THE PHONOTACTICS OF PLATEAU CLUSTERS
Typological and Experimental Evidence

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Questions

- Is there a preferred order in word-initial plateau cluster? Is some plateau cluster better formed than others?
- If there is indeed a preferred order, on what does it depend?

Structure of the talk

- Description and definition of plateau clusters
- Typological survey
- Results of a perception experiment
- Conclusion.

Definition

- A plateau cluster is a consonant cluster whose members are of (almost) equal sonority. This definition includes:
  - Stop clusters: TT
  - Fricative clusters: FF
  - **Fricative + Stop, Stop + Fricative clusters: FT, TF**
  - Nasal clusters: NN
  - Liquid clusters: LL

What does phonology tell us about plateau clusters?

Sonority Sequencing Principle (Selkirk 1984, Clements 1990).

Onset			Nucleus			Coda
Obstruent	$<$	Sonorant	$<$ Vowel	$>$	Sonorant	$>$ Obstruent

Stop $\leq$ Fricative $<$ Nasal $\leq$ Liquid   Liquid $\geq$ Nasal $>$ Fricative $\geq$ Stop

<u>**Traditional phonological analysis:**</u> plateau clusters are ill-formed. However, from their frequency of occurrence in the world's languages, it is apparent that not all plateau clusters are the same.

/sk/ is much more frequent than, say, /tp/. Why is that?

What does phonetics have to say?

Combinations of adjacent consonants tend to be preserved depending on a series of factors:

Cue Robustness & Cue Precision (Henke et al. 2012)

Modulation (Ohala & Kawasaki-Fukumori 1997)

- **Cue Robustness** is basically the acoustic salience of a segment – its perceptibility/audibility for a listener under normal listening conditions → absolute value: sibilants are salient/have robust cues.
- **Cue Precision** is determined by how much a segment differs from its contenders → relative value: Spanish has /s/, Polish has /s, z, ʂ, ʐ, ɕ, ʑ/.
- **Modulation** is given by the spectral change triggered by a sequence of sounds: /st/ will have a much greater modulation than /sʃ/, even if taken singularly, /s/ and /ʃ/ are more salient than /t/.

Cues

Stops. *Main internal cue*: noise burst. *Main external cue*: formant transitions of the following vowel → the optimal position for a stop is pre-vocalic.

Fricatives. Given their longer duration, fricatives' internal cues are recognizable even in absence of an adjacent vowel. That is particularly true for noisy fricatives, such as sibilants, and less so for /f, x/, which are less loud.

Prediction for plateau clusters: since stops need vowels much more than fricatives do, FTV is a better sequence than TFV, *pace* the Sonority Sequencing Principle.

What about sonorants?

Both nasals and liquids are highly sonorous and they should be heard more easily than obstruents. However, they rarely combine, probably because of lack of modulation.

Greenberg's Generalizations (1978)

(a) #TT implies #FT (p. 254)

(b) #FF implies #FT or #TF (p. 255)

(c) /rl/ is the only possible type of liquid cluster and only occurs with morpheme boundary (p. 257)

(d) #CC implies $\#C_{cor}C$ (p. 269).

(a, b) probably depend on the preference for greater modulations. Or, in traditional phonological terms, depend on the OCP[manner] effect.

(c) is probably due to articulatory and perceptual difficulties.

(d) unmarkedness of coronal?

Typological Survey

Sample of **39** languages allowing word-initial plateau clusters.

Sources: personal research, Morelli (1999), Parker (2012).

Language families: Indo-European, Austronesian, Mon Khmer, Sino-Tibetan, Siouan, Benue-Congo, Caucasian, Semitic, Zapotec, Haida, Yuman, Plateau Penutian, Chadic, Qiang, Misantla Totonac, Tsimshianic, Otomi, Dravidian, Chibchan, Caddoan, Yuchi.

T_{cor} = any coronal stop, P = any labial stop, K = any dorsal stop, S = any sibilant, J = any palatal stop, Φ = any labial fricative, X = any dorsal fricative.

Results:

SK (93.75%) > ST_{cor} (90.6%) > SP (87.5%) > PT_{cor} (59.4%) > PS (53.1%) > KS (50%) > $T_{cor}K$, KT_{cor} (34.4%) > PJ (28.1%) > PK (25%) > SΦ, SJ, KP (22%) > $T_{cor}S$, XP (18.75%) > TP (15.7%) > other clusters (less than 12.5%).

Implications

O = any obstruent, H = any non-sibilant fricative, G = glide.

(a) if a language allows OO, then it allows SO. Exception: possibly Margi.

(b) if a language allows TT, FF, HT, then it allows SO. Exception: possibly Margi.

(c) If a language allows HT, then TT. Exceptions: Mawo, Pashto, Walapai.

(d) If a language allows, TH, then HT. Exception: Modern Hebrew.

(e) If a language allows FF, then TT. Exceptions: English, Pashto, Walapai.

(f) If a language allows NN, LL and/or GG, then it allows OO. Exception: none.

(g) If a language allows OP, then it allows KO. Exception: Wichita.

(h) If a language allows /nm/, then it allows /mn/. Exception: none.

Labial first, Dorsal last

- (g) states that it is more marked for a labial consonant to be the second member of a cluster than it is for a dorsal to be the first. As a matter of fact, out of 39 languages in the survey, only 10 have C_1C_2 sequences where C_2 is labial while 24 allow C_1 to be dorsal.
- Fikkert & Levelt (2008): Dutch infants, while acquiring their phonology, pass through a stage where, in C_1VC_2 words, C_1 is always a labial and C_2 always a dorsal. As a result, a word like *kip* 'chicken' [kɪp], at this stage, is realized as [pɪk].
- It has been noted that, in early child language, the first combination of consonants with different place of articulation is labial + coronal (McNeilage & Davis 2000) and this preference is explained by the fact that a sequencing of consonants goes from front to back across the word (Ingram 1974).
- The complementary tendency, that of dorsals to occur finally, is less evident, at least regarding obstruents, but there are many languages in which velar /ŋ/ is restricted to occur only syllable-finally (Anderson 2011).

Stop clusters

- PT_{cor} (38.5%) > $T_{cor}K$ (31%) > PK, KT_{cor} (23%) > PJ, KP (20.5%) > $T_{cor}P$, KJ (12.8%) > JK (10.2%) > JT_{cor} (5.1%) > JP (2.5%).
- It is better for P to occur before T and K and for K to occur after P and T.

Sonorants

- (h) is a very tentative generalization on nasal clusters, basically arguing that /mn/ is less marked than /nm/, but I could find only one language allowing /nm/ word-initially, i.e., Tsou.
- Regarding liquid clusters, these appear to be extremely marked, so much that they are attested only in a handful of languages. /rl/ is attested word-initially, although the liquids are said to belong to separate morphemes. I could not find any language with word-initial /lr/.

The other side of the word

- A quick look on word-final plateau clusters
- Much smaller sample (only 15 languages)

-SO, -OS > -OT_{cor}, -OK > all other –OO clusters > sonorant clusters.

Again, preference for the presence of a sibilant.

Avoidance of final P.

Hypothesis

- In a word-initial plateau cluster C_1C_2, C_1 must be more salient than C_2, while the opposite holds for word-final clusters.
- <u>The more salient a consonant, the more likely it will be identified correctly as #C_1 and as C_2#.</u>
- In obstruent clusters, preferably a sibilant.
- In nasal clusters, preferably /m/ (Greenlee & Ohala 1980: m > n > ŋ).
- In liquid clusters, preferably /r/ (a prototypical rhotic normally lasts longer than a lateral).
- Among the three stops /p, t, k/, experimental results are contradictory.
  - Jun 1995, Hume et al. 1999: k > p > t.
  - Miller & Nicely 1955: t > k, p.
  - Malécot 1958: p > t, k.
  - Wang & Bilger 1973: t, p > k.
  - Winters (2000): p > k > t.

- Proposed salience scale (Baroni 2012): s > ʃ > f > k > p > t, m > n, r > l.

Perception Experiment

- $\#C_1C_2V$ and $VC_1C_2\#$ clusters.
- **Example**: given the input [#st], <st>, <ts>, <sp> would all count as correct answers, because [s] is heard correctly. On the contrary, <ft> or <t> would qualify as mistakes.
- Participants = 64 (30 Italian, 34 Dutch), enrolled from Utrecht and Padua universities, respectively, making sure that they were monolingual and with no significant linguistic experience in languages allowing extremely complex clusters (e.g., Hebrew, Georgian, Khasi, Slavic languages, etc.).

Methods and Materials

- The stimuli consisted in 64 nonce disyllabic words, each of them containing a consonant cluster, either word-initially or word-finally (e.g., [ˈstapul], [taˈmusk]).
- The clusters created were only plateau clusters, obtained combining the following sounds: [ʃ, s, f, k, p, t, r, l, m, n]. [ʃs] and [sʃ] combinations were avoided for obvious articulatory and perceptual difficulties.
- Participants had to sit in a soundproofed room in front of a PC screen wearing headphones and instructions on the screen told them to listen to a series of a words and type on the keyboard what they thought they had heard. They could listen to each word only once. The task was self-paced but normally did not take longer than 15 – 20 minutes.

Results

- In general, the predictions made by the salience scale for obstruents were not met.
- Whilst [s] was identified correctly most of the times, [f] and [p] were very often misheard or not heard at all, whereas [k] and [t] ranked much better than expected.
- With regards to liquids and nasals, [m] was identified correctly more often than [n] and [r] more often than [l], both word-initially and word-finally, confirming the sonorant salience scale.
- Other than salience, the following variables were considered: position (word-initial vs. word-final), context (following or preceding consonant), legality, language (Dutch vs. Italian) and NAD (distance in Manner and Place of Articulation, Dziubalska-Kołaczyk 2002). The correlation between the correctness rate (CR) and each of the variables was checked running a bivariate Pearson correlation.

CR (word-initially)

Word-initial clusters	Salience	Language	Context	Legality	NAD
Pearson	.027	.080**	.056**	.144**	.175**
Sig. (2-code)	.259	.001	.017	.000	.000

CR (word-finally)

Word-initial clusters	Salience	Language	Context	Legality	NAD
Pearson	.085**	.042	.136**	.217**	.021
Sig. (2-code)	.000	.075	.000	.000	.381

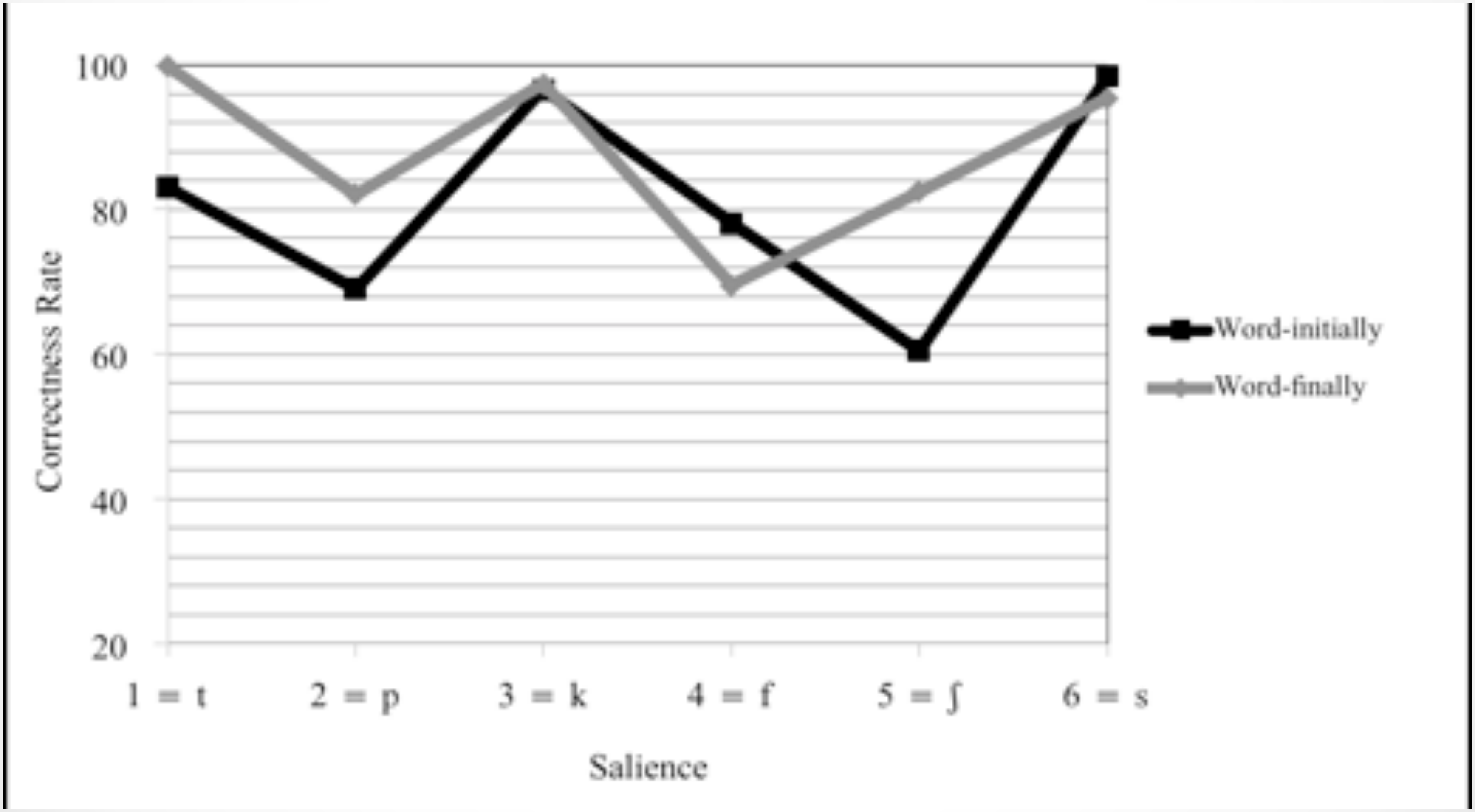
CR (total)

Word-initial clusters	Salience	Language	Context	Legality	NAD
Pearson	.024	.062**	.099**	.092**	.015
Sig. (2-code)	.155	.000	.000	.000	.362

CR for each obstruent

	s	ʃ	f	k	p	t
Word-initial	98.4%	60.5%	78%	96.5%	69%	83%
Word-final	95.3%	82.4%	69.4%	97.25%	82%	99.7%

Salience * CR



100
80
60
40
20
Correctness Rate
1 = t
2 = p
3 = k
4 = f
5 = ʃ
6 = s
Salience
Word-initially
Word-finally

Legality (1)

Word-initial clusters.

- Legal (both Dutch and Italian)

sf, ks (100%) > st, sp, ps (98.4%) > *tʃ*, sk (95.3%) > pt (92.2%) > *ts* (67.2%).

- Illegal (in both languages)

tf, kf, fk (100%) > kʃ (98.4%) > ft (97%) > kp (95.3%) > tp, kt (87.5%) > fʃ (79.7%) > ʃf (73.4%) > pʃ (72%) > tk (67.2%) > ʃk, fs (65.6%) > ʃp (62.5%) > pf (59.4%) > fp (45.3%) > ʃt (43.75%) > pk (26.5%).

- Notably, the clusters that turn out to be harder to identify correctly imply a lack of contrast, or put differently, a violation of OCP, e.g., OCP[continuant] (fs), OCP[labial] (pf, fp).

Legality (2)

Word-final clusters that are legal in Dutch seem to be identified more easily by both Dutch and Italians.

- Legal in Dutch

kt, ft, st, sp, ps (100%) > pt, sk, ks (98.4%) > ts (87.5%).

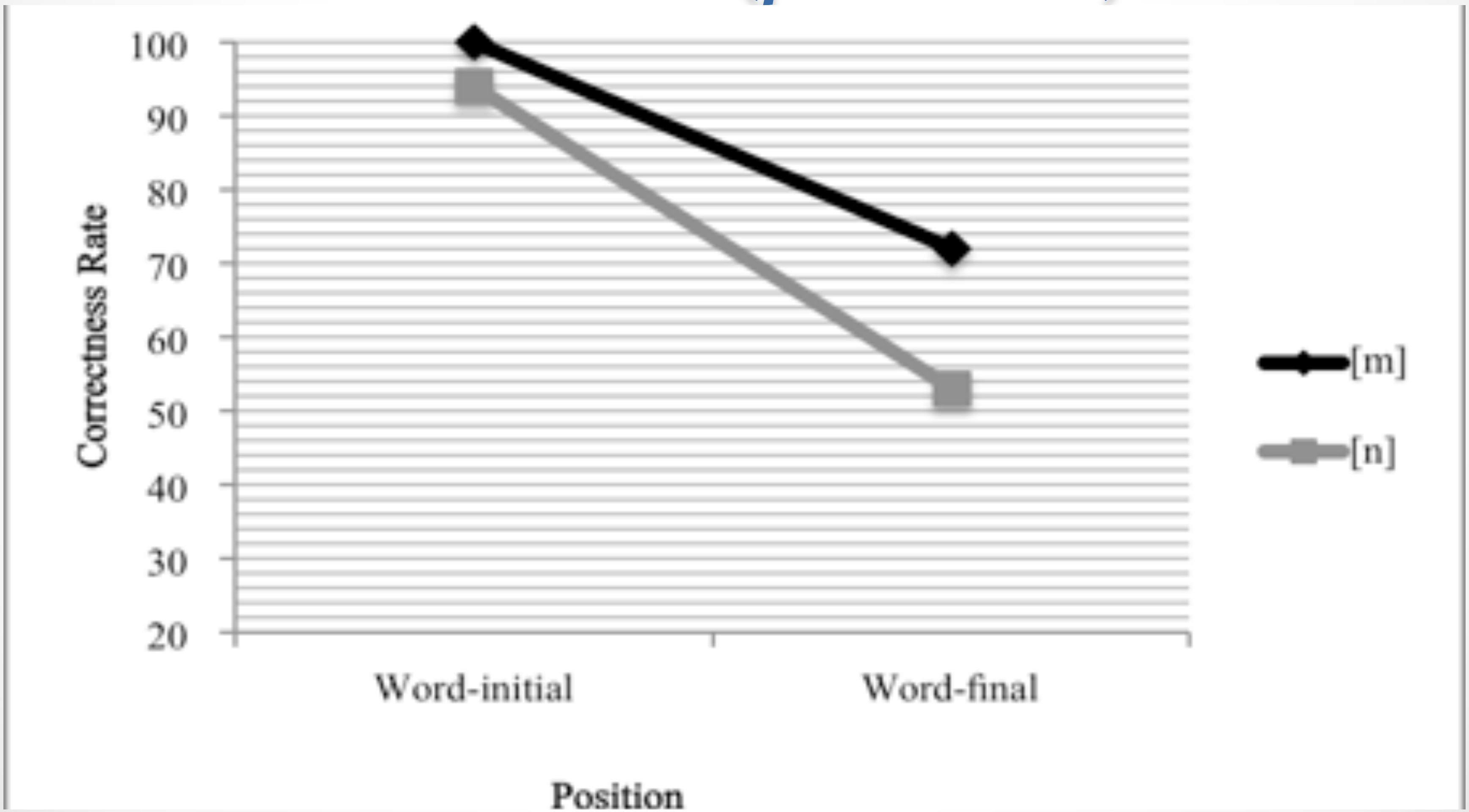
- Final clusters illegal in both languages:

ʃt, fk (100%) > tk (98.4%) > pk (95.3%) > ʃk, fs (93.75%) > kp, ʃp, fʃ (92.2%) > pf (90.6%) > pʃ (82.8%) > sf, tʃ (76.6%) > kʃ (75%) > ʃf (73.4%) > fp (70.3%) > kf (65.6%) > tp (56.25%) > tf (51.5%).

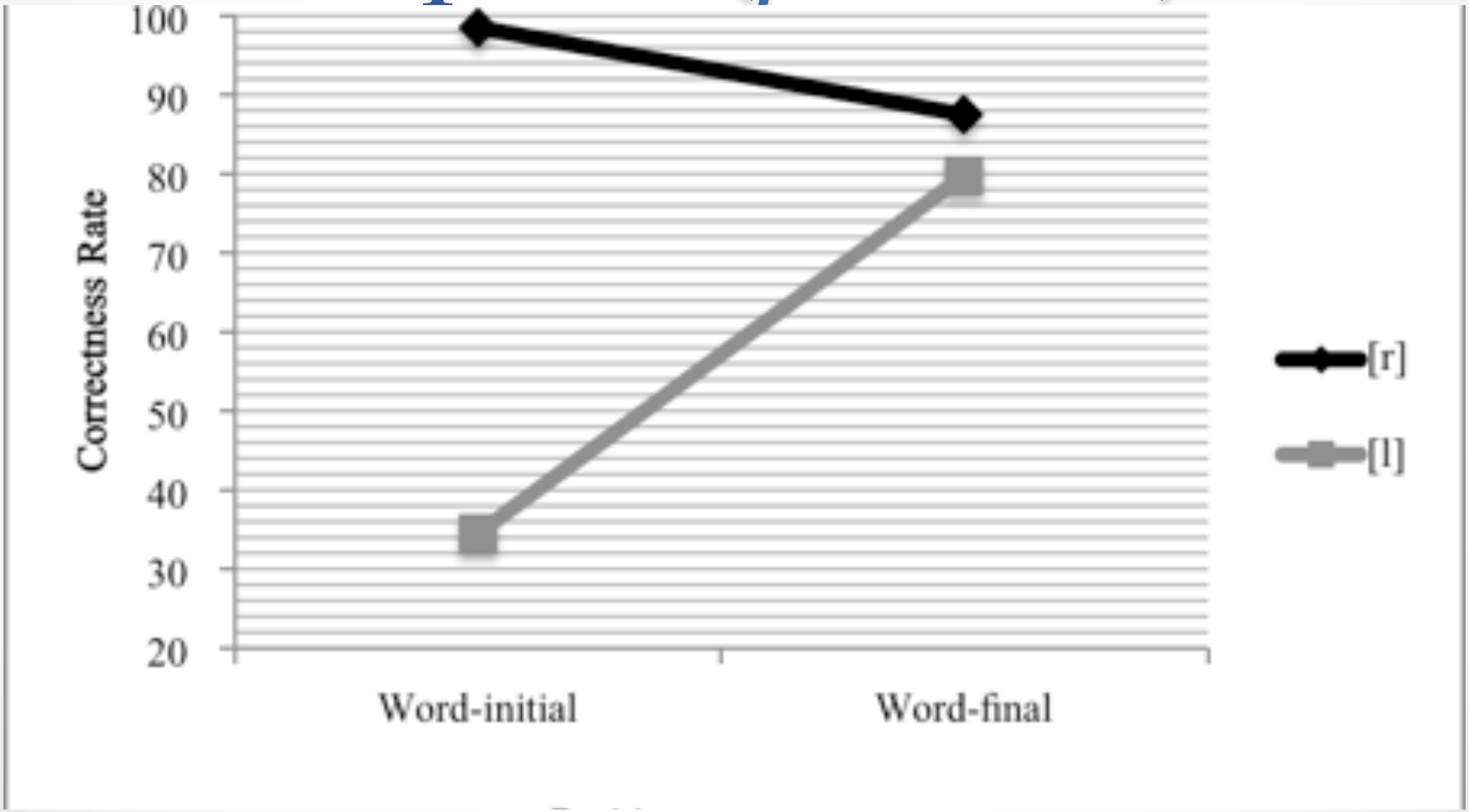
Temporary conclusions on obstruents

- In general, modulation (great acoustic difference) turns out to be a good indicator for segment recognition word-initially.
- Word-finally, recognition of sibilants and labials is made more difficult if they are preceded by either [k] or [t]. I propose to interpret this fact as follows: both [k] and [t] tend to be associated with the end of the word and everything that comes after does not receive enough attention.
- Sometimes participants were hallucinating a [t] that was not there, e.g., [kp] transcribed as <ktp> or some sequences were re-ordered, e.g., [tp, tk] → <pt, kt>, [nm] → <mn>, [kp] → <pk>. Evidence of the unmarkedness of coronals and of the preference for labials as C_1?

Nasals ($p < .05$)


100
90
80
70
60
50
40
30
20
Correctness Rate
Word-initial
Word-final
Position
[m]
[n]

Liquids ($p < .001$)



Discussion

- The salience scale was confirmed for liquid and nasal clusters, but not for obstruent clusters.
- Leaving aside the difference between [s] and [ʃ], it seems established that sibilants are the most salient obstruents.
- When it comes to non-sibilant fricatives and stops, the results suggest that [f] is very likely to be confused with silence or non-linguistic noise. As a matter of fact, [f], together with [p], turned out to be the perceptually weakest segment and probably the most affected by white noise.
- Among stops, [p] was the most difficult to perceive, whereas [k] was identified almost as easily as sibilants word-initially and more easily than sibilants word-finally.
- Unexpectedly, [t] was heard correctly most of the time. This does not necessarily mean that [t] is more acoustically salient than [p] or [f], but that by virtue of a top-down effect, participants judged [t] more likely than [f] or [p] to occur in a consonant cluster. The fact that [t] was very often hallucinated is significant.
- **sibilants > non-sibilants (dorsal > labial > coronal)**

  s, ʃ > k > f, p > t.

Word-final vs. Word-initial

- Whilst word-initially there is a tendency for the more salient segment to occur first, word-finally other factors seem to play a greater role, i.e., [t] is the preferred final obstruent, probably because it is the unmarked stop. Also [s], the unmarked fricative, often occurs (and is easily recognized) word-finally, as well as [k] (Dorsal Last principle?).

Comparing Data

- Six most frequent word-initial obstruent clusters:

SK, ST_{cor} SP, PT_{cor}, PS, KS.

- **Word-initial clusters more easily identified:**

sf, <u>ks</u>, ʃt, fk (100%) > <u>st</u>, <u>sp</u>, <u>ps</u>, tk (98.4%) > tʃ, <u>sk</u> (95.3%) > <u>pt</u> (92.2%)

- Most frequent word-final obstruent clusters:

-SO, -OS, $-OT_{cor}$, -OK.

- **Word-final clusters more easily identified:**

<u>kt, ft, st, sp, ps, ʃt, fk</u> (100%) <u>> pt, sk, ks</u> (98.4%)

Conclusions (1)

- Among plateau clusters, obstruent clusters are more frequent than sonorant clusters (NN, LL).
- In an obstruent cluster, one of the two consonants is preferably a sibilant. The preferred order is SO word-initially, whereas word-finally SO and OS seem to be equally good.
- Two adjacent obstruents must preferably differ in manner of articulation, e.g., FT or TF.
- If two obstruents are both stops, the first one is preferably a labial, while the second can be a dorsal or a coronal.
- Dorsal and labial tend to not co-occur.

Conclusions (2)

- Nasal and liquid clusters are extremely rare. If they occur, however, /mn/ and /rl/ are preferred (*/lr/ is unattested).
- The results of the perception experiment suggest that the well-formedness of a plateau cluster depends on the perceptibility of the consonant which is farthest from the vowel. Other factors at play are: ***markedness***, since less marked segments tend to appear word-finally, and ***articulatory ease*** (front-to-back articulation – natural jaw movement).

Thanks for your attention

References

- Anderson, G. D. S. 2011. The Velar Nasal. In: Dryer & Haspelmath (eds.), *The World Atlas of Language Structures Online*. Munich: Max Planck Digital Library, chap. 9.
- Baroni, A. 2012. A Beats-and-Binding Account of Italian Phonotactics. *Padua Working Papers in Linguistics* 5. 45-72.
- Clements, G. N. 1990. The role of the sonority cycle in core syllabification. In: Kingston & Beckman (eds.), *Papers in Laboratory Phonology I*. CUP. 283-333.
- Dziubalska-Kołaczyk, K. 2002. *Beats-and-binding phonology*. Frankfurt am Main: Peter Lang.
- Fikkert, P. & Levelt, C., 2008. How does Place fall into place? In: Avery, Dresher. & Rice (eds.), *Contrast in Phonology. Theory, perception and acquisition*. Berlin: Mouton. 231-268.
- Greenberg, J. H., 1978. Some generalizations concerning initial and final consonant clusters. In: Greenberg (Ed.), *Universals of Human Language vol. 2: Phonology.* Stanford: Stanford University Press. 243-279.
- Greenlee, M. & Ohala, J. J., 1980. Phonetically motivated parallels between child phonology and historical sound change. *Language Sciences* 2. 283-308.
- Henke, E., Kaisse, E. M., & Wright, R., 2012. Is the Sonority Sequencing Principle an epiphenomenon? In: Parker (ed.), *The Sonority Controversy.* Berlin: Mouton de Gruyter. 65-100.

References

- Hume, E., Johnson, K., Seo, M. & Tserdanelis, G., 1999. A cross-linguistic study of stop place perception. *Proceedings of the International Congress of Phonetic Sciences*. 2069-2072.
- Ingram, D. 1974. Phonological rules in young children. *Journal of Child Language* 1. 29-64.
- Jun, J. 1995. *Perceptual and articulatory factors in place assimilation: an Optimality Theoretic approach.* PhD diss., University of California, LA.
- Malěcot, A. 1958. The role of releases in the identification of released final stops. *Language* 34. 370-380.
- MacNeilage, P. F. & Davis, B. L. 2000. Origin of the internal structure of word forms. *Science* 288. 527-531.
- Morelli, F. 1999. *The Phonotactics and Phonology of Obstruent Clusters in Optimality Theory*. PhD diss., University of Maryland.

References

- Ohala, J. J., & Kawasaki-Fukumori, H., 1997. Alternatives to the sonority hierarchy for explaining segmental sequential constraints. In: Eliasson & Jahr (eds.), *Language And Its Ecology*. Berlin: Mouton de Gruyter. 343-365.
- Parker, S. 2012. Onset consonant clusters database. Unpublished manuscript. Dallas, TX: Graduate Institute of Applied Linguistics.
- Selkirk, E. O. 1984. On the Major Class Features and Syllable Theory. In Aronoff & Oehrle (eds) *Language Sound Structure.* Cambridge: MIT Press. 107-136.
- Wang, M. D. & Bilger R. C. 1973. Consonant confusions in noise: A study of perceptual features. *Journal of the Acoustical Society of America* 54. 1248-1266.
- Winters, S. 2000. Turning phonology inside out, or testing the relative salience of audio and visual cues for place of articulation. *Ohio State University Working Papers in Linguistics* 53. 168-199.