages with ambiguous patterning of /v/ (non-exhaustive)

<table>
<thead>
<tr>
<th></th>
<th>Final Devoicing</th>
<th>RVA Target</th>
<th>RVA Trigger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Russian</td>
<td>✓</td>
<td>✓</td>
<td>×</td>
</tr>
<tr>
<td>Bulgarian</td>
<td>✓</td>
<td>✓</td>
<td>×</td>
</tr>
<tr>
<td>Slovak</td>
<td>/v/ → [w]</td>
<td>✓</td>
<td>×</td>
</tr>
<tr>
<td>Hungarian</td>
<td>N/A</td>
<td>✓</td>
<td>×</td>
</tr>
<tr>
<td>Hebrew</td>
<td>N/A</td>
<td>✓</td>
<td>×</td>
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</table>
Russian /v/ in a (cross-)linguistic context

Linguists on /v/ (non-exhaustive)


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Maybe there’s something about /v/ in these languages...
Acoustic study
Does ambiguity reflect intermediacy?

**Padgett (2002):** Patterning of ambiguous /v/ derives from its intermediate phonetic nature together with a cue-based approach to phonology.

Assumption: phonological identity $\Leftrightarrow$ phonetic realization

<table>
<thead>
<tr>
<th>patterning:</th>
<th>obstruent</th>
<th>ambiguous</th>
<th>sonorant</th>
</tr>
</thead>
<tbody>
<tr>
<td>realization:</td>
<td>$v$</td>
<td>$\breve{v}$</td>
<td>$\nu$</td>
</tr>
<tr>
<td>classification:</td>
<td>fricative</td>
<td>“narrow approximant”</td>
<td>approximant</td>
</tr>
</tbody>
</table>

Claim (Padgett): The articulation of “ambiguous /v/” is inherently intermediate between a fricative (obstruent) and approximant (sonorant).
Results: relativized spectral centroid

Relative Spectral Centroid: WI Condition

<table>
<thead>
<tr>
<th>Language</th>
<th>Spectral Centroid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serbian</td>
<td>m v f z s</td>
</tr>
<tr>
<td>Russian</td>
<td>m v f z s</td>
</tr>
<tr>
<td>Greek</td>
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Relative Spectral Centroid: WM Condition

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</tbody>
</table>

Note that no tokens of /v/ exhibited significant devoicing in any language.
The ambiguity of /v/ in Russian is not due to a special, “inherent” intermediacy.
Phonological classification vs. phonetic realization

Padgett: phonological identity $\leftrightarrow$ phonetic realization

<table>
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<tr>
<td>realization:</td>
<td>$\nu$</td>
<td>$\nu\dot{\tau}$</td>
<td>$\nu$</td>
</tr>
<tr>
<td>classification:</td>
<td>fricative</td>
<td>“narrow approximant”</td>
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</tr>
</tbody>
</table>

- Acoustic characteristics of languages with ambiguous /$\nu$/
  - Slovenian: very sonorous
  - Czech: like a stop

- No language contrasts /$\nu$/ $\sim$ /$\nu\dot{\tau}$/
  or /$\nu\dot{\tau}$/ $\sim$ /$\nu$/
    ➢ rare (and unstable) to contrast /$\nu$/ $\sim$ /$\nu$/!
Patterning of /v/
Russian /v/: Is it special?

It seems obvious that Russian /v/ requires special treatment, because:

1. There is a symmetry in the relationship between other voicing pairs and RVA:
   /b, z/ $\rightarrow$ [p, s]; /p, s/ $\rightarrow$ [b, z]

2. /v/ is a fricative, so it ought to pattern with other fricatives

BUT: this rests on a crucial assumption:

Unity of (voiced) obstruents hypothesis:
Relationship of voicing in /v, f/ parallels the other obstruents:

In search of [−sonorant] /v/

Given the attention that ambiguous /v/ has attracted, it should be easy to find examples of /v/ being *phonologically classified* with other voiced obstruents...
In search of [−sonorant] /v/

Given the attention that ambiguous /v/ has attracted, it should be easy to find examples of /v/ being phonologically classified with other voiced obstruents...

Conjecture: (OCP, January 2015)
/v/ can never trigger voicing assimilation (like /b, z/).
In search of [−sonorant] /v/

Given the attention that ambiguous /v/ has attracted, it should be easy to find examples of /v/ being *phonologically classified* with other voiced obstruents...

**Conjecture: (OCP, January 2015)**

/v/ can never trigger voicing assimilation (like /b, z/).

**Counterexamples:**

1. Polish (Warsaw dialect only)
2. “Hungarian grandmother”: some dialects of Hungarian; apparently unstable, and in some regions /v/ is devoiced following voiceless obstruents
# Classes of obstruents

## Definition (Types of fricatives)

**Sibilants:** produced with a grooved tongue such that noise is generated both at locus of constriction and downstream against obstacle (teeth)

**Spirants:** produced with narrow articulation such that noise is only generated at locus of constriction
The phonetics of obstruent voicing

**Fricatives (Sibilants and Spirants):** Difficult to maintain adequate airflow for voicing and frication; typically shorter and partially devoiced.

- **Sibilants:** ([s, z]) Voicing does not affect frication as drastically for sibilants as it does for spirants, since two sources of noise generation (at locus of constriction and downstream).

- **Spirants:** ([f, v]) Insofar as well voiced, poorly fricated, insofar as well fricated, poorly voiced (Ohala, 1983). ⇒ /v/, being voiced, is a bad obstruent
Voicing $\mapsto [\text{voice}]$ across the classes

Recap:

- **Sonorants (nasals)** do not impede airflow, hence do not impede voicing $\Rightarrow$ voicing default

- **Obstruents (stops, fricatives)** articulated with sufficiently narrow constriction to make voicing difficult $\Rightarrow$ voicelessness default

- Many languages *phonologize* this distinction, where voicing in sonorants is:
  - maintained in places obstruent voicing is not inert with respect to voicing assimilation (sonorants do not “assert” their voicing)

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**Asserting obstruent voicing**

Broad phonetic (i.e., aerodynamic) principles underlying the challenges of obstruent voicing are phonologized in different, but restricted, ways.
Triggers of (regressive) voicing assimilation: a typology

Triggers of voicing assimilation

1. All voiced segments – Greek
2. Stops – Dutch
3. Stops and sibilants – Russian
4. Stops, sibilants and spirants – Hungarian dialect

Partitions of voicing

<table>
<thead>
<tr>
<th>Language</th>
<th>Partitions of voiced segments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greek</td>
<td>{/[m, b, z, v]/} (vs. {/[p, s, f]/})</td>
</tr>
<tr>
<td>Dutch</td>
<td>{/[m]/} vs. {/[b]/} vs. {/[v, z]/}</td>
</tr>
<tr>
<td>Russian</td>
<td>{/[m]/} vs. {/[b, z]/} vs. {/[v]/}</td>
</tr>
<tr>
<td>Hungarian (dialect)</td>
<td>{/[m]/} vs. {/[b, z, v]/}</td>
</tr>
</tbody>
</table>
Linguistic claims

1. There is nothing special about the *phonetic intermediacy* of Russian /v/.

2. Phonology (as categorization) does not encode fine-grained details of the phonetics.

3. The default assumption about /v/ as a voiced obstruent is rarely (and unstably) attested.

4. Categorization of voiced segments as sonorants vs. obstruents (or classes within) reflects broad phonetic principles.
### Where do the categorizations come from?

#### What makes a good obstruent?
- Complete stoppage of air? ⇒ /b/
- Noise (i.e., frication)? ⇒ /b, z/
- Close enough articulation? ⇒ /b, z, v/

#### What kinds of general principles might phonology care about?
- “Minimize the number of representations”
- “Define categorizations using articulation”
- “Define categorizations using acoustics / perception”
Thank you!

Special thanks to Adam BJORNDahl, Jaye Padgett, Rafael Stern, Robin Karlin and Ewan Dunbar for helpful discussion and correspondence, as well as audiences at OCP 12 and MOLT 2015.


Intermission: Myoelastic aerodynamic theory of phonation

How does voicing work?

- Vocal fold position & tension: adducted & taut
- As air flows out of lungs, pressure builds up behind closed vocal folds
- When sub-glottal pressure increases sufficiently, folds blown open
- Air flow through narrower passage of the glottis, velocity increases (Venturi effect)
- Increased velocity of airflow causes pressure drop perpendicular to direction of flow (Bernoulli effect)
- Bernoulli effect & natural elasticity: folds sucked back together
Controls

To adequately test whether ambiguous /v/ is intermediate (1) across languages and (2) within inventory, must use control cases:
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1. Control languages:
   - Greek: obstruent distribution; triggers RVA
     /tis varvaras/ → [tiz varvaras]  *Barbara’s*
   - Serbian: sonorant distribution; neither triggers nor targets RVA
     [ovca]  *sheep*   [svariti]  *digest*
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2. **Control segments:**
   - /f/ ← voiceless member of “pair”
   - /s, z/ ← uncontroversial obstruent fricative pair
   - /m/ ← sonorant (sanity check)
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3. **Control for local inventory structure:** all three languages lack labial approximant (e.g., /w, v/)
Stacking the deck

If we want to find \( [\mathfrak{v}] \), need to look in favourable positions:

- word-initial stressed (WIS)
- word-medial unstressed (WMU)
- flanking vowels /a, o/ (no palatalization, spirantization)
- \( C_1 VC_2 V(C) \)
Assessing intermediacy of /v/ tokens

Question: Modulo the effect of voicing, are tokens of voiced and voiceless fricatives realized with similar degree of frication?

Spectral Centroid
Measure of how high frequencies in spectrum are on average (Boersma and Weenink, 2011).

Voicing and frication
Voicing introduces low frequency energy and “multimodal” distribution of frequency ⇒ can’t interpret centroid of voiced fricative!

solution:
high-pass filtered at 1500Hz ⇒ remove effect of voicing
Assessing degree of frication in /v/ tokens

**Question:** Modulo the effect of voicing, are tokens of voiced and voiceless fricatives realized with similar degree of frication?
Assessing degree of frication in \( \text{v} \) tokens

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  \( \Rightarrow \) can’t interpret centroid of voiced fricative!
- **solution:** high-pass filtered at 1500Hz
  \( \Rightarrow \) remove effect of voicing
Assessing frication relationally

Normalization

For each speaker $s$,

- $\mu[f], s = \text{mean centroid value for utterances of } [f], \text{averaged across words and repetitions of that speaker}$
- For each centroid $c_i$ of speaker $s$, the relative measure $\tilde{c}_i$ is $c_i - \mu[f], s$

$\Rightarrow \tilde{c}_i$ denotes relative difference of centroids of $[v, s, z, m]$ to $[f]$

Prediction: phonological pairing $\iff$ phonetic pairing

<table>
<thead>
<tr>
<th>Greek</th>
<th>Russian</th>
<th>Serbian</th>
</tr>
</thead>
<tbody>
<tr>
<td>$v - f$</td>
<td>$\varphi - f$</td>
<td>$v - f$</td>
</tr>
<tr>
<td>small</td>
<td>medium</td>
<td>large</td>
</tr>
</tbody>
</table>
Results: power spectra

Broadband power spectra were computed using a 64-point FFT on a 2 ms Hann window in the middle of the segment. The log-transformed power spectra were then averaged over all repetitions, words and speakers, for each condition. The shaded area shows confidence intervals of two standard errors.
Database

Inventory structure potentially relevant for /v/

- local contrasts (e.g., /v/ vs. /w/)
- voicing contrasts in obstruents: stops vs. sibilants vs. spirants

Database construction

- based on PBase (Mielke, 2008)
- more languages (571): added languages part of WALS 100 language sample
- no duplicates: languages had to have unique ISO codes
- checked sources: if language was in LAPSyD, cross-checked inventory; discrepancies resolved in favour of LAPSyD (Maddieson et al., 2013)
Implicational relations of voicing

The presence of a voiced plosive/fricative implies the presence of its voiceless member.

Questions

What is the “normal” obstruent rate of violation? What is the rate of violation among the spirants?
Violations of implicational relations in voicing pairs