Intermediacy, Ambiguity and Categorization at the Phonetics-Phonology Interface

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March 23, 2015

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 seqeuences are licit:
English *[#zg] vs. Czech [#zg]
➢ Note: a[z g]ood

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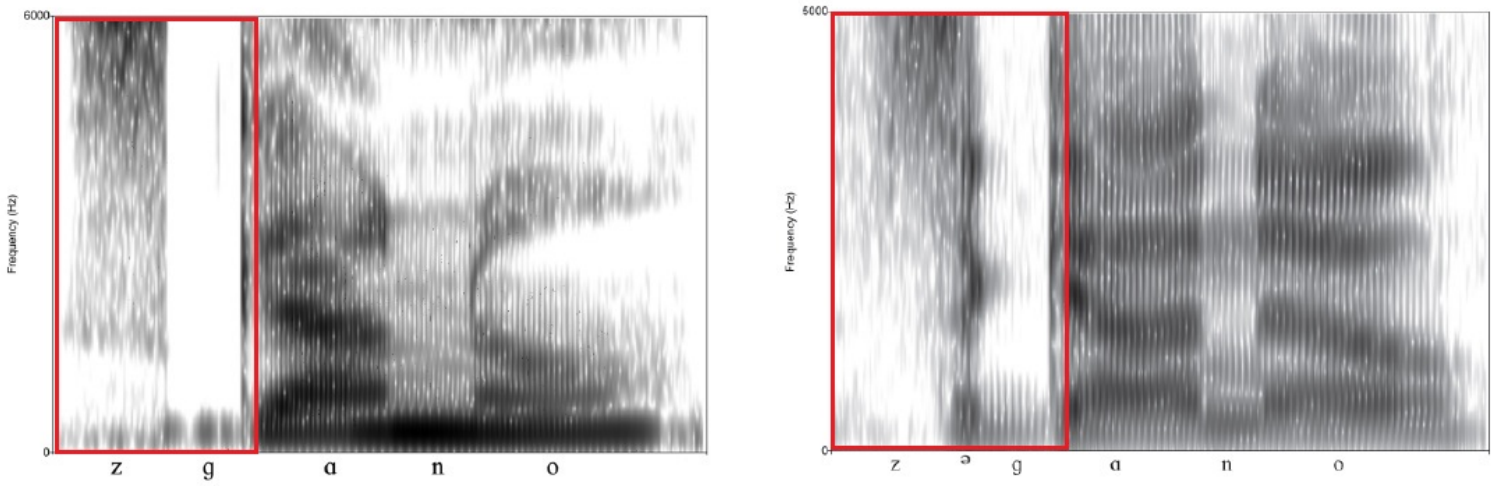

Figure : Nonword /zgano/: Czech (left) and English (right)

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*

Phonology: Sounds group together due to phonetics

Sounds in languages do not exist in isolation. Sounds are grouped into **(natural) classes**, grounded phonetically and manifested phonologically.

Phonetic grounding: classes defined phonetically

Feature	**Sounds**	**Phonetic definition**
[nasal]	[m, n, ŋ]	lowered velum
[+continuant]	[f, v, s, z]	continuous airflow (oral)
[−continuant]	[p, b, t, d, k, g]	airflow blocked
[+voice]	[b, d, g, v, z, m, l]	vocal folds vibrate
[−voice]	[p, t, k, f, s]	vocal folds do not vibrate

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

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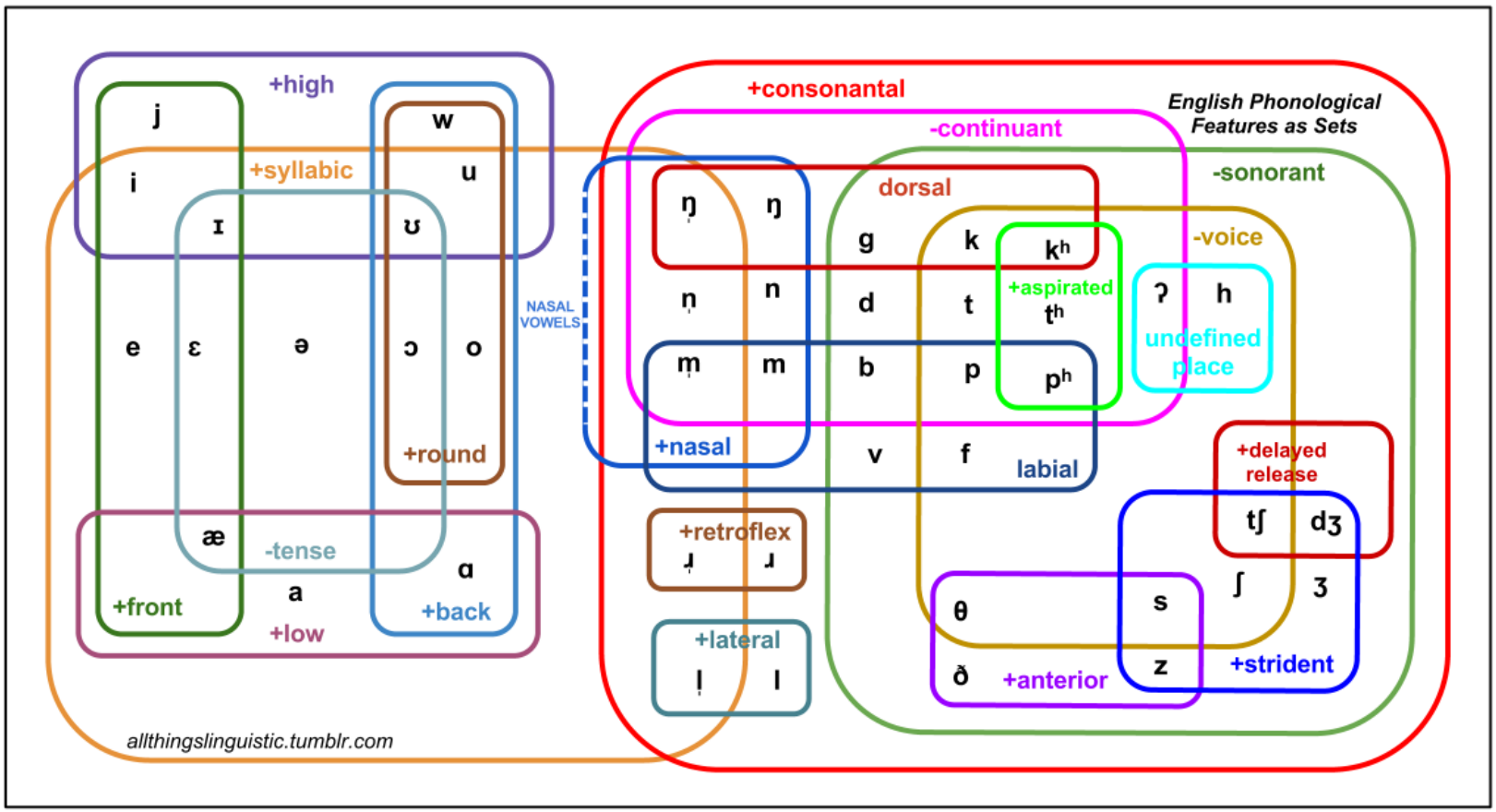
Canadian Raising

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

Phonology: Features as inventory partitions

The sound **inventory** of a language is partitioned by the classes; typically captured with (binary) features.



http://allthingslinguistic.com/post/33605639325/phonological-natural-classes-and-set-theory

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 $\Rightarrow$ features.

Phonology: Classes vs. Features

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- Sounds can differ in **distribution**, **contrast** and **patterning**.
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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

	Labial		Dental		Palato-Alveolar		Velar	
Stop	p	b	t	d			k	g
	p^j	b^j	t^j	d^j			(k^j)	(g^j)
Affricates			ts		$t\int^j$			
Fricative	f	v	s	z	∫	ʒ	x	
	f^j	v^j	s^j	z^j			(x^j)	
Nasal		m		n				
		m^j		n^j				
Lateral				l				
				l^j				
Rhotic				r				
				r^j				
Approximant						j		

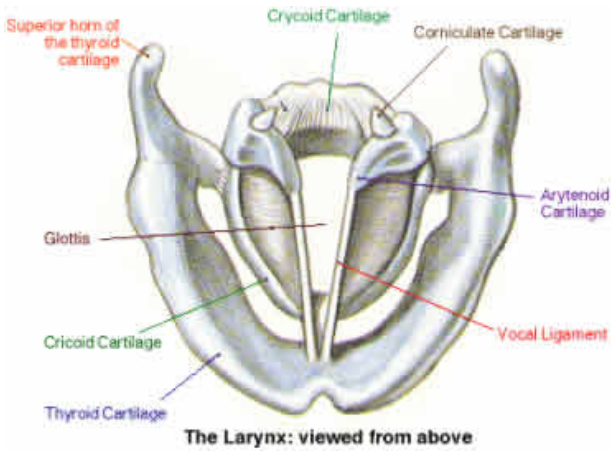
Russian: Consonant Inventory (Abridged)

	Labial		Dental		Palato-Alveolar		Velar	
Stop	p	b	t	d			k	g
Fricative	f	v	s	z	ʃ	ʒ	x	
Nasal		m		n				
Lateral				l				
Rhotic				r				
Approximant						j		

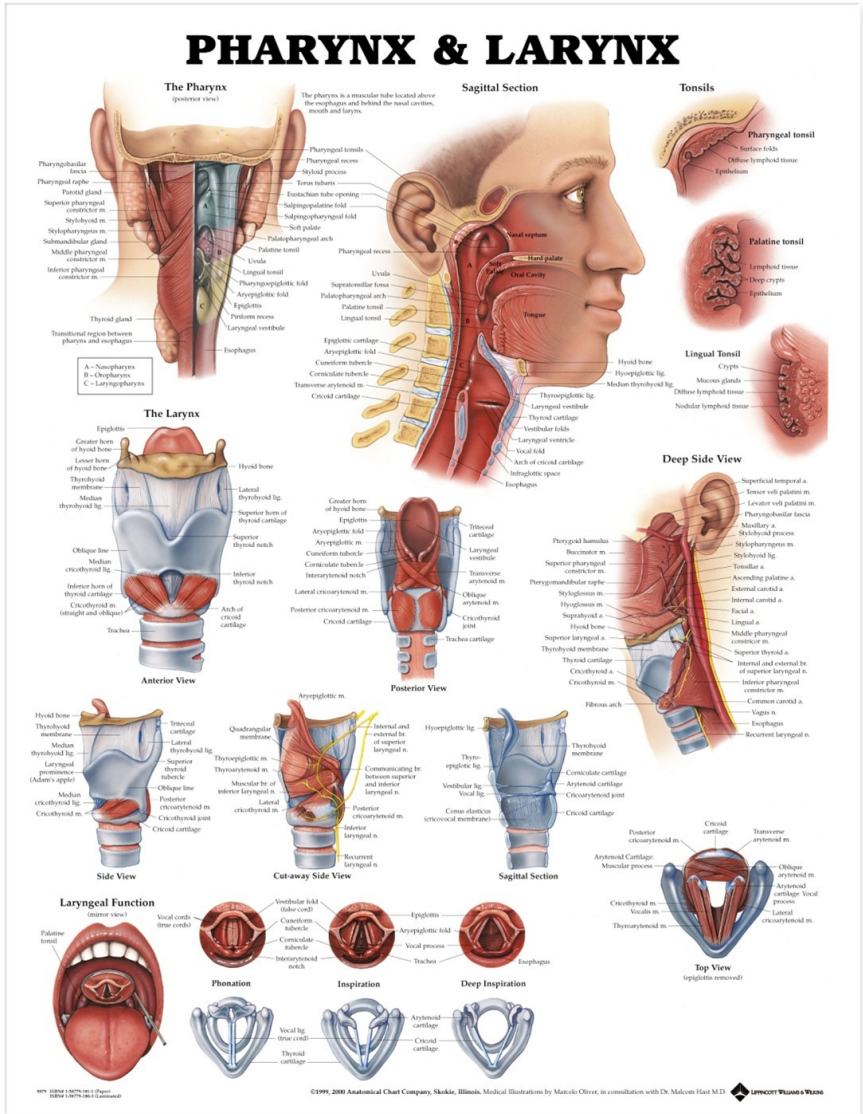
Intermission: Voicing

How does voicing work?

- Not muscular!
- Control vocal fold position and tension...
- Expel air from lungs...
- Let aerodynamics do the rest!



The Larynx: viewed from above



Intermission: Obstruent vs. Sonorant Voicing

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

Sonorants: nasals [m, n, ŋ], 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, g], 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

Russian: Consonant Inventory (Abridged)

	Labial	Dental	Palato-Alveolar	Velar
Stop	p b	t d		k g
Fricative	f v	s z	ʃ ʒ	x
Nasal	m	n		
Lateral		l		
Rhotic		r		
Approximant			j	

Relations in voicing: (disunity of voice)

- Voiced obstruents stand in relation to the voiceless obstruents (contrastive along the parameter of voicing) $\Rightarrow$ [$\pm$ voice]
- Sonorants are voiced, but they are unpaired on this parameter
- We might expect different phonological behaviour from the sonorants and voiced obstruents. . .

Russian /v/: Final Devoicing

- Voiced obstruents devoice to voiceless counterparts in word-final position
- /v/ devoices to [f] in word-final position
- Sonorants do not devoice

Final Devoicing: /v/ → [f] / ___#

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

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➢ phonological manifestation of distinction in voicing between obstruents and sonorants

Russian /v/: Regressive Voicing Assimilation

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Regressive Voicing Assimilation: D → T / __T

5)	/pod-nesti/	[podnesti]	*to bring (to)*
6)	/pod-pisatʲ/	[potpisatʲ]	*to sign*
7)	/pod-ʒetʃ/	[podʒetʃ]	*to set fire to*
8)	[volk]	*[volk̥]	*wolf*

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8)	[volk]	*[vo̥lk]	*wolf*

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

9)	/v ruke/	[v ruke]	*in one's hand*
10)	/v gorode/	[v gorode]	*in the city*
11)	/v supe/	[f supe]	*in the soup*

Russian /v/: Regressive Voicing Assimilation

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

Regressive Voicing Assimilation: T → D / ___D

12)	/ot-jexat^{j}/	[otjexat^{j}]	*to ride off*
13)	/ot-stupit^{j}/	[otstupit^{j}]	*to step back*
14)	/ot-brosit^{j}/	[odbrosit^{j}]	*to throw aside*

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- Voiceless obstruents do not become voiced before /v/

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Regressive Voicing Assimilation: /T/ ↛ [D] / ___v

15)	/ot-vesti/	[otvesti]	*lead away*	*[odvesti]

Summary: Russian /v/ patterns anomalously

Like voiced obstruents, unlike sonorants:

/v/ ⇒ [f] / {__#, __T}

- A target for final devoicing
  [prav-a] ∼ [praf], *right (fem./masc.)*
- A target for regressive voicing assimilation
  /v supe/ > [f supe], *in the soup*

Unlike voiced obstruents, like sonorants:

/T/ ↛ [D] / __v

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

➢ Phonological classification of Russian /v/ is *ambiguous*.

Russian /v/ in a (cross-)linguistic context

Linguists on /v/ (non-exhaustive)

Halle (1959), Lightner (1965), Andersen (1969), Coats and Harshenin (1971), Daniels (1972), Barkai and Horvath (1978), Jakobson (1978), Vago (1980), Hayes (1984), Burton and Robblee (1997), Kavitskaya (1999), Padgett (2002), Petrova and Szentgyörgyi (2004) Lulich (2004), Kiss and Bárkányi (2006), and many others...

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

	Final Devoicing	RVA	
		Target	Trigger
Russian	✓	✓	✗
Bulgarian	✓	✓	✗
Slovak	/v/ → [w]	✓	✗
Hungarian	N/A	✓	✗
Hebrew	N/A	✓	✗

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Hungarian	N/A	✓	✗
Hebrew	N/A	✓	✗

Maybe there's something about /v/ in these languages...

Acoustic study

Does ambiguity reflect intermediacy?

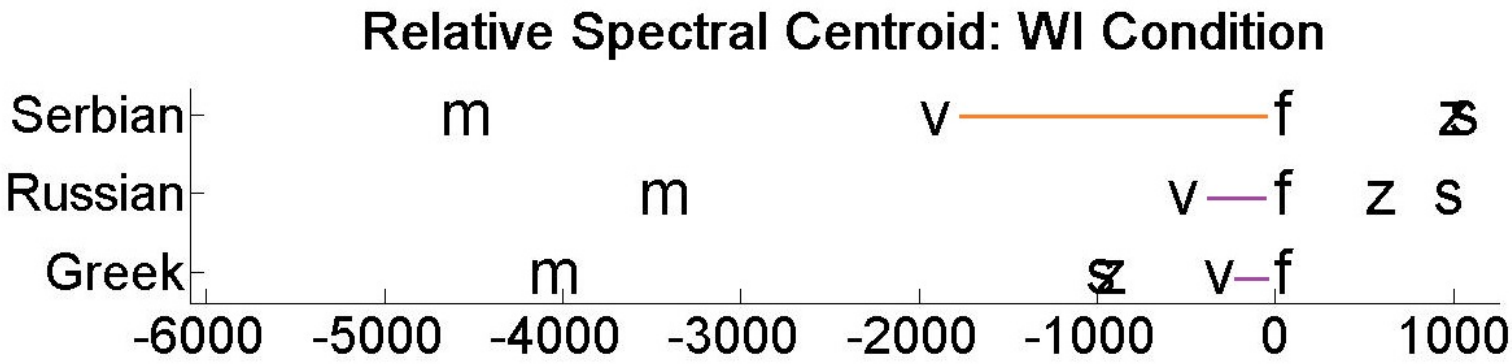
Padgett (2002): Patterning of ambiguous /v/ derives from its *intermediate phonetic nature* together with a cue-based approach to phonology.

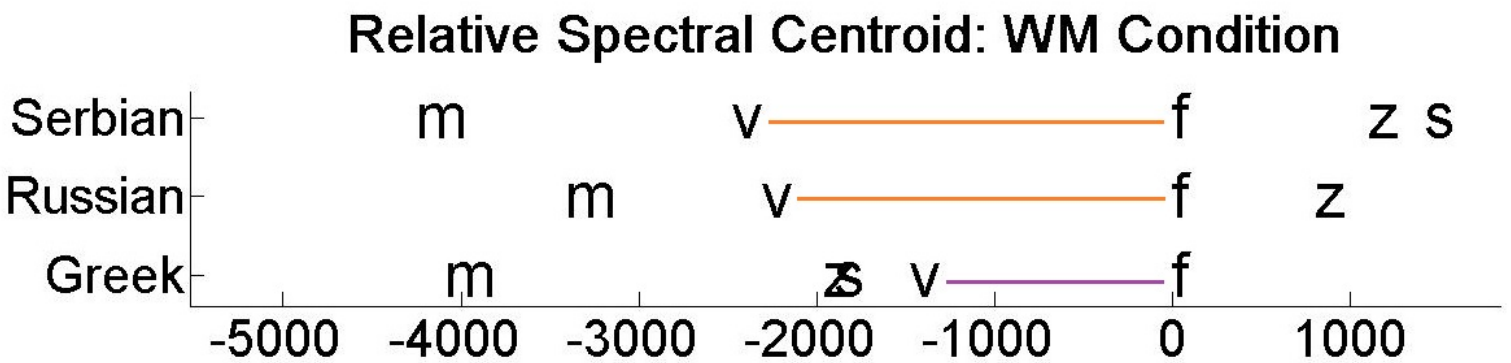
Assumption: phonological identity ⇔ phonetic realization

patterning:	obstruent	ambiguous	sonorant
realization:	v	v̞	ʋ
classification:	fricative	"narrow approximant"	approximant

Claim (Padgett): The articulation of "ambiguous /v/" is inherently intermediate between a fricative (obstruent) and approximant (sonorant).

Results: relativized spectral centroid





Note that no tokens of /v/ exhibited significant devoicing in any language.

Acoustic study: Conclusion

The ambiguity of /v/ in Russian is not due to a special, "inherent" intermediacy.

Phonological classification vs. phonetic realization

Padgett: phonological identity ⇔ phonetic realization

patterning:	obstruent	ambiguous	sonorant
realization:	ʋ	ʋ̞	ʊ
classification:	fricative	"narrow approximant"	approximant

- Acoustic characteristics of languages with ambiguous /ʋ/
  - Slovenian: very sonorous
  - Czech: like a stop
- No language contrasts /ʋ/ ∼ /ʋ̞/ or /ʋ̞/ ∼ /ʊ/
  ➢ rare (and unstable) to contrast /ʋ/ ∼ /ʊ/!

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/ → [p, s]; /p, s/ → [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:

/v/ : /f/ :: /b/ : /p/ :: /z/ : /s/.

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. . .

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Conjecture: (*OCP, January 2015*)

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

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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

THE INTERNATIONAL PHONETIC ALPHABET (revised to 2005)

CONSONANTS (PULMONIC) © 2005 IPA

	Bilabial	Labiodental	Dental	Alveolar	Postalveolar	Retroflex	Palatal	Velar	Uvular	Pharyngeal	Glottal
Plosive	p b			t d		ʈ ɖ	c ɟ	k g	q ɢ		ʔ
Nasal	m	ɱ		n		ɳ	ɲ	ŋ	N		
Trill	ʙ			r					ʀ		
Tap or Flap		ⱱ		ɾ		ɽ					
Fricative	ɸ β	f v	θ ð	s z	ʃ ʒ	ʂ ʐ	ç ʝ	x ɣ	χ ʁ	ħ ʕ	h ɦ
Lateral fricative				ɬ ɮ							
Approximant		ʋ		ɹ		ɻ	j	ɰ			
Lateral approximant				l		ɭ	ʎ	ʟ			

Where symbols appear in pairs, the one to the right represents a voiced consonant. Shaded areas denote articulations judged impossible.

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).
  $\Rightarrow$ /v/, being voiced, is a bad obstruent

Voicing $\mapsto$ [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)

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

Language	Partitions of voiced segments
Greek	{/m, b, z, v/} (vs. {/p, s, f/})
Dutch	{/m/} vs. {/b/} vs. {/v, z/}
Russian	{/m/} vs. {/b, z/} vs. {/v/}
Hungarian (dialect)	{/m/} vs. {/b, z, v/}

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*.

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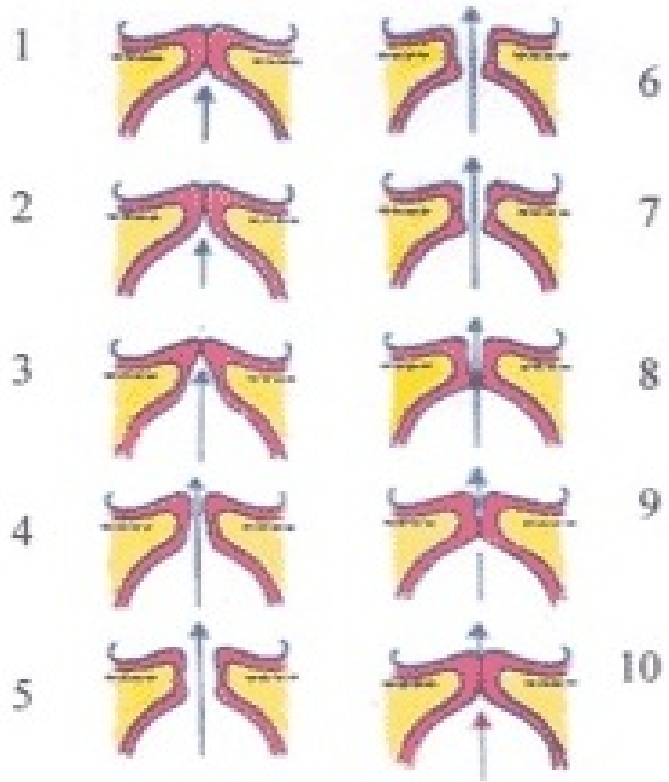
Intermission: Myoelastic aerodynamic theory of phonation

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



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3. Control for local inventory structure: all three languages lack labial approximant (e.g., /w, ʋ/)

Stacking the deck

If we want to find [v̞], need to look in favourable positions:

- word-initial stressed (WIS)
- word-medial unstressed (WMU)
- flanking vowels /a, o/ (no palatalization, spirantization)
- $C_1VC_2V(C)$

Assessing intermediacy of /v/ tokens

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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
  $\Rightarrow$ 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,

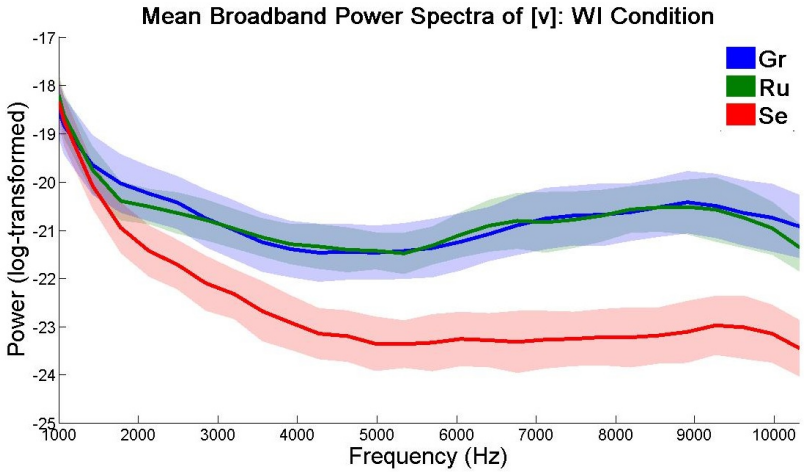
- $\mu_{[f],s}$ = mean centroid value for utterances of [f], averaged across words and repetitions of that speaker
- For each centroid c_i of speaker s, the *relative* measure $\tilde{c}_i$ is $c_i - \mu_{[f],s}$

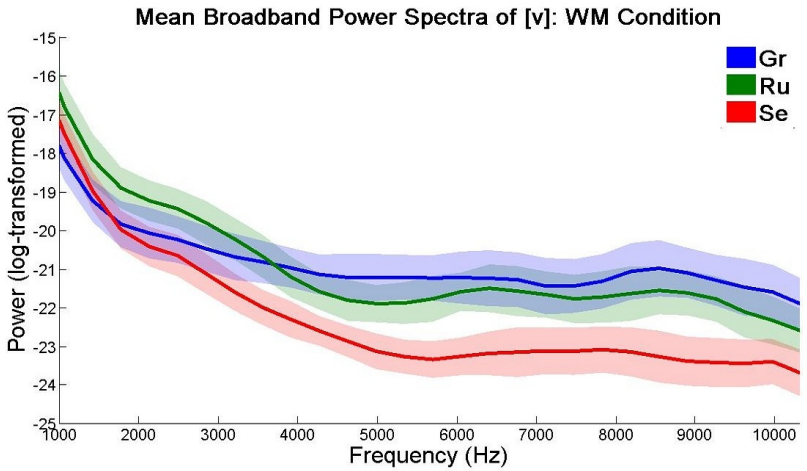
$\Rightarrow$ $\tilde{c}_i$ denotes *relative* difference of centroids of [v, s, z, m] to [f]

Prediction: phonological pairing $\Leftrightarrow$ phonetic pairing

Greek	Russian	Serbian
v − f	ⱱ − f	ʋ − f
small	medium	large

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)

Obstruent voicing pairs

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