5pSC18

Cues to Stop Place in Stop-Liquid Clusters

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Introduction

Project:

- A preliminary investigation of cues to stop place contrasts in stop-liquid clusters, e.g. **b**r vs. **d**r, **b**l vs. **g**l, based on an acoustic study of American English.

Motivation:

- The cues to stop place contrasts have been studied extensively but the majority of studies have examined prevocalic stops, and very few look at stops in consonant clusters.

- Understanding cues to contrasts across the full range of contexts is important for the theory of speech perception and for phonological theory – there is evidence that contextual variability in the nature and availability of cues across contexts plays an important role in accounting for phonological restrictions on the distribution of contrasts.
- Example:
  - In Japanese, Luganda and Selayarese (among other languages) place contrasts are permitted only before vowels, not word-finally or before consonants (Steriade 1999).

  - Major place contrasts are less confusable in pre-vocalic position than in pre-consonantal or pre-pausal position (Redford & Diehl 1999, Wright 2001).
- In general, the acceptability of a contrast in given context appears to depend on the quality of cues available in that context (Steriade 1999).
- Developing this line of analysis requires a better understanding of the nature and distribution of perceptual cues to contrasts across contexts.

The present study:

- This study investigates acoustic properties that could serve as cues to stop place contrasts in stop-liquid clusters, using American English as a case study.
- Many languages permit stop place contrasts before liquids. E.g. English:
  - ➢ [b-d-g] contrast before [r], *brew-drew-grew*,
  - ➢ [b-g] contrast before [l], *blue-glue*
    - initial [dl-] is not possible.
- What is the nature of cues to place in this position? How do they compare to place cues in prevocalic position?

Cues to stop place contrasts

- The primary cues to stop place in prevocalic position reside in the release burst and the formant transitions into the following vowel (e.g. Dorman et al 1977).
- Liquids are similar to vowels – they involve relatively open constrictions and have well-defined formant structure, so both types of cues could in principle be realized before liquids.
- However approximant gestures can obscure stop formant transitions if they overlap with

the stop, as in Russian palatalized stops where primary place is not well-differentiated by release transitions (Halle 1959:151, Richey 2000).

- In [gl, gr] clusters, the velar closure may be released into the liquid constriction – this would affect burst acoustics.
  - Labial closure is further forward, so burst should be relatively unaffected by a following liquid.
- Alveolar [d] and [r] involve coronal articulators, so we might expect assimilation between the two consonants, altering the precise constriction location of the stop, affecting burst and formant transitions.

Materials

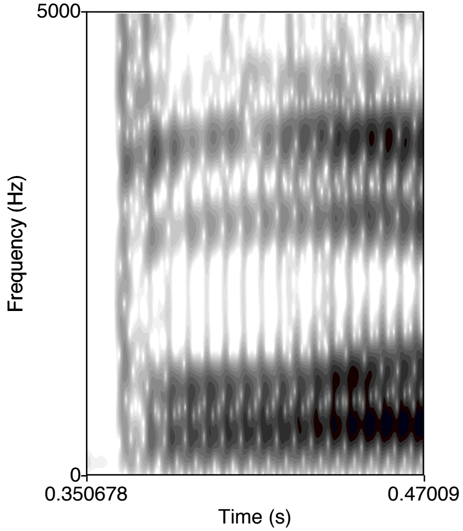
- 6 near-minimal triplets for br-dr-gr
- 6 near-minimal pairs for bl-gl
- 9 triplets for [b, d, g], each preceding the same set of nine vowels.

	b	d	g
_r	brown	drown	ground
_l	blow		glow
_V	bid	did	gig

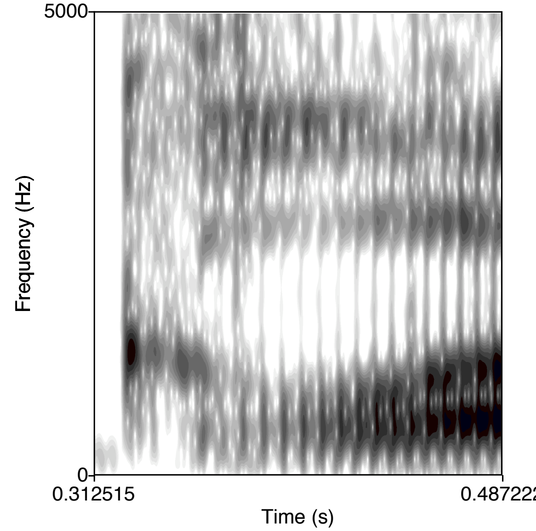
bream	dream	green	bleed	glee
bray	dray	gray	blare	glare
bran	dram	grand	bland	gland
brown	drown	ground	blob	glob
brogue	drone	groan	blow	glow
brew	drew	grew	blue	glue

Recording

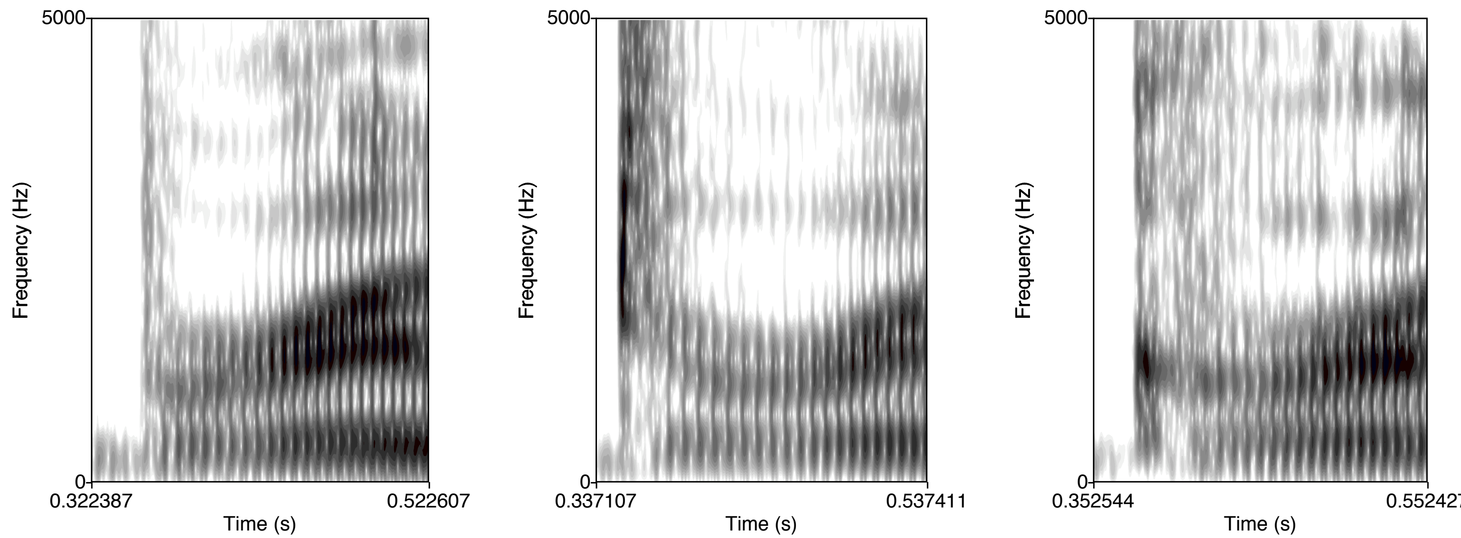
- All words were read in the sentence frame
  ‘Say X to me’
- Presented twice in random order.
- Read by 5 native speakers of American English, 4 female, 1 male.


5000
Frequency (Hz)
0
0.350678
0.47009
Time (s)

bl(ow)


5000
Frequency (Hz)
0
0.312515
0.487222
Time (s)

gl(ow)



br(ew) dr(ew) gr(ew)

Measurements

Burst

- Burst duration – from stop release to onset of first formant.
  - Usually coincides with onset of voicing, but weakly voiced frication is included in the burst.
- Shape of burst spectrum – quantified in terms of spectral moments (Forrest et al 1988).
  - Analyzed a 20 ms Hamming window centered on the stop release.
    - If burst duration is less than 10ms, window was shortened to twice the burst duration.

- Waveform pre-emphasized by 6dB/octave from 1000 Hz to approximately offset spectral slope of noise source (cf. Sundara 2005).
- Calculated the first four moments of the fourier power spectrum over the frequency range 200-10,000 Hz, using Praat functions (Boersma & Weenink 2006).
    - center of gravity (CoG), standard deviation (sd), skewness and kurtosis.
    - High pass filtering above 200 Hz serves to reduce effects due to any voicing during the burst (Sundara 2005).

Formants

- Measured F1 and F2 at the end of the burst (or the onset of the formants).
  - In many Cr clusters, F3 could not be differentiated from F2 until well after the end of the burst.

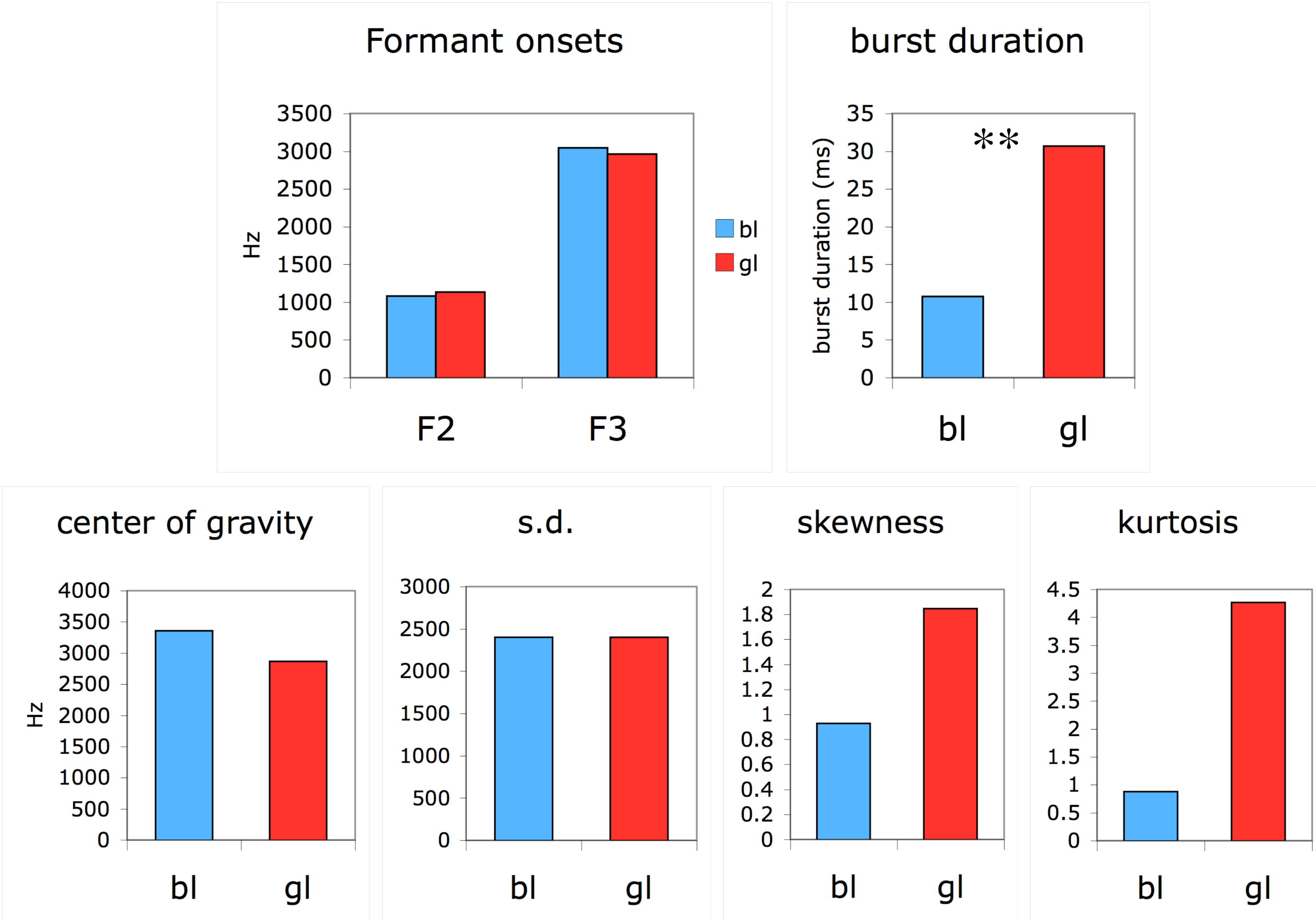
Results – bl *vs.* gl

- Means (standard deviations in parentheses)

	bl		gl		
F2 onset (Hz)	1081	(137)	1133	(155)	n.s.
F3 onset (Hz)	3042	(257)	2961	(252)	n.s.
burst duration (ms)	11	(3)	31	(10)	**
CoG (Hz)	3353	(855)	2863	(1378)	n.s.
s.d. (Hz)	2400	(508)	2399	(687)	n.s.
skewness	0.93	(0.5)	1.85	(1.4)	n.s.
kurtosis	0.88	(2.04)	4.27	(6.7)	n.s.

* $p < 0.05$, ** $p < 0.01$

- Significance tested via repeated measures ANOVA, factors Stop, Vowel, Stop*Vowel. Measures from the two repetitions of a word by a subject were averaged before analysis.


Formant onsets
Hz
3500
3000
2500
2000
1500
1000
500
0
F2
F3
bl
gl
burst duration
burst duration (ms)
35
30
25
20
15
10
5
0
**
bl
gl
center of gravity
Hz
4000
3500
3000
2500
2000
1500
1000
500
0
bl
gl
s.d.
3000
2500
2000
1500
1000
500
0
bl
gl
skewness
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
bl
gl
kurtosis
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
bl
gl

- Formant transitions do not differentiate [bl] from [gl].
- [gl] has a significantly longer burst than [bl].
- Spectral moments are highly variable.

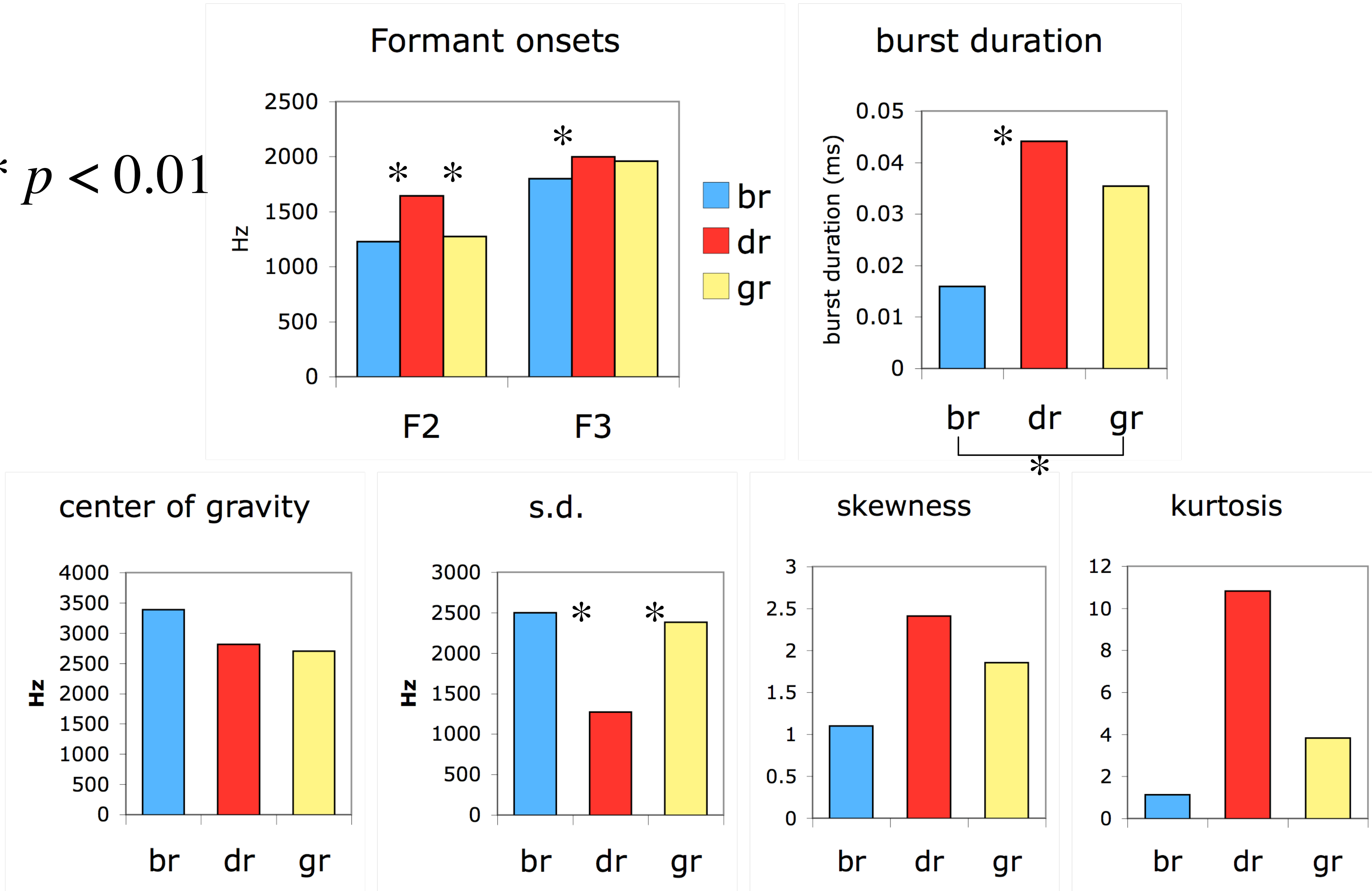
Results - br *vs.* dr *vs.* gr

Means (standard deviations in parentheses)

	br		dr		gr		
F2 onset (Hz)	1225	(150)	1641	(177)	1272	(215)	**
F3 onset (Hz)	1800	(214)	1998	(224)	1957	(205)	**
burst durn (ms)	16	(6)	44	(15)	35	(9)	**
CoG (Hz)	3385	(961)	2814	(609)	2703	(1065)	n.s.
s.d. (Hz)	2497	(537)	1273	(371)	2381	(640)	*
skewness	1.10	(0.80)	2.41	(1.1)	1.86	(1.0)	*
kurtosis	1.13	(4.4)	10.82	(9.3)	3.82	(4.9)	**

* $p < 0.05$, ** $p < 0.01$

* $p < 0.01$


Formant onsets
Hz
2500
2000
1500
1000
500
0
F2
F3
*
*
*
br
dr
gr
burst duration
burst duration (ms)
0.05
0.04
0.03
0.02
0.01
0
*
br
dr
gr
*
center of gravity
Hz
4000
3500
3000
2500
2000
1500
1000
500
0
br
dr
gr
s.d.
Hz
3000
2500
2000
1500
1000
500
0
*
*
br
dr
gr
skewness
3
2.5
2
1.5
1
0.5
0
br
dr
gr
kurtosis
12
10
8
6
4
2
0
br
dr
gr

- Both formant transitions and burst properties differentiate stops before [r].
- A small pilot study with cross-spliced stimuli suggests that the burst dominates formant transitions in perception in both Cr and Cl clusters.

Comparison to Prevocalic Stops

Formant transitions:

- [dr] is distinguished from [br, gr] by a relatively high F2 onset. This is also the case for stops preceding vowels with low F2 (back vowels).
  - E.g.

	bog	*dog*	*god*
mean F2 onset (Hz)	1180	1871	1620

  - The falling F2 transition in [dr] indicates that [d] does not assimilate fully to a following [r].

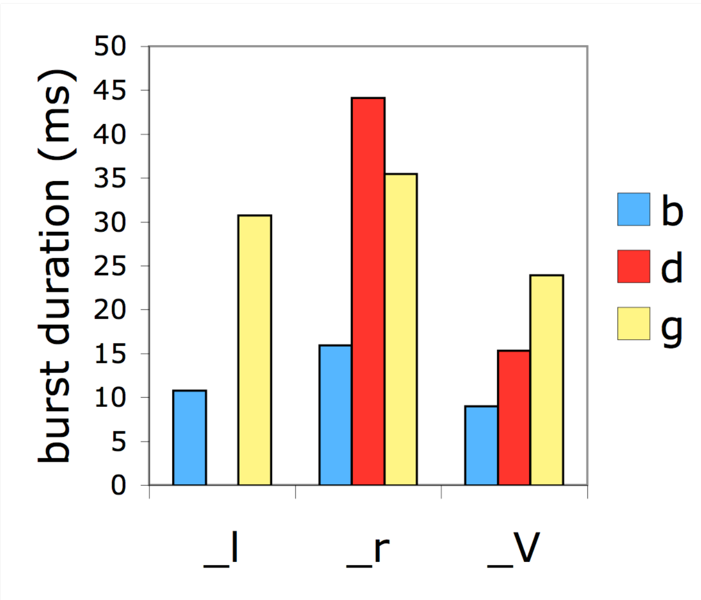
- The lowered F3 after [b] in [br] is also characteristic of labial stops in general.
- Formant transitions do not differentiate [bl] *vs*. [gl] – this may be a general pattern before sounds with very low F2:
  - E.g.

	bowl	*goal*
mean F2 onset (Hz)	967	1075
mean F3 onset (Hz)	2864	2758

  - All speakers produced strongly velarized [l] with very low F2.

<u>Burst characteristics</u>:

- Prevocalic stops are also differentiated by burst duration (e.g. Byrd 1993).
  - but all stop bursts are longer before liquids.
  - For prevocalic stops g > d > b, but dr can be significantly affricated.



Conclusions

- Stop place contrasts are distinguished by burst characteristics and formant transitions in stop-liquid clusters.
- The burst appears to provide stronger cues.
- Both types of cues appear to be comparable to prevocalic cues to stop place.

References

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