A Phonetic Account of the Sonority Hierarchy with reference to Bavarian German <rl>

David Bolter (Denison University) and Erin Noelliste (University of Northern Colorado)

GLAC 29, April 20-22, 2023

1. Introduction

- Background: The Sonority Sequencing Generalization (Clements 1990) predicts that more sonorous segments should occur closer to the center of a syllable (nucleus), whereas less sonorous segments should occur at syllable edges (margins).

- In Standard German /kɛlr/ 'cellar' and /kɛrl/ 'guy' surface as [kʰɛ.lɐ] (disyllabic) and [kʰɛɐ̯l] (monosyllabic).

- Therefore, in Standard German, one would conclude that /r/ is more sonorous than /l/, based on the fact that /r/ occurs readily in the nucleus, as opposed to /l/, which occupies the margin.

- However, this is not the case in all German dialects.

(1) Data Set for [ɾl̩], modified from Noelliste (2019: 13)

	Phonetic Form	German Orthography	Gloss
a.	[kɔ.ɾl̩]	*Karl*	'Charles'
	[kɛ.ɾl̩]	*Kerl*	'guy'
	[kvɪ.ɾl̩]	*Quirl*	'beater'
b.	[ʃmaŋ.kə.ɾl̩]	*Schmankerl*	'delicacy'
	[ka.ʃpə.ɾl̩]	*Kasperl*	'clown'
	[sa.kə.ɾl̩]	*Sackerl*	'bag'
	[tsveɐ̯.gə.ɾl̩]	*Zwergerl*	'munchkin'

- The data presented in (1) are further subdivided into two different types of examples. (1) shows examples where the corresponding Standard German form always ends in an orthographic <rl>, whereas (1) presents data with the *-erl* diminutive.

- Based on data from English and Quechua Spanish, Parker (2008, 2011) argues that the sonority hierarchy is defined as a universal, and sonority can be defined by physical phonetic properties.

- We apply Parker's (2008, 2011) methodology to Bavarian German data, but we find a result which does not follow Parker's universal hierarchy. Instead, the data suggest that a different solution is needed.

- In this paper, we suggest two solutions which point towards the same conclusion: any universal hierarchy would necessarily need to expand on or revise what is argued for in Parker (2008, 2011), in light of how the Bavarian German flap's behavior in relation to the lateral differs from that of the flap found in Quechua Spanish.

2. Background on Sonority

- Sonority has a lengthy history in the phonological literature dating back to scholars such as Sievers (1881), Jespersen (1904), and Saussure (1916).

- Many scholars invoked theories of sonority within the latter part of the last century, including Vennemann (1972), Kiparsky (1979), Steriade (1982), Selkirk (1984), Zec (1988), and Clements (1990). Great recent attention has been given to sonority by Parker (2002, 2008, 2011), who approaches sonority with a less abstract phonological and more quantifiable phonetic-property methodology.

- All of this research begs the question: what exactly is sonority? Parker (2011: 1) describes the concept of sonority in the following quote:

  > Sonority can be defined as a unique type of relative, *n*-ary (non-binary) feature-like phonological element that potentially categorizes all speech sounds into a hierarchical scale. For example, vowels are more sonorous than liquids, which are higher in sonority than nasals … sonority is like most other features: it demarcates groups of segments that behave similarly in cross-linguistically common processes. At the same time, however, sonority is unlike most features in that it exhaustively encompasses all speech sounds simultaneously, i.e. every type of segment has some inherent incremental value for this feature.

(2) Sonority Hierarchies
  a. General Sonority Hierarchy (Clements 1990)
      vowels > glides > liquids > nasals > obstruents

  b. German Sonority Hierarchy (Wiese 1996, Hall 2002)
      vowels > glides > rhotics > laterals > nasals > obstruents

  c. Bavarian German Sonority Hierarchy (Noelliste 2019)
      vowels > glides > trills, laterals > flaps > nasals > obstruents

- The question of whether sonority hierarchies should be considered language-specific or universal has received much attention in the last several decades. See, for example, works on sonority hierarchies within the Optimality Theory framework (Prince & Smolensky 1993, 2004), particularly by de Lacy (2002, 2004, 2006, 2007).

- As mentioned above, Parker (2008, 2011) also advocates for a universal sonority hierarchy, proposing that the most quantifiable determination of sonority can be found by measuring the intensity of individual segments. This is supported by earlier works such as Bloomfield (1914) and Laver (1994).

- Parker (2008: 79) gives the following formula for calculating the mean intensity for segments.

(3) Formula for determining sonority

$$sonority = 13.9 + .48 \times L_{rel} \text{ (in dB)}$$

- Based on his data and calculations, Parker (2008, 2011) provides the sonority hierarchy given in (4) and makes the list of conclusions about sonority hierarchies in (5).

(4) Parker's Universal Sonority Hierarchy

Natural Class	**Sonority Index**
Low Vowels	17
Mid peripheral vowels (not [ə])	16
High peripheral vowels (not [ɨ])	15
Mid interior vowels ([ə])	14
High interior vowels ([ɨ])	13
Glides	12
Rhotic approximants ([ɹ])	11
Flaps	10
Laterals	9
Trills	8
Nasals	7
Voiced fricatives	6
Voiced affricates	5
Voiced stops	4
Voiceless fricatives (including [h])	3
Voiceless affricates	2
Voiceless stops (including [ʔ])	1

(5) Parker's Conclusions about sonority hierarchies (Parker 2011: 17)

All else being equal, an ideal sonority scale would have these characteristics:

a. *Universal:* It potentially applies to all languages.

b. *Exhaustive:* It encompasses all categories of speech sounds.

c. *Impermutable:* Its rankings cannot be reversed (although they may be collapsed or ignored).

d. *Phonetically grounded:* It corresponds to some consistent, measurable physical parameter shared by all languages.

- Importantly for discussion here, Parker predicts that sonority hierarchies should be both **universal** and **impermutable**, both of which Noelliste (2019) argues against based on data from Bavarian German.

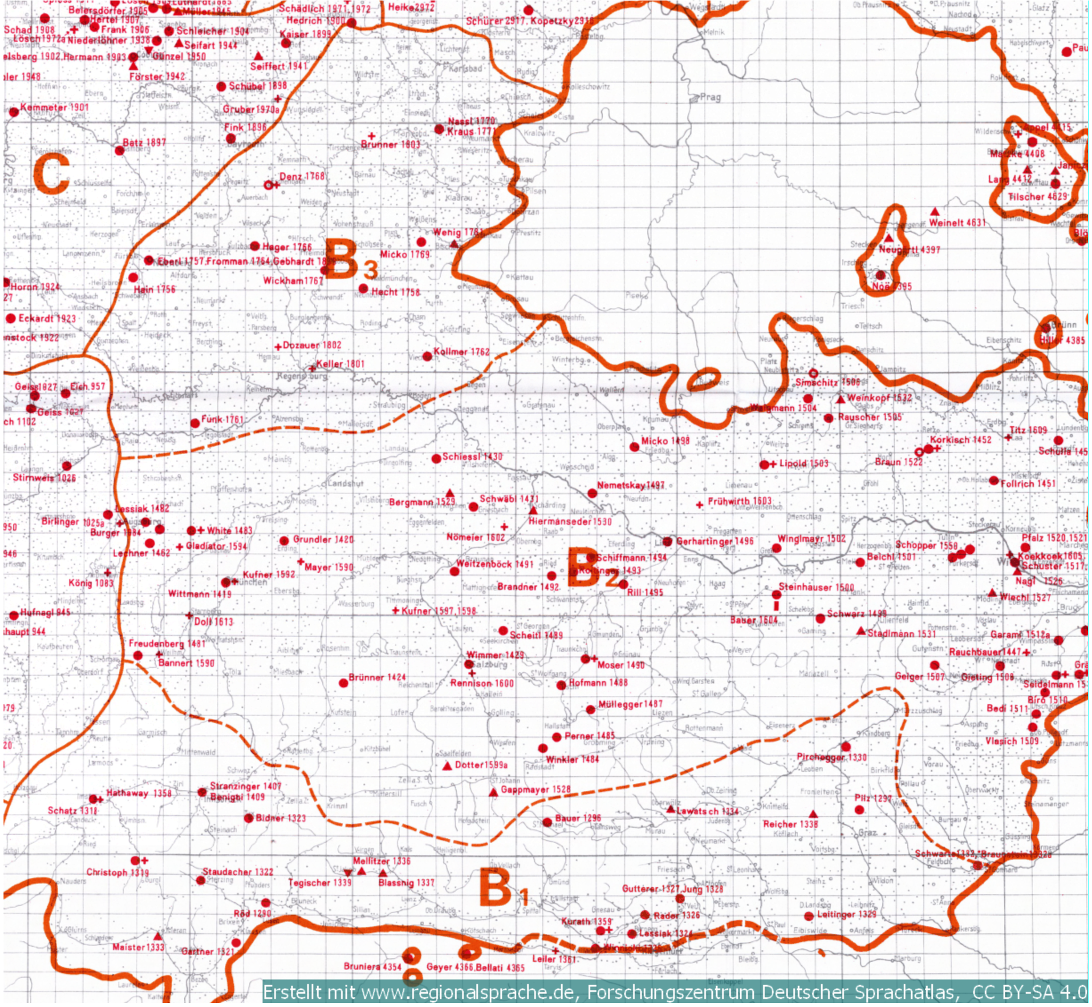
- In the following sections, we discuss an interesting case study for sonority based on data from Bavarian German dialects, specifically instances of <rl> sequences. In section 3, we discuss previous literature on such sequences in Bavarian German, and in section 4, we provide a phonetic account for Bavarian German <rl>.

3. Previous Accounts of Bavarian German <rl>

- Bavarian German, with its estimated 14.5 million speakers (Eberhard et al. 2022), represents one of the largest and most well-known dialect regions of the German-speaking world.

- Traditionally, Bavarian German is subdivided between North Bavarian, Central Bavarian, and South Bavarian, which can be seen on the map in (6) as B3, B2, and B1, respectively.

(6) Map of *Ortsdarstellungen* for Bavarian German (Wiesinger, Raffin, & Voigt 1982)



Erstellt mit www.regionalsprache.de, Forschungszentrum Deutscher Sprachatlas, CC BY-SA 4.0

- Kranzmayer (1956), in his work on the historical phonology of Bavarian German writes extensively on the topic of <rl> sequences. Kranzmayer (1956: 124) writes:

> Now we come to the most difficult part, to the sound sequences *-rl*, *-rn*, *-rt*, *-rr*, in other words *r* + coronal. In Central Bavarian including Burgenland, Styria and Lower Carinthia, the sound sequence *-rl*, assuming an original tongue tip r, has become *-dl* (today still found in the Lavant Valley, the upper Styrian Uppermur area, and in Western Styria) and then developed further to the Central Bavarian

post-dental -^{d}*l*, for example in *khę̄*^{d}*l* (Kerl), *khǭ*^{d}*l* (Karl) or rather in *ghę̄*^{d}*l*, *ghǭ*^{d}*l* or *ghę̄ɒ*^{d}*l*, *ghǭɒ*^{d}*l*.

- Therefore, according to Kranzmayer, most Central Bavarian varieties have developed $^{+}$rl sequences as either |dl| or |^{d}l|.

- It is not immediately clear to us how the distinction between |dl| and |^{d}l| would translate in the present-day IPA; one conceivable interpretation would be that |^{d}| would be a flap/tap transcribed in the IPA as [ɾ]. We return to this question in section 4.

- Outside of Kranzmayer (1956), there are a number of grammatical descriptions of Bavarian German that are specific to a particular town or region.

(7) Summary of $^{+}$rl and $^{+}$rn data in some Austrian German *Ortsgrammatiken*

Source	Location	Data Point(s)	Page
Schatz (1897)	Imst, Tirol	|kχādl| *Kerl* ‘guy’ [kxaːdl]	p. 94, §72
		|fǭrə| *fahren* ‘to drive’ [fɔːrə]	p. 167, §153
Lessiak (1903)	Pernegg, Carinthia	|khǫrl| *Karl* ‘Charles’ [kʰɔʁl]	p. 13, §5
		|fīrŋ| *führen* ‘to lead’ [fiːʁŋ]	p. 143, §114
Pfalz (1911, 1913)	Marchfeld, Lower Austria	|khęęɒ-l̥| *Kerl* ‘guy’ [kʰɛɐ̯.l̩]	p. 248
		|fǭɒn| *fahren* ‘to drive’ [fɔɐ̯ːn]	p. 50 (1913)
Pilz (1938)	Semriach Basin, Styria	|ə̇̄i·lən| *Erle* ‘alder (tree)’ [əɪ̯ː.lən]	p. 155, §55
		|kē·n| *gern* ‘gladly’ [keː.n̩]	p. 62, §26
Leitinger (1939)	Sulm Valley, Styria	|šwā·lı| *schwerlich* [ʃwaː.lɪ]	p. 92, §127
		|fǫ·n| *fahren* ‘to drive’ [fɔ.n̩]	p. 15, §19
Lawatsch (1945)	Oberwölz, Styria	|ō.l̥| ‘small plough [oː.l̩]	p. 39
		|fō.n̥| *fahren* ‘to drive’ [foː.n̩]	p. 39
Rader (1966)	Feldkirchen, Carinthia	|fǫɐr̯n| (old) / |fǫɐ̃n| (young) *fahren* ‘to drive‘ [fɔɐ̯ʀn] / [fɔɐ̯̃n]	p. 13, §6
Perner (1971)	Ramsau am Dachstein, Styria	|τę̄ɫ̥| *Törlein* ‘little gate’ [tęː.ɫ̩]	p. 139, §8

- From the table in (7), it can be seen that early scholars had different descriptions of /rl/, including |dl|, |-l̥||, |˙l|, |.l̥|.

- Of course, these authors are presenting descriptions of different localities throughout the Bavarian speaking world. Thus, it could be the case that each town or locality pronounced these segments differently, as found in the descriptions in the table.

- However, it is equally plausible that the phonetic realizations in the different towns and localities given in the table in (7) were actually the same but were merely interpreted differently by different authors.

- We conclude on the basis of our interviews with present-day speakers that there is one type of consonantal realization for /r/ in /rl/ sequences and that that realization is [ɾ].

4. Phonetic Account of Bavarian German <rl>

4.1. *Data collection and methodology*

- We discuss two data sets.

- One in Ramsau, Austria in the years 2013-14 by having subjects read aloud wordlists (written in Standard German but produced by subjects in dialect), as well as reading nouns and then producing the dialectal form for that noun's diminutive. See Noelliste (2017: 34–35, 39).

- The second data set involves speakers originally analyzed in Bolter (2022). These speakers were interviewed in the summers of 2017 and 2018. All recordings in Bolter (2022) took place in or around Graz, Austria. Although all speakers were interviewed in Graz, some speakers originally grew up in some other location in the southeastern area of Austria (usually within Carinthia, Southern Styria, or Southern Burgenland).

- Audio recordings were analyzed with Praat phonetic software (Boersma & Weenink 2022). For this study, vowels + flap + lateral sequences were segmented by hand for 30 tokens of monomorphemic flap + lateral sequences and 35 tokens of *-erl* Diminutive.

- After segmenting these sequences, we collected measurements of the minimum, average, and maximum intensities (measured in decibels) for each of the segments in question as well as the duration (measured in milliseconds) of each of the segments. These measurements were tabulated in an Excel spreadsheet, which can be made available to an interested reader.

- Segmenting liquids, especially discerning the boundaries between a liquid and an adjacent vowel can be challenging, as has been noted in the literature (cf. Nelson 2013, Skarnitzl 2009). We determine segment boundaries based on three factors; namely, we analyze the boundaries between word-internal segments to be at the point where a marked change occurs and aligns for the waveform, spectrogram, and formant values.

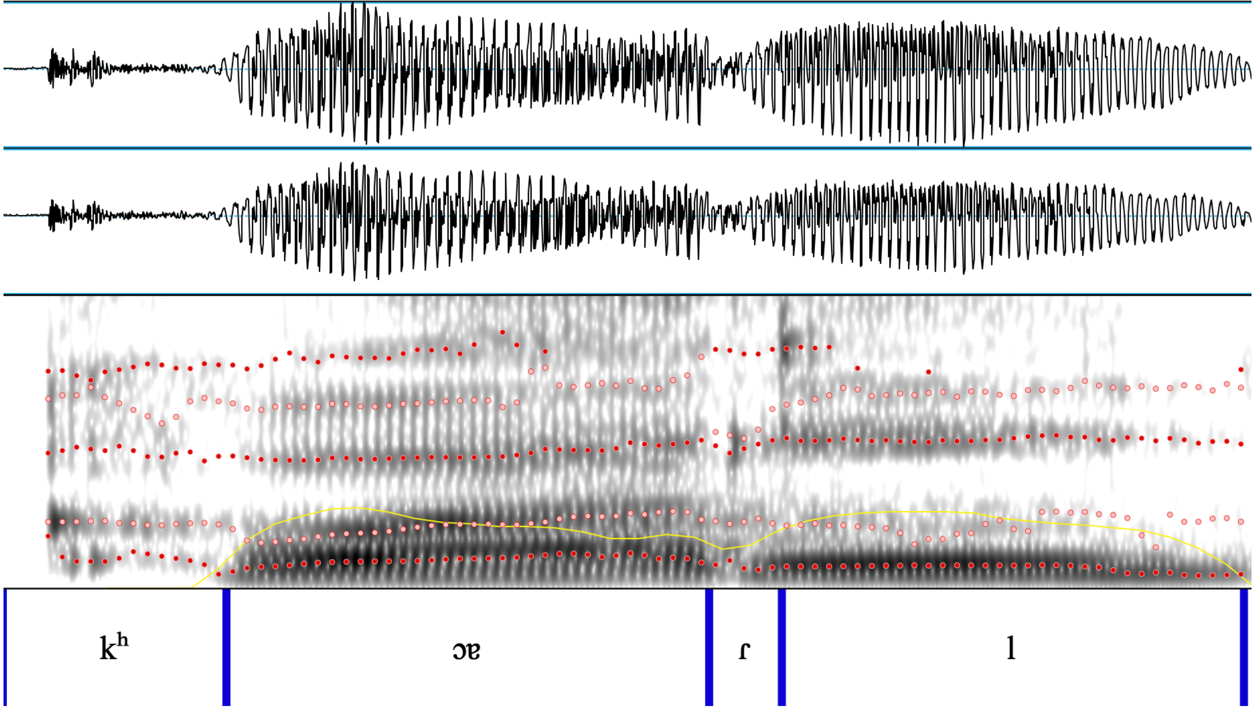
- In most cases, this process is relatively intuitive, as laterals in our sample stand out from adjacent flaps by having a noticeably higher amplitude (see examples in the following section). Furthermore, laterals differ from vowels in that their waveforms are noticeable "simpler" than adjacent vowels (on segmenting laterals, see Skarnitzl 2009). In difficult cases, we resorted to the cross-modal method (Skarnitzl 2009), that is, we determined the boundaries based on our auditory impression of where the sound in question began or ended.

***4.2. Phonetic Analysis of Bavarian German* <rl>**

- Data come in two different subtypes: Monomorphemic <rl> e.g. *Kerl*, *Karl* etc. and *-erl* Diminutives e.g. *Schmankerl*, *Kasperl*.

- The first set of examples, given in (8) and (10) are notable because they demonstrate most clearly that /rl/ data in these varieties may be realized with an intervening flap, although this has not always been noted in the earlier literature (see section 3).

(8) Waveform and Spectrogram of *Karl* (Female speaker, UK7504)



(9) Intensity measurements from above sample

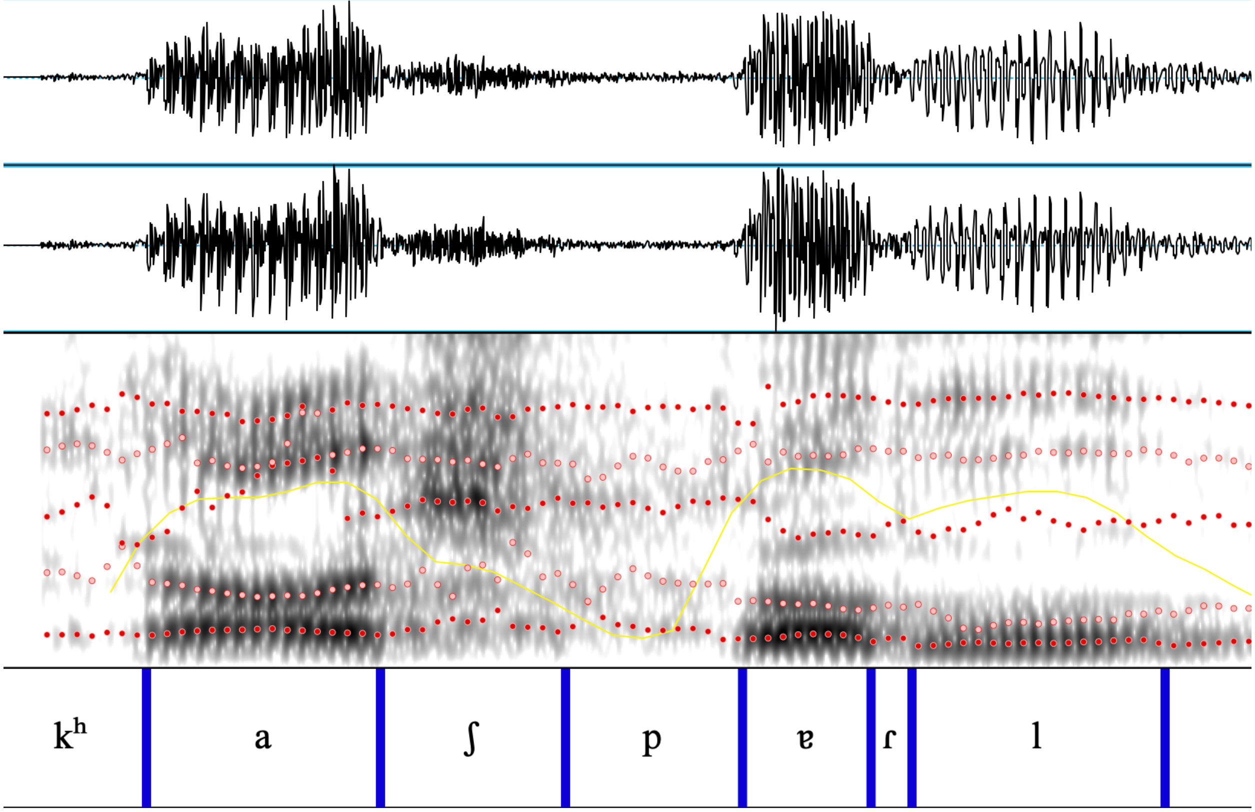
Sound	Intensity minimum (dB)	Average intensity (dB)	Intensity maximum (dB)	Duration (ms)
[ɔɐ]	55.61	60.92	63.67	212
[ɾ]	56.50	**57.76**	**59.30**	32
[l]	52.74	**61.22**	**63.06**	203

- In the example in (8), it can be seen that there is a brief low amplitude period that it is surrounded by two noticeably higher (and noticeably longer) amplitude peaks. We would therefore transcribe this example as [kʰɔɐ̯.ɾl̩]. The [ɔɐ̯] peak is diphthongal, as can be seen in the rise of F2 prior to the following sound [ɾ].

- In any case, it is apparent from the values in (9) that [l] has a higher intensity profile than [ɾ], since it has both a higher average intensity and a higher maximum intensity. In fact, the average intensity of [l] is louder than the first peak.

- Next, we present an example of the segmentation of an *-erl* diminutive. This is given in (10).

(10) Waveform and Spectrogram of *Kasperl* (Male speaker, HS5502)

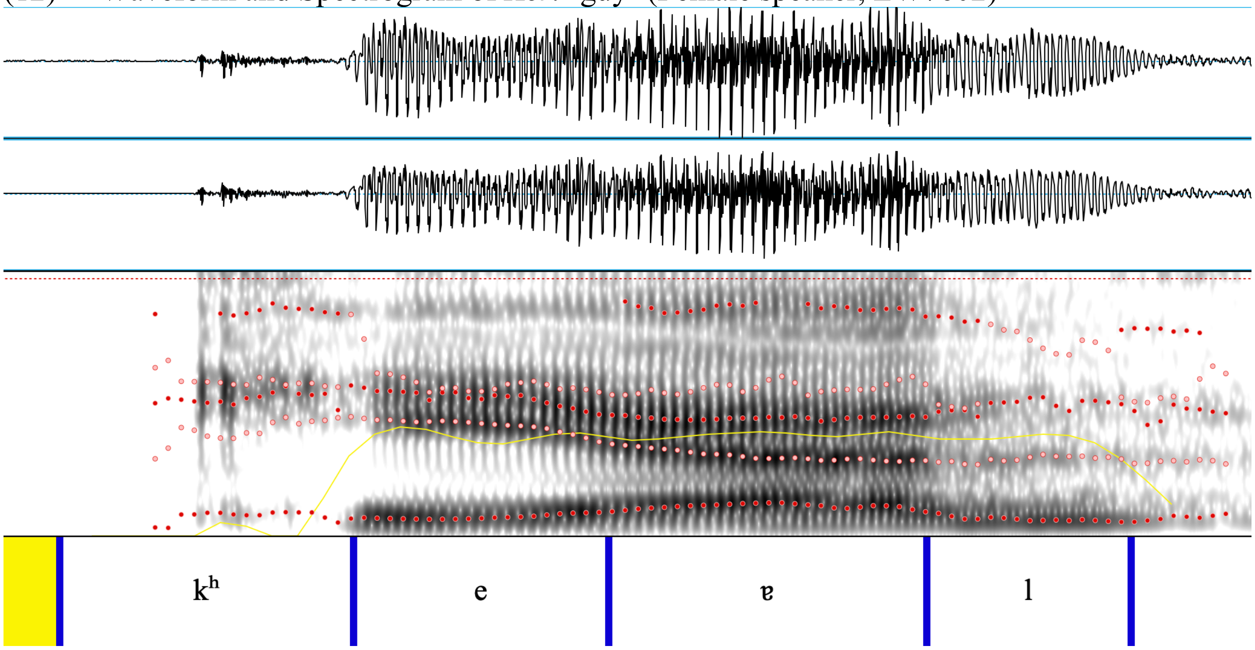


(11) Intensity measurements from above sample

Sound	Intensity minimum (dB)	Average intensity (dB)	Intensity maximum (dB)	Duration (ms)
[a]	72.00	75.81	77.83	97
[ɐ]	76.08	78.52	79.73	53
[ɾ]	72.04	**73.74**	**74.96**	17
[l]	68.39	**74.50**	**76.24**	105

- Having presented the unambiguous flap + lateral sequences in the examples in (8) and (10), we now give some cases where there is no clear lateral. These examples are interesting, but they do not factor in the data sets given in section 4.3. Such an example is provided in (12).

(12) Waveform and Spectrogram of *Kerl* ‘guy’ (Female speaker, EW7602)



- The example given in (12) shows no low amplitude period between the vocalic period, here a phonetic diphthong [eɐ̯], and the final lateral, indicating that there is variability in the realization of flaps / taps in Bavarian German.

4.3. Summary of Measurements Taken

- The tables in (13) and (14) present the examples of Monomorphemic /rl/ and *-erl* Diminutive /rl/, respectively.

- Table (15) collects both types into one master table.

- Figure 1 displays the information given in Table (15) in the form of boxplots.

(13) Averages of Monomorphemic /rl/ (N=30)

	Minimum Intensity (dB)	Average Intensity (dB)	Maximum Intensity (dB)	Average Duration (msec)
Stressed Vowel	58.94	63.67	65.76	176
Flap	58.74	59.96	61.15	28
Lateral	58.61	62.41	63.92	115

(14) Averages of *-erl* Diminutive /rl/ (N=35)

	Minimum Intensity (dB)	Average Intensity (dB)	Maximum Intensity (dB)	Average Duration (msec)
Stressed Vowel	60.70	63.90	65.69	108
Second Vowel	62.93	65.35	66.38	65
Flap	60.92	61.85	62.72	21
Lateral	59.00	63.19	64.70	89

(15) Averages of all /rl/ (N=65)

	Minimum Intensity (dB)	Average Intensity (dB)	Maximum Intensity (dB)	Average Duration (msec)
Stressed Vowel	59.89	63.79	65.72	139
Flap	59.92	60.98	62.00	24
Lateral	58.82	62.83	64.34	101

- It can be seen from the tables in (13) through (15), that both data subtypes show a higher average intensity reading in the lateral than in the flap, a difference that is also found when the two subtypes are pooled together.

- This difference is not always particularly large, **but it is statistically significant.**

- Linear regression models:
  - Maximum intensity in [ɾ] vs. maximum intensity of [l]: Significant p-value =0.006. Maximum Intensity for laterals is 2.3421 units higher.
  - Average intensity in [ɾ] vs. average intensity of [l]: Significant p-value =0.0311. Average Intensity for laterals is 1.8486 units higher.
  - Minimum Intensity in [ɾ] vs. minimum intensity of [l]: not significant p-value =0.2108

  - Minimum intensity in [ɾ] vs. maximum intensity of [l]: Significant p-value < 0.001. (see Parker 2008, 2011)

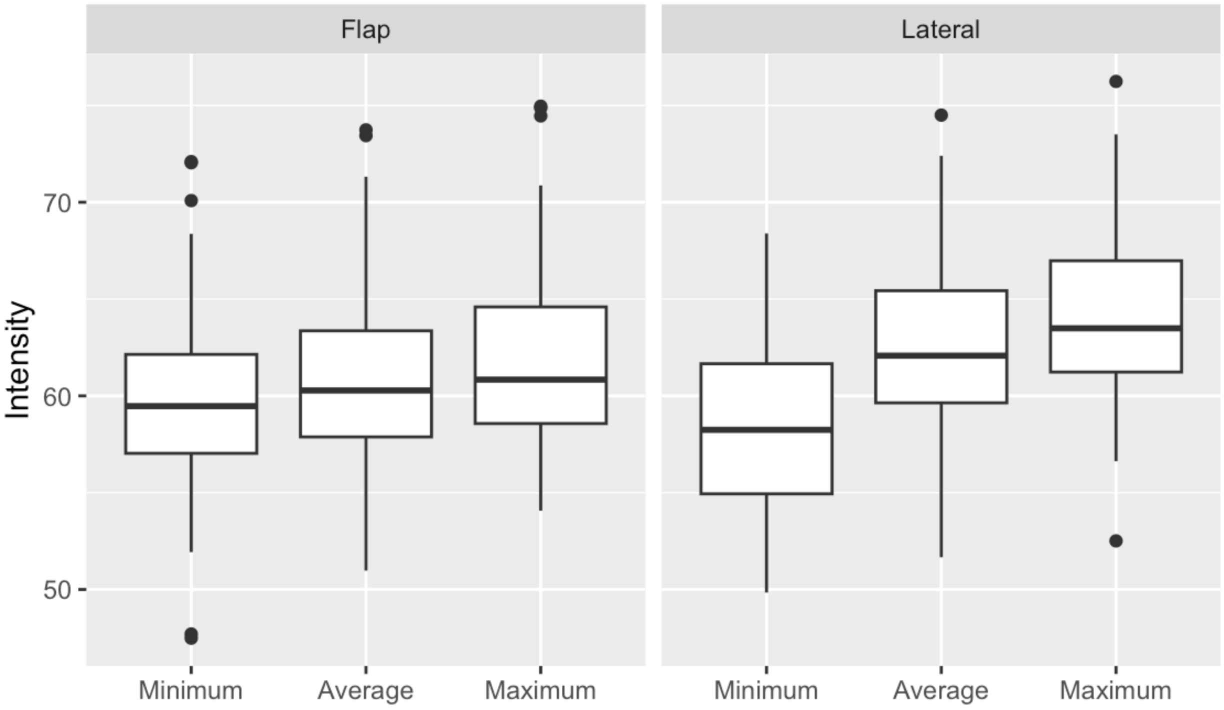


Figure 1: Boxplots for Minimum, Average, and Maximum Intensities for [ɾ] and [l] in all [ɾl] sequences

- In addition to the decibel readings, we also took measurements of the duration of the segments in question. For these measurements, the difference between flap and lateral is noticeably greater. For both data types given above, the lateral is more than four times as long as the flap.

- By extension, the lateral is much closer in duration to the (stressed) vowel, being about ~73% as long in the average of the two types given in (15).

- Therefore, to the extent that duration and intensity can be viewed as phonetic correlates of sonority, the lateral is noticeably higher in both cases.

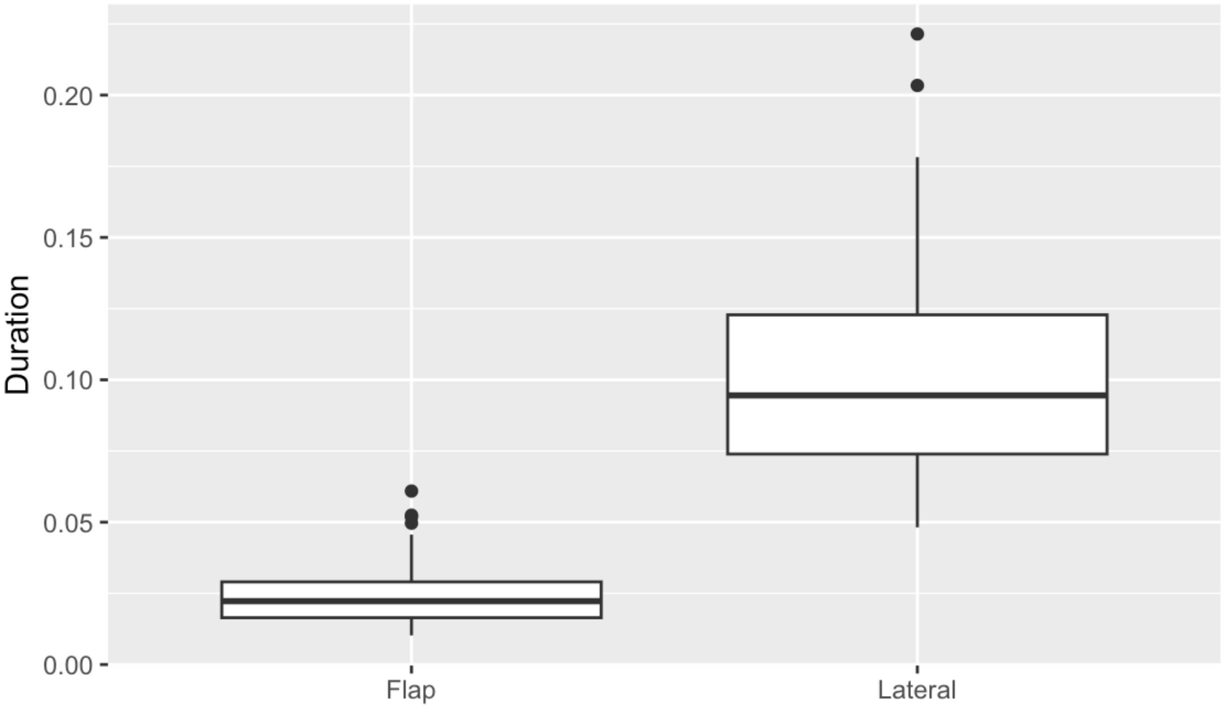


Figure 2: Boxplots for Duration for [ɾ] and [l] in all [ɾl] sequences

- Linear regression model for duration: p-value < 0.001. Duration for laterals is 07.67ms longer.

5. Discussion

- In this paper, we approach the Bavarian German data with a phonetically-defined analysis of sonority in the spirit of Parker (2008, 2011), and this analysis provides several interesting advancements to both the literature on sonority, as well as the literature on Bavarian German <rl>.

- Based on our phonetic analysis, we conclude that the Bavarian German flap [ɾ] is less sonorous than the syllabic lateral [l̩]. Note that Parker (2008, 2011) finds that flaps are more sonorous than laterals.

- We see two possible solutions to this problem.

- In Thesis A, given in (16), there is a language-specific sonority hierarchy for Bavarian German (in line with Noelliste 2019), where laterals are more sonorous than rhotics (including flaps); following Parker's (2008, 2011) data, there is then a different language-specific sonority hierarchy for Quechua Spanish, where the reverse is true: rhotics are more sonorous than laterals.

(16) Thesis A: Language-Specific Hierarchy

Bavarian German		Quechua, Spanish	
Vowels	1	Vowels	1
Laterals	2	**Flaps**	2
Trills	3	**Laterals**	3
Flaps	4	Trills	4
Nasals	5	Nasals	5
Obstruents	6	Obstruents	6

- Thesis B, given in (17), is more in line with Parker's (2008, 2011) inquiry, where the universal hierarchy has been expanded to include two different types of flaps. Flap type 1 is that of Quechua, Spanish and is more sonorous than laterals, and Flap type 2 represents the sound spoken in Bavarian German, which is less sonorous than laterals.

- Following Thesis B, the universal sonority hierarchy would need to be expanded to include and account for sounds which behave differently in terms of sonority, depending on the language and speakers thereof.

- We hypothesize, for example, that under Thesis B, cross-linguistic studies of languages where laterals behave differently would necessitate at least two different levels for laterals, particularly when one considers research from Sproat & Fujimura (1993), which shows that the velar lateral is higher in sonority (i.e. it has a dorsal articulation more similar to vocalic articulations) than apical laterals.

(17) Thesis B: Universalist Hierarchy

Low Vowels	18
Mid peripheral vowels (not [ə])	17
High peripheral vowels (not [ɨ])	16
Mid interior vowels ([ə])	15
High interior vowels ([ɨ])	14
Glides	13
Rhotic approximants ([ɹ])	12
Flaps: Type 1 (Quechua, Spanish)	11
Laterals	10
Trills	9
Flaps: Type 2 (Bavarian German)	8
Nasals	7
Voiced fricatives	6
Voiced affricates	5
Voiced stops	4
Voiceless fricatives (including [h])	3
Voiceless affricates	2
Voiceless stops (including [ʔ])	1

- We believe that both theses discussed above can coexist; namely, languages can have their own sonority hierarchies, which are a subset of an expanded version of Parker's

(2008, 2011) universal hierarchy.

- Based on the data presented here and in Noelliste (2019), we would like to propose that sonority can best be modelled as a conglomeration of characteristics that are both phonological and phonetic in orientation, as given in the graphic in (18). For a similar proposal, see Price (1980).

(18) Correlates of Sonority (our proposal)
   a. Higher sonority segments have higher intensity than lower sonority segments
   b. Higher sonority segments are longer in duration (or rather, they are prolongable)
   c. Higher sonority segments are more periodic and less "noise"-driven
   d. Higher sonority segments are more likely to occur closer to the center of a syllable.

- Accordingly, we would like to propose that speech segments that meet all of these characteristics (e.g. vowels) can be ordered highest in a sonority hierarchy and those that exhibit none of these characteristics (e.g. voiceless stops) are of lowest sonority. The problematic cases arise when one of the above characteristics is not met. Such segments occupy the middle-ground of the sonority hierarchy.

- With this in mind, we may say that the sonority hierarchy is *universal* and *impermutable* in as much as it is grounded in the inherent characteristics of the vocal tract, but it may instantiate itself differently in different languages. Indeed, different languages have different phones and phonemes and thus, the specifics of the sonority hierarchy for a given language will always differ from some other language.

6. Conclusion

- In our quest to define and constantly redefine the sonority hierarchy based on the phonetic properties of individual languages, we are likely to find yet other examples that fall outside of the pattern. For example, Russian *ртуть* 'mercury' with its falling sonority onset cluster /rt/ presents a difficult case. A conceivable phonetic explanation as to why falling sonority onset clusters like /rt/ do not present genuine counterexamples to the Sonority Sequencing Principle (Clements 1990) could be found in the phonetic properties of trills. Due to the aerodynamic requirements of producing a trilled [r], it is likely that brief vocalic periods will occur prior to (and potential also after) the beginning of trilling proper (cf. Bolter 2021, Ladefoged & Maddieson 1996). Thus, a sequence like /rtutʲ/ might be produced as [ᵊrᵊtutʲ] (for some discussion of these epenthetic periods in some Slavic languages, see Savu 2013: 145-147). If this the case, then the surface syllabification could be [ᵊr.tutʲ] or [rᵊ.tutʲ], neither of which would present a problem for the Sonority Sequencing Principle (Clements 1990). However, this potential phonetic explanation would require a phonetic study verifying the presence of such vocalic periods. Currently, the present authors are unaware of such work. When such evidence is lacking, explanations such as the following (viz. *In Russian, falling sonority onsets such as /rt/ are permitted at a language-specific level*) might well be the best explanation that can currently be offered.

- We have given a phonetic-based analysis of the sonority of the Bavarian German flap and proposed two different angles from which linguists can see a viable solution in line with earlier work on both Bavarian German (cf. Noelliste 2019) and sonority (cf. Parker 2008, 2011). We believe there is much more work to be done on sonority and the sonority hierarchy, and we ultimately leave open for future research questions about which lens can best account for data like those in Bavarian German.

Appendix A

Demographic information for speakers

Speaker		Origin of speaker	Gender	Age at recording
RS 2		Ramsau, Styria	M	45
RS 3		Ramsau, Styria	M	30-40
GZ 1	MW7605	Graz, Styria	M	41
GZ 2	EW7602	Gleisdorf, Styria	F	41
GZ 3	HL5902	Graz, Styria	M	58
GZ 5	BN7601	Graz, Styria	F	41
GZ 7	HS5502	Graz, Styria	M	62
GZ 8	UK7504	Knittelfeld, Styria	F	43
GZ 10	DK6811	Güssing, Burgenland	F	49
GZ 11	MG5803	Gasen, Styria	F	60
GZ 13	AK9612	Deutschlandsberg, Styria	F	21
GZ 14	EM8405	Rottenmann, Styria	F	34
GZ 15	ML9803	Judenburg, Styria	F	20
GZ 16	EZ8502	Vorau, Styria	F	33

References

Bloomfield, Leonard. 1914. *An introduction to the study of language*. New York: Henry Holt & Co.

Boersma, Paul & David Weenink. 2022. *Praat: doing phonetics by computer [Computer program]*. Version 6.2.14, retrieved 8 July 2022 from http://www.praat.org/

Bolter, David. 2021. Vowel prothesis before/r/revisited: acoustics and typology. *Glossa: a journal of general linguistics*, *6*(1).

Bolter, David. 2022. *Liquid enhancement, liquid polarization and Bavarian German L-rounding*. Bloomington, IN: Indiana University dissertation.

Clements, George N. 1990. The role of the sonority cycle in core syllabification. In John Kingston & Mary E. Beckman (eds.), *Papers in Laboratory Phonology I: Between the Grammar and Physics of Speech*, 283–333. Cambridge: Cambridge University Press.

Eberhard, David M., Gary F. Simons, and Charles D. Fennig (eds.). 2022. Ethnologue: Languages of the World. Twenty-fifth edition. Dallas, Texas: SIL International.

Hall, Tracy Alan. 2002. Against extrasyllabic consonants in German and English. *Phonology* 19. 33–75.

Jespersen, Otto. 1904. *Lehrbuch der Phonetik*. Leipzig and Berlin.

Kiparsky, Paul. 1979. Metrical structure assignment is cyclic. *Linguistic Inquiry* 10: 421–441.

Kranzmayer, Eberhard. 1956. *Historische Lautgeographie des gesamtbairischen Dialektraumes*. Vienna: Verlag der Österreichischen Akademie der Wissenschaften.

de Lacy, Paul. 2002. *The formal expression of markedness*. Amherst, MA: University of Massachusetts dissertation.

de Lacy, Paul. 2004. Markedness conflation in Optimality Theory. *Phonology* 21. 145–199.

de Lacy, Paul. 2006. *Markedness: Reduction and preservation in phonology*. Cambridge: Cambridge University Press.

de Lacy, Paul. 2007. The interaction of tone, sonority, and prosodic structure. In Paul de Lacy (ed.), *The Cambridge handbook of phonology*, 281–308. Cambridge: Cambridge University Press.

Ladefoged, Peter & Ian Maddieson. 1996. The Sounds of the World's Languages. Malden, MA, USA: Blackwell.

Laver, John. 1994. *Principles of phonetics*. Cambridge: Cambridge University Press.

Lawatsch, Gundhild. 1945. *Die Mundart des Gerichtsbezirks Oberwölz:(Vokalismus)*. Doctoral Dissertation. Graz: Universität Graz.

Leitinger, Gerta. 1939. *Die Mundart des oberen Sulmtales:(Lautlehre)*. Doctoral dissertation. Graz: Universität Graz.

Lessiak, Primus. 1903. *Die Mundart von Pernegg in Kärnten*: (*Beiträge zur Geschichte der deutschen Sprache und Literatur. Unter Mitwirkung von Hermann Paul und Wilhelm Braune Hrsg. von Eduard Sievers. Bd. 28, Hft. 1.*). Halle a.S: Max Niemeyer.

Nelson, Onna A. 2013. Acoustic properties of coda liquids in Californian English. In *Proceedings of Meetings on Acoustics 162ASA* (Vol. 14, No. 1, p. 060008). Acoustical Society of America. DOI: 10.1121/1.4794853.

Noelliste, Erin. 2017. *The phonology of Bavarian German Sonorants*. Bloomington, IN: Indiana University dissertation.

Noelliste, Erin. 2019. Bavarian German r-Flapping: Evidence for a dialect-specific sonority hierarchy. *Glossa: a journal of general linguistics*, 4(1).

Parker, Steve. 2002. *Quantifying the sonority hierarchy*. Amherst, MA: University of Massachusetts dissertation.

Parker, Steve. 2008. Sound level protrusions as physical correlates of sonority. *Journal of phonetics*, 36(1), 55-90. DOI: https://doi.org/10.1016/j.wocn.2007.09.00

Parker, Steve. 2011. Sonority. In Marc van Oostendorp, Colin J. Ewen, Elizabeth Hume & Keren Rice (eds.), *The Blackwell companion to phonology*, 1160–1184. Oxford: Wiley-Blackwell. DOI :https://doi.org/10.1002/9781444335262.wbctp0049

Pfalz, Anton. 1911. Phonetische Beobachtungen an der Mundart des Marchfeldes in Nieder-Österreich. *Zeitschrift für deutsche Mundarten*, 244-260.

Pfalz, Anton. 1913. *Die Mundart des Marchfeldes.* Sitzungsberichte der kaiserlichen Akademie der Wissenschaften in Wien. Philosophisch-historische Klasse 170. Bd. 6. Abhandlung. Wien: Hölder. In: Seemüller, J. (ed.), *Deutsche Mundarten.)*

Pilz, Friederike. 1938. *Die Mundart des Semriacher Beckens in der Mittelsteiermark*. Doctoral dissertation. Graz: Universität Graz.

Prince, Alan & Paul Smolensky. 1993. Optimality Theory: constraint interaction in generative grammar. Ms. Rutgers University, New Brunswick and University of Colorado, Boulder.

Prince, Alan & Paul Smolensky. 2004. *Optimality Theory: Constraint interaction in generative grammar*. Oxford: Basil Blackwell.

Price, P. J. (1980). Sonority and syllabicity: Acoustic correlates of perception. *Phonetica*, *37*(5-6), 327-343.

Rader, Wolfram. 1966. *Sprachbiologische Untersuchungen an der Mundart von Feldkirchen in Kärnten*. Doctoral Dissertation. Vienna: Universität Wien.

Savu, Carmen-Florina. 2013. Another look at the structure of [ɾ]: Constricted intervals and vocalic elements. *Rhotics. New data and perspectives.*

Saussure, Ferdinand de. 1916. *Cours de linguistique générale*. Lausanne and Paris: Payot.

Selkirk, Elizabeth O. 1984. On the major class features and syllable theory. In Mark Aronoff and Richard T. Oehrle (eds.), *Language sound structure: Studies in phonology presented to Morris Halle by his teacher and students*, 107–136. Cambridge, MA: MIT Press.

Skarnitzl, Radek. 2009. Challenges in segmenting the Czech lateral liquid. In Esposito, A. & Vích, R. (eds.) *Cross-modal analysis of speech, gestures, gaze and facial expressions*. Berlin, Heidelberg: Springer, 162-172.

Sievers, Eduard. 1881. *Grundzüge der Phonetik*. Leipzig: Breitkopf and Hartel.

Steriade, Donca. 1982. *Greek prosodies and the nature of syllabification*. Cambridge, MA: Massachusetts Institute of Technology dissertation.

Sproat, Richard & Osamu Fujimura. 1993. Allophonic variation in English /l/ and its implications for phonetic implementation. *Journal of Phonetics*, 21(3), 291-311.

Vennemann, Theo. 1972. On the theory of syllabic phonology. *Linguistische Berichte*, *18*(1), 1-18.

Wiese, Richard. 1996. *The phonology of German*. Oxford: Clarendon.

Wiesinger, Peter, Elisabeth Raffin, & Gertraude Voigt. 1982. *Bibliographie zur Grammatik der deutschen Dialekte: 1800 bis 1980* (Vol. 1). Peter Lang.

Zec, Draga. 1988. *Sonority constraints on prosodic structure*. Stanford University doctoral dissertation.