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Phonological variation from perceptual asymmetry

Overview:

- Norwegian retroflexion is applied more often in some contexts than in others.
- The perceptual properties of retroflexion can explain its distribution in the grammar.
- The link between perceptual properties and phonology has evolved indirectly through grammar learning.

1 Perception in phonology

A central problem in phonology:

(1) Why do phonological processes apply more often in some contexts than in others?

An example of this is found in Norwegian retroflexion:

(2) In Norwegian, alveolars / t d n s / become retroflexes [ʈ ɖ ɳ ʂ] after / ɾ /.

(3) Retroflexion can always apply, but it is more frequent in some contexts than in others.

A possible solution to this problem can be found in perceptual properties:

(4) Neutralization:
    - Distinctions that are hard to perceive tend to be neutralized (Steriade 1999).

(5) Alternation:
    - Alternating items tend to be perceptually similar to each other (Steriade 2009).

The distribution of retroflexion in Norwegian reflects such perceptual properties:

(6) The greater the perceptual distance between an alveolar and a retroflex, the less likely the alveolar is to surface as a retroflex.

2 Norwegian retroflexion

Norwegian has a contrast between alveolar coronals / t d n s / and retroflex coronals / ʈ ɖ ɳ ʂ /:

(7)	/ kɑt / ‘cat’	/ kɑʈ / ‘map’
	/ bɔːd / ‘boring’	/ bɔːɖ / ‘a man’s name’
	/ tʉːn / ‘yard’	/ tʉːɳ / ‘gymnastics’
	/ kɔs / ‘heap’	/ kɔʂ / ‘cross’

The tap / ɾ / deletes before a consonant when there is a morpheme boundary between them:

(8)	/ ʊintər-føːɾə /	→	[ʊintəføːɾə]	‘winter condition’
	/ ʊintər-jɑkə /	→	[ʊintəjɑkə]	‘winter coat’
	/ ʊintər-kʉlə /	→	[ʊintəkʉlə]	‘winter cold’

When this consonant is an alveolar / t d n s /, it surfaces as a retroflex [ʈ ɖ ɳ ʂ]:

(9)	/ ʊintər-tiː /	→	[ʊintəʈiː]	‘winter time’
	/ ʊintər-dɑː /	→	[ʊintəɖɑː]	‘winter day’
	/ ʊintər-nɑt /	→	[ʊintəɳɑt]	‘winter night’
	/ ʊintər-sœʊn /	→	[ʊintəʂœʊn]	‘winter sleep’

3 Variation in Norwegian retroflexion

Earlier descriptions of Norwegian retroflexion:

(10) Retroflexion is exceptionless and obligatory (Kristoffersen 2000).

(11) There is some variation, but it is not caused by the grammar (Eliasson 1986).

Retroflexion is indeed obligatory for / t d n /:

(12)	/ ʊintər-tiː /	→	[ʊintəʈiː]	* [ʊintətiː]	‘winter time’
	/ ʊintər-dɑː /	→	[ʊintəɖɑː]	* [ʊintədɑː]	‘winter day’
	/ ʊintər-nɑt /	→	[ʊintənɳɑt]	* [ʊintənɑt]	‘winter night’

But retroflexion is optional for / s /:

(13)	/ ʊintər-sœʊn /	→	[ʊintəʂœʊn] ~ [ʊintəsœʊn]	‘winter sleep’

According to intution, retroflexion of / s / is preferred when it is followed by a consonant, but less preferred when it is followed by a vowel:

(14)	/ ʊintər-skuː /	→	☺ [ʊintəʂkuː] ~ 😑 [ʊintəskuː]	‘winter shoes’
	/ ʊintər-suːʈ /	→	😑 [ʊintəʂuːʈ] ~ ☺ [ʊintəsuːʈ]	‘winter sun’

We need to verify that the optionality of / s /-retroflexion and its distribution are correct.

4 Production experiments – variation in / s /-retroflexion

4.1 Experiment 1a – real words

(15) Material: 10 most common nouns in / sV- / and / st- / in Norwegian.

(16) Participants: 10 native speakers of Norwegian.

(17) The nouns in / s- / followed a made up morpheme / bɛmər- /.

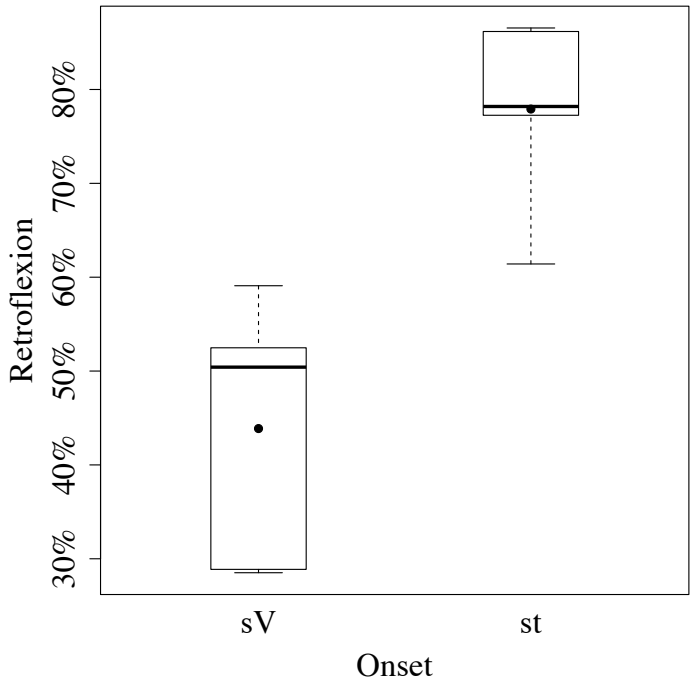
(18) These words were interspersed in stories that participants read aloud.

(19) 2406 tokens analyzed independently by two Norwegian phonologists.

(20) Results:

- Optional retroflexion of / s /.
- Significantly less retroflexion for words in / sV- / (44% vs. 78%, mixed effects logistic regression, $p < .0001$).

(21) Less retroflexion for words in / sV- /:



4.2 Experiment 1b – nonce words

(22) Material: 9 made up nouns in / sV- /, / st- /, and / sk- / – the three most common *s*-onsets in Norwegian.

(23) Participants: 10 native speakers of Norwegian.

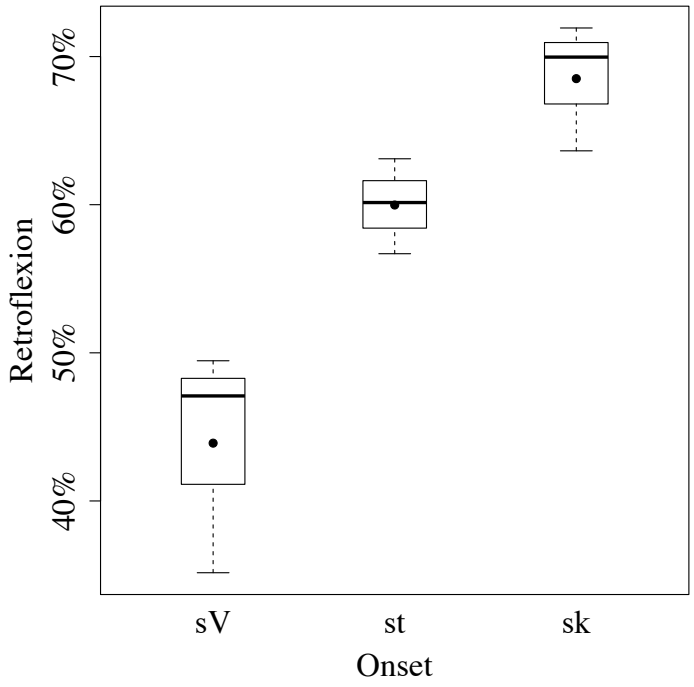
(24) The nouns in / s- / followed the morpheme /sɔmər-/ ‘summer’.

(25) 3340 tokens produced and analyzed as in experiment 1.

(26) Results:

- Optional retroflexion of / s /.
- Significantly less retroflexion for words in / sV- / than for / st- / and / sk- / (44%, mixed effects logistic regression, $p < .0001$).
- Significantly less retroflexion for words in / st- / than for words in / sk- / (60% vs. 69%, mixed effects logistic regression, $p < .01$).

(27) Less retroflexion for words in / sV- / and / st- /:



(28) ⇒ Likelihood scale of retroflexion: / t /, / d /, / n / > / sk / > / st / > / sV /.

Hypothesis: This distribution reflects the perceptual properties of retroflexion.

5 Retroflexion hierarchy from perceived distances

(29) The greater the perceived distance between *x* and *x′*, the less likely that *x* and *x′* alternate (Steriade 2001).

(30) Hypothesis: The greater the perceived distance between an alveolar and a retroflex, the less likely that the alveolar undergoes retroflexion.

(31)

Probability of retroflexion		Perceived distance	
Increasing ↑	/ t d n /	↓	[t d n]–[ʈ ɖ ɳ]
	/ sk /		[sk]–[ʂk]
	/ st /		[st]–[ʂʈ]
	/ sV /	Increasing	[sV]–[ʂV]

(32) We test this hypothesis by finding out how well participants can distinguish between alveolars and retroflexes.

6 Perception experiments – perceived distance in retroflexion

6.1 Experiment 2a – discriminating alveolars and retroflexes

(33) Material: 6 categories of alveolar and retroflex consonants:

- Category / sV /: [ɑsɑ] [ɑʂɑ]
- Category / st /: [ɑstɑ] [ɑʂʈɑ]
- Category / sk /: [ɑskɑ] [ɑʂkɑ]
- Category / t /: [ɑtɑ] [ɑʈɑ]
- Category / d /: [ɑdɑ] [ɑɖɑ]
- Category / n /: [ɑnɑ] [ɑɳɑ]

(34) Participants: 14 native speakers of Norwegian.

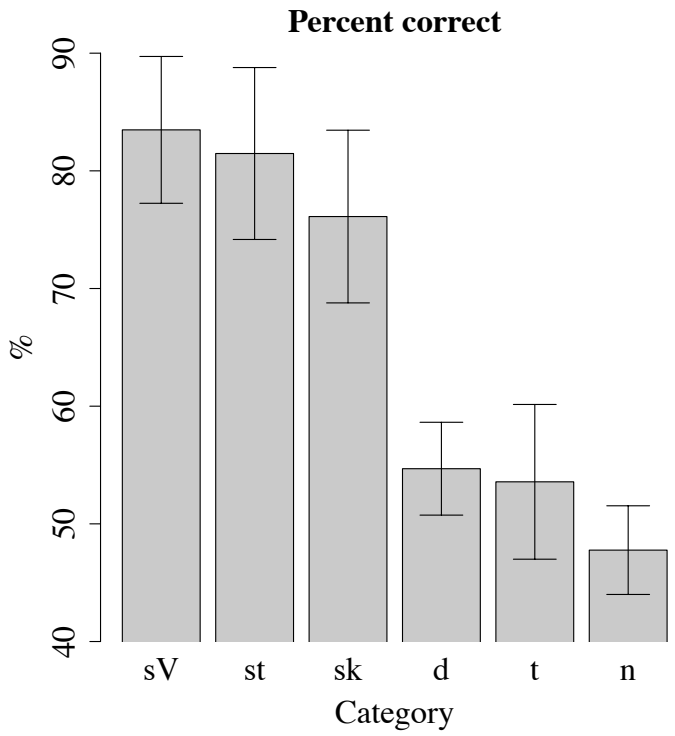
(35) Procedure: Participants listen to random pairs within each category (with background noise), and decide if the pairs are ‘same’ or ‘different’.

(36) More correct responses ⇒ greater perceived distance.

(37) Results:

- Greater perceived distance for / sV st sk / than for / t d n / (mixed effects logistic regression, $p < .0001$).
- Greater perceived distance for / sV st / than for / sk / ($p < .001$, $p < .05$).

(38) Greater perceived distances for / sV st sk /:



(39) Hypothesized perceptibility scale based on productions:

/ sV / > / st / > / sk / > / t /, / d /, / n /.

(40) Perceptibility scale in experiment:

/ sV /, / st / > / sk / > / t /, / d /, / n /.

(41) The perceptibility scale in (40) is consistent with the hypothesized scale in (39).

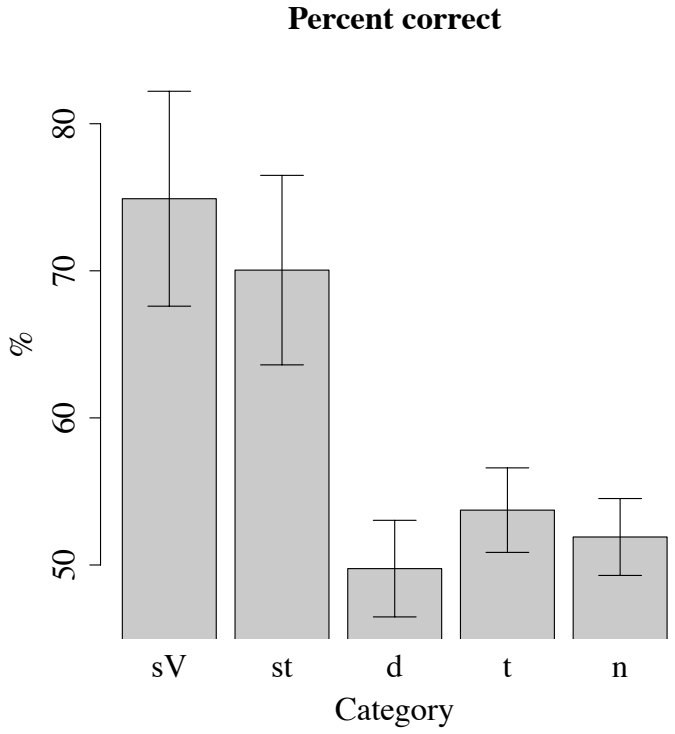
(42) The difference between / sV / and / st / does not reach significance, but it trends in favor of the hypothesis.

6.2 Experiment 2b – discriminating alveolars and retroflexes quickly

(43) In this experiment, participants were given 900ms to decide on a response.

(44) Participants: 12 native speakers of Norwegian.

(45) Results: Greater perceived distance for / sV / than for / st / (p = .01).



⇒ Hypothesized perceptibility scale / sV / > / st / > / sk / > / t /, / d /, / n / is confirmed.

7 From perception to phonology

Why is there a link between perceptual distances and phonology?

Perceptibility-map hypothesis (Steriade 2001, 2009, Wilson 2006):

(46) The link between perceptual distances and phonology is built into the grammar by default.

(47) The ranking of faithfulness constraints reflects perceptual distances:

- FAITH / sV / >> FAITH / st / >> FAITH / sk / >> FAITH / t d n /.

Alternative:

(48) We can *derive* the faithfulness ranking from mechanisms of grammar learning.

(49) ⇒ No need to stipulate that perceptual distances are reflected directly in the phonological grammar.

8 Perceptual distance → categorization → phonology

Human perception in general:

(50) The greater the perceived distance between category *x* and stimulus *x′*, the less likely *x′* is to be labeled as a token of *x* (Nosofsky 1986).

In language:

(51) This effect is found both in word priming (Marslen-Wilson et al. 1996) and phonological learning (Skoruppa et al. to appear).

(52) ⇒ The likelihood that token *x′* is categorized as word *x* is a function of its perceived similarity to *x*.

Perception in retroflexion:

(53) When there is a large perceptual distance between an alveolar word in / t- d- n- s- / and a retroflex token in [ʈ- ɖ- ɳ- ʂ-]

⇒ Listeners are less likely to categorize the retroflex token in [ʈ- ɖ- ɳ- ʂ-] as a token of the alveolar word in / t- d- n- s- /.

Learning a grammar:

(54) Listeners will construct a grammar based on the distribution of tokens they perceive and categorize.

(55) If perceptually distant retroflex tokens are less likely to be categorized as alveolar words

⇒ Then listeners will construct a grammar where these alveolar words are less likely to surface with retroflex tokens.

9 Modeling the link from categorization to phonology

Initial bias in grammar learning (McCarthy 1998, Hayes 2004, Coetzee 2009):

(56) Assume that a word behaves uniformly – it does not alternate.

- When a learner learns the word / sœʊn / ‘sleep’, he will assume that this word will be realized uniformly as [sœʊn].

- An output form [sœʊn] should be faithful to the other output forms [sœʊn] of the same word.
- The initial bias is a bias for OUTPUT-OUTPUT-FAITHFULNESS.

(57) Two conflicting constraints in Norwegian:

i. APPLY RETROFLEXION AFTER / ɾ /.

ii. OUTPUT-OUTPUT-FAITHFULNESS (≈ 'do not apply retroflexion after / ɾ /').

(58) The learner will suppress the initial bias for OUTPUT-OUTPUT-FAITHFULNESS if there is sufficient evidence that the word does alternate.

(59) Hypothesis: The more often the learner categorizes retroflex tokens in [ʈ- ɖ- ɳ- ʂ-] as tokens of the alveolar words in / t- d- n- s- /, the more he will suppress OUTPUT-OUTPUT-FAITHFULNESS for that segment.

9.1 Learning simulation

(60) Model: Harmonic Grammar ('OT with constraint weights', Pater 2009).

(61) Learning algorithm: Maximum entropy (Goldwater & Johnson 2003, Wilson & George 2009).

(62) Learning data: Retroflex tokens of alveolar words in / t- d- n- sk- st- sV- /:

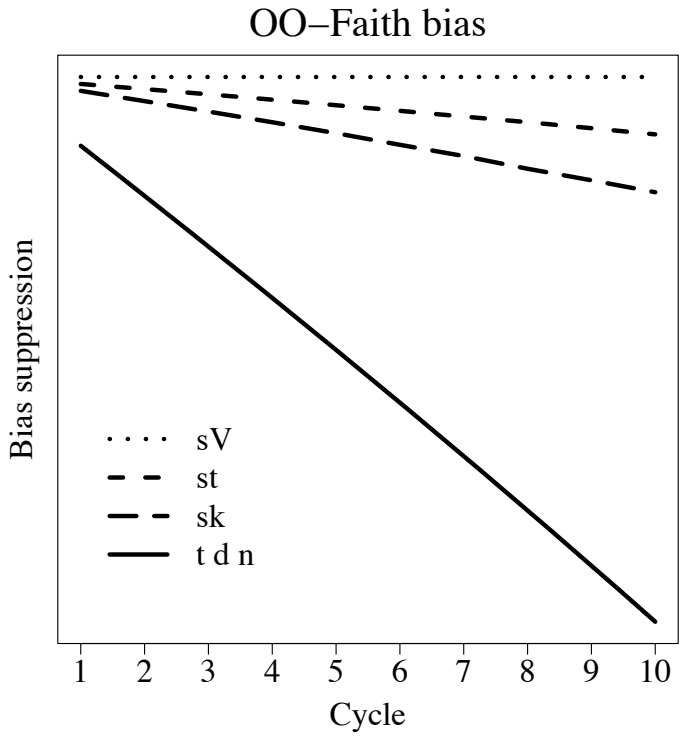
- The initial speaker produces 1,000 retroflex tokens for each onset.
- The listener categorizes the retroflex tokens as alveolar words according to their similarity to the alveolar category:
  - 100% of the retroflex tokens in [ʈ- ɖ- ɳ-].
  - 96% of the retroflex tokens in [ʂk-].
  - 95,5% of the retroflex tokens in [ʂʈ-].
  - 95% of the retroflex tokens in [ʂV-].

(63) The listener learns a grammar and becomes a speaker for the next listener → 1 cycle.

(64) The simulation runs over 10 cycles.

(65) Prediction: The learner will suppress the initial bias for OUTPUT-OUTPUT-FAITHFULNESS according to the categorization scale / t ɖ n / > / sk / > / st / > / sV /.

(66) Suppression of OO-FAITH relative to the suppression of OO-FAITH for / sV /:



(67) ⇒ The greater the likelihood of categorizing retroflex tokens as alveolar words, the more the constraint against retroflexion is suppressed.

(68) The grammar at cycle 10:

Constraint	Weight
OO-FAITH / sV /	9.48
OO-FAITH / st /	9.46
OO-FAITH / sk /	9.45
OO-FAITH / t d n /	9.32

⇒ OO-FAITH / sV / >> OO-FAITH / st / >> OO-FAITH / sk / >> OO-FAITH / t d n /

(69) The derived faithfulness ranking in (68) is identical to the stipulated faithfulness ranking from the P-map hypothesis in (47).

10 Conclusions

(70) Norwegian speakers apply retroflexion more often to some alveolars than to others: / t d n / > / sk / > / st / > / sV /.

(71) The greater the perceived distance between the alveolar and the retroflex, the less likely speakers are to apply retroflexion to the alveolar.

(72) The link between perceptual distances and phonology does not need to be stated directly in the grammar.

(73) Perceptual distances affect word recognition, and word recognition forms the basis for grammar learning.

(74) The link between perceptual distances and phonology has emerged indirectly through grammar learning.

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