5pSC16: Phonotactic constraints, frequency, and legality in English onset-cluster perception

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Abstract

When a speech signal is acoustically ambiguous between two parses, perception is biased in favor of native-language sound patterns. What determines the size of the bias? We consider factors arising from (1) the sound pattern of the language (frequency of each parse, or phonotactic constraints?) and (2) the link between the sound pattern and perceptual response (does bias depend on the relative or on the absolute badness of the two parses?).

The experiment exploited the badness of same-place stop-sonorant clusters (e.g., [dl]) in English syllable onsets. Stimuli were synthetic [CCæ] syllables in which the second C is ambiguous between [l] and [w]. In one condition, the first C was ambiguous between [b] and [d], so that two of the four parses were attested English onsets ([blæ dwæ]; in the other, between [m] and [n], so that none were. Bias was quantified as the effect of the stop decision on the sonorant decision.

Results showed bias in the b/d condition, but little or none in the m/n condition. This, together with previous findings, favors a model in which (1) the sound pattern is represented by phonotactic constraints, and (2) bias depends on absolute rather than relative phonotactic badness.

Phonotactics biases perception

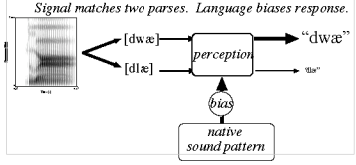
Native sounds combined in a non-native way can be misperceived to fit the sound pattern of the native language.

Ex. English listeners hear a sound acoustically between [r] and [l] as [r] in [t_i], but as [l] in [s_i] (Massaro & Cohen 1993, Pitt 1998).

Ex. Japanese listeners hear an illusory vowel in non-Japanese consonant clusters (e.g., [ebzo] heard as [ebuzo], Dupoux et al. 1999).

Ex. French listeners misperceive un-French initial [tl] as [kl] in several tasks (Hallé et al. 1998).

⇒ When the acoustic signal is ambiguous between two phonetic parses, X and Y, where X is consistent with the native sound pattern but Y is not, perception is biased towards X.



What determines bias size?

Bias differs depending on what X and Y are (Massaro & Cohen 1983, Pitt 1998, Moreton 2002). Possible factors:

In the sound pattern itself:

➢ Cluster frequency: Bias depends on frequency of the specific items X and Y in the language.

➢ Phonotactic constraints: Sound pattern is encoded in abstract constraints stated over phonological classes.

In the link between the sound pattern and perception:

➢ Legality: All items are either legal or illegal, i.e., there is a frequency or constraint-violation threshold. Fixed bias if X is legal and Y is not, else no bias.

➢ Relative markedness: Perceptual bias between X and Y depends on *differences* between X and Y. Variable bias.

Test case: OCP-Place

Dispreference for consonants with same place of articulation in same domain (e.g., syllable onset, or root). Stronger when the consonants are more similar in other ways, e.g., continuancy or sonority.

- Holds for phonology of many languages (Yip 1989, Padgett 1991, McCarthy 1994, Frisch et al. 2004).
- Affects wordlikeness judgments in Arabic (Frisch & Zawaydeh 2001) and Hebrew (Berent & Shimron 1997).
- Affects phoneme perception in English (Moreton 2002).

Q: Are there OCP-Place biases between different illegal, zero-frequency syllable onsets?

Experiment

Design: Present two 6x6 stimulus arrays. In each one, measure effect of stop decision on "l"/"w" decision.

"b/d array"	"m/n array"
dlæ … dwæ	nlæ … nwæ
: :	: :
blæ …. bwæ	mlæ … mwæ

b/d array has legal/occurring and illegal/non-occurring clusters differing on OCP-Place. m/n array has only illegal/non-occurring clusters, also differing in OCP place.

Predictions:

Cluster frequency: Syllable- and word- initial tokens in 18-million-word CELEX corpus (combined written and spoken, EPW.CD, Baayen et al 1995):

	l	w
d	0	1003
	0	983
b	71081	0
	27948	0

	l	w	
n	0	20	*syll.-init.*
	0	0	*wd.-init.*
m	0	1	
	0	1	

ennui, petgnoir, moiré

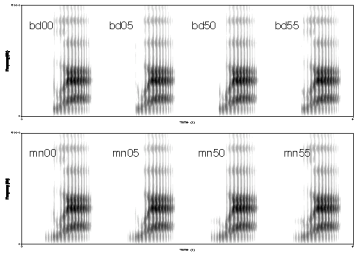
- Legality ⇒ Large bias in b/d array ("d" inhibits "l"), but none in m/n array.
- Relative markedness ⇒ (same as Legality)

OCP-Place applies to the [dl bw] and [nl mw] onsets. Should be stronger for [nl mw], which are closer in sonority.

"b/d array"	"m/n array"
~~dlæ~~ … dwæ	~~nlæ~~ … nwæ
: :	: :
blæ …. ~~bwæ~~	mlæ … ~~mwæ~~

- Legality: Entire m/n array illegal ⇒ no bias there.
- Relative markedness: Stronger OCP-Place in m/n array ⇒ *more* bias there than in b/d array.

Stimuli: Two 6x6 arrays, synthesized using SENSYN. The two arrays were identical after the release.

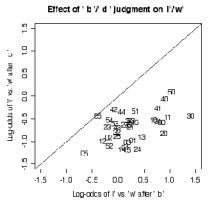


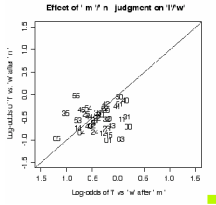
Participants: 16 native English speakers in Los Angeles (USC undergraduates).

Procedure: Each array was presented separately through headphones in a quite room 10 times for 4-choice identification. Buttons on screen were labelled with some permutation of "dl dw bl bw" or "nl nw ml mw". Eight listeners did the b/d array first, and eight did m/n first. Each filled out a post-experiment questionnaire.

Results: Statistic of interest is how "l"/"w" judgment on a stimulus was affected by the stop judgment.

For each stimulus, responses are pooled across listeners, and then
—"l"/"w" judgment is quantified as log-transformed odds ratio of "l" vs. "w" responses to that token
—computed separately for each stop response
—and the two log-odds ratios plotted as X and Y.
No bias ⇒ same "l"/"w" log-odds regardless of stop judgment ⇒ X=Y ⇒ all plotted points lie on line $y=x$.
Displacement from $y=x$ means bias.





⇒ Bias in m/n array is greatly reduced (if present at all) compared to the b/d array.

Statistical tests: Mixed-effects logistic-regression model on both arrays. Sonorant response as dependent variable.

Independent variables:

Son	Position on l-w continuum
Stop	Position on b-d or m-n continuum
b/d:	True for b/d array
LabialResp:	True for "b" or "m" response

Interaction terms of interest::

StopResp:Stop (compensation for coarticulation)
Nas:StopResp (difference in phonotactic effect between bd and mn array)

Fixed effects	Value	SE	p	
Intercept	0.731	0.205	0.0004	***
Stop	-0.136	0.040	0.0007	***
Son	0.087	0.281	0.0019	**
LabialResp	-0.845	0.308	0.0061	**
b/d	0.169	0.197	0.3886	
Stop:LabialResp	0.149	0.520	0.0043	**
Son:LabialResp	0.090	0.033	0.0069	**
LabialResp:b/d	-0.834	0.247	0.0008	***

Reference category: mn00 'n'.

Discussion

The stop decision had a much smaller effect in the m/n array than the b/d array; i.e., less bias in m/n than in b/d.

Inconsistent with OCP-Place (Relative Markedness).

Previous results using same paradigm: bias in [dl dw gl gw] but not in [bl bw gl gw] (Moreton 2002). Inconsistent with Cluster Frequency (Relative Markedness) and Cluster Frequency (Legality), since both [dl] and [bw] have zero frequency.

⇒ findings to date favor OCP-Place (Legality).

Perceptual ceiling effect:

- Phonotactic constraint violations (here, OCP-Place and a sonority-sequencing constraint) make certain onset clusters worse than others.
- Perception favors phonotactically good parses
- **Standard of badness is absolute, not relative**: Good clusters are favored over bad ones, but there is little or no preference between sufficiently bad clusters.