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The origin of variation in Norwegian retroflexion

Overview part I:

- 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.

Overview part II:

- Norwegian speakers apply retroflexion more often when it is harmful for listeners, but do not extend this pattern to novel words.
- An evolutionary account explains the harmful pattern as a result of a recent historical accident.
- Novel words have no evolutionary history, so this pattern is absent in novel words.

Part I – Phonological variation from perceptual asymmetry

1 Perception in phonology

A central problem in phonology:

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

The same problem 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 / → [ʊintəɳɑt] * [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 / bɛməɾ- /.

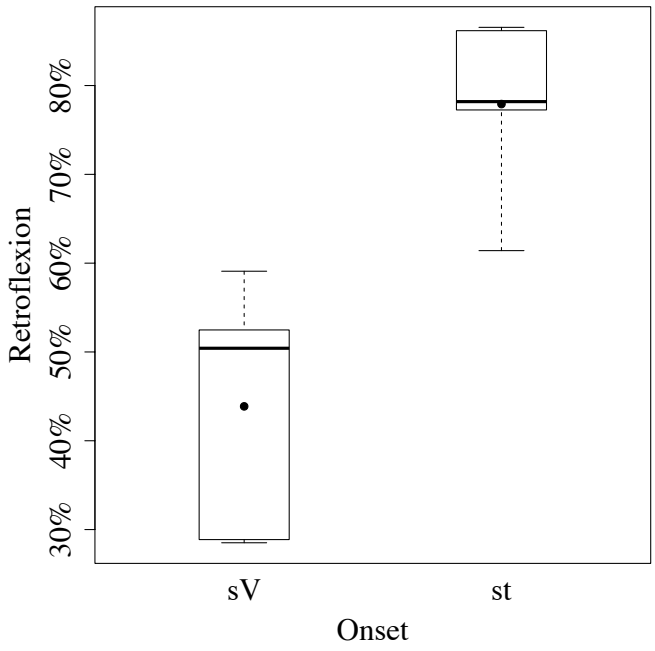
(18) These words were interspersed in stories that participants read aloud.

(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.

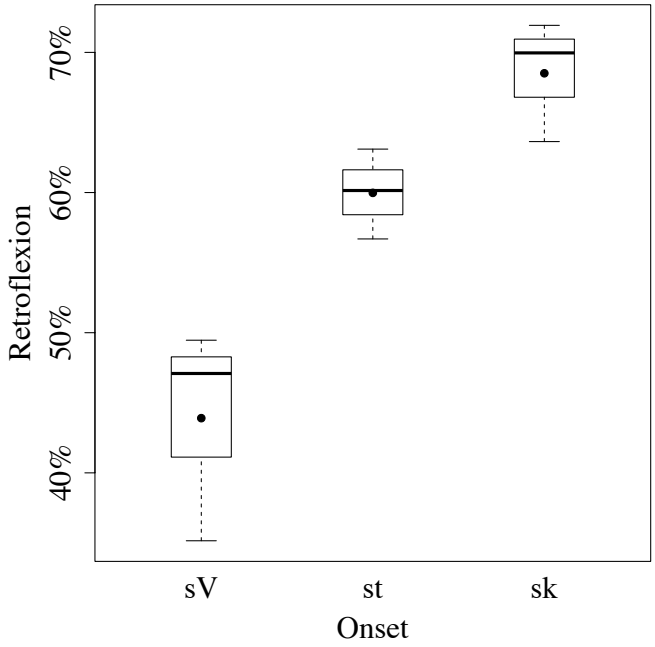
(24) The nouns in / s- / followed the morpheme /sɔməɾ-/ ‘summer’.

(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.

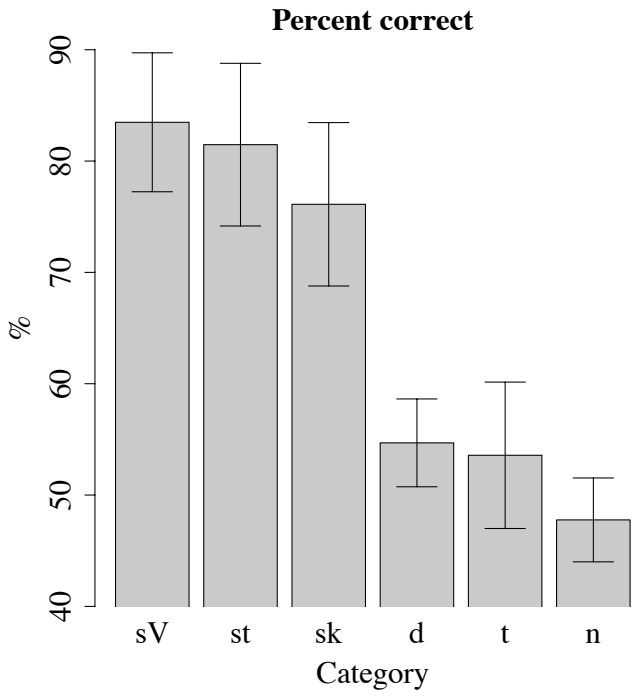
(35) Procedure: Participants listen to random pairs within each category (with background noise), and decide if the pairs are ‘same’ or ‘different’.

(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).

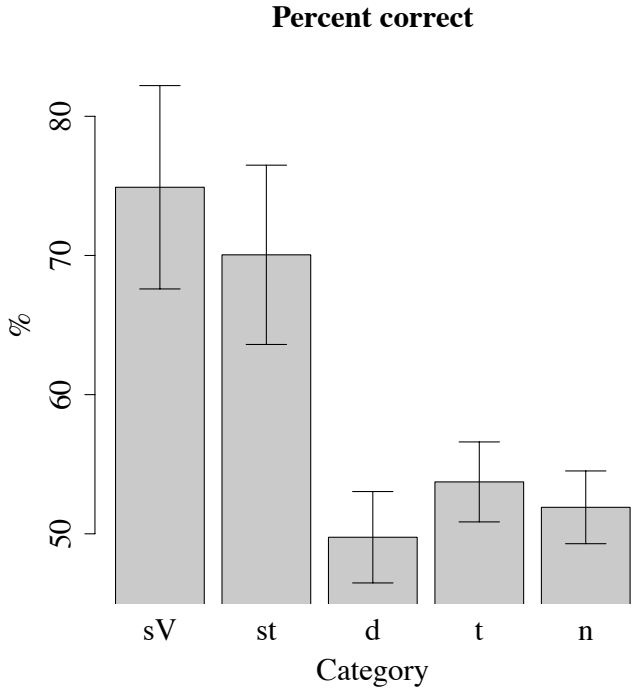
(42) The difference between / sV / and / st / does not reach significance, but it trends in favor of the hypothesis.

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- /:

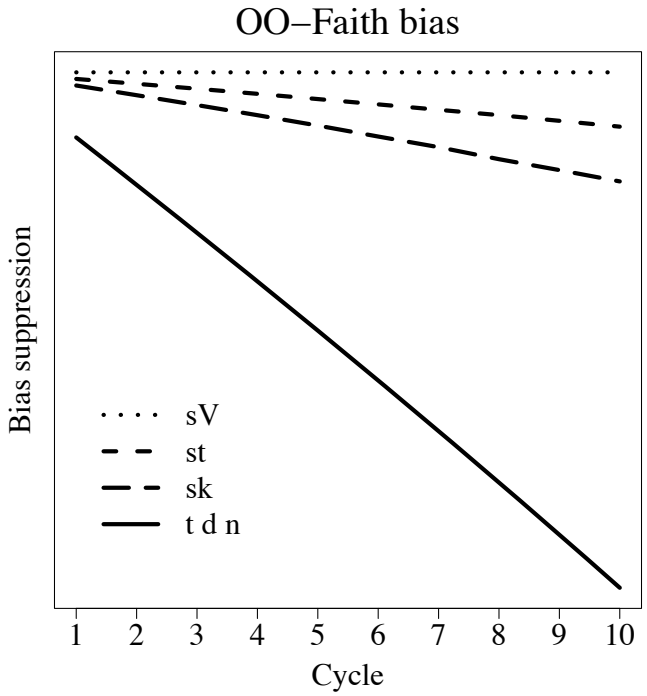
- The initial speaker produces 1,000 retroflex tokens for each onset.
- The listener categorizes the retroflex tokens as alveolar words according to their similarity to the alveolar category:
  - 100% of the retroflex tokens in [ʈ- ɖ- ɳ-].
  - 96% of the retroflex tokens in [ʂk-].
  - 95,5% of the retroflex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

Part II – An evolutionary account of listener accommodation

11 Listener accommodation in speech

(75) Some situations hinder efficient communication:

- Background noise.
- Listeners hard of hearing.
- Non-native listeners.

(76) In these situations, people apply global changes to their speech to clarify the message for listeners (Smiljanić & Bradlow 2009):

- Speech is slower and louder.
- Contrasts are enhanced.

How far does listener accommodation in speech go?

Listener-oriented hypothesis (Wright 2003, Scarborough 2003):

(77) Listener accommodation extends down to the individual word.

(78) Speakers will clarify some words more than others if this benefits listeners.

Evolutionary hypothesis:

(79) Listener accommodation is only global.

(80) Differences among individual words are caused by evolutionary developments, not by listener accommodation.

12 Clear speech in harder words

Words that are very similar to other words are harder for listeners to identify (Luce & Pisoni 1998).

⇒ These words are ‘hard’ – words that are less similar to other words are ‘easy’.

12.1 Listener-oriented hypothesis

Speakers clarify hard words more than easy words for the benefit of listeners (Wright 2003, Scarborough 2003).

The expanded vowel space example:

(81) Listeners understand speech with an expanded vowel space more easily (Bradlow et al. 1996).

(82) Hard words are produced with an expanded vowel space (Wright 2003, Munson & Solomon 2004).

⇒ Speakers expand the vowel space in hard words to accommodate the perceptual needs of listeners (Wright 2003).

12.2 Evolutionary hypothesis

Speakers produce words in the way they survived the transmission process.

The expanded vowel space example:

(83) There is variability in the production of any word.

(84) Easy words produced with a condensed vowel space can still be recognized, since they are still not very similar to other words.

(85) Hard words produced with a condensed vowel space risk not being recognized, since the condensed vowel space makes hard words even more similar to each other.

⇒ Hard words with a condensed vowel space are lost in transmission.

⇒ Hard words have an expanded vowel space because these are the words that survived (Pierrehumbert 2001).

13 Hypothesis predictions

13.1 Predictions for real words

Both hypotheses would generally make the same prediction for real words:

(86) Speakers tend to produce words in a way that is beneficial to listeners.

The evolutionary hypothesis allows deviations from this tendency:

(87) Historical accidents can result in speaker behavior that is not beneficial for listeners.

In the listener-oriented hypothesis, speakers only care about the present needs of listeners:

(88) History is not relevant – principles of listener accommodation reset the conditions for the speaker.

(89) Speakers cannot act in a way that is harmful to listeners.

13.2 Predictions for nonce words

Listener-oriented hypothesis:

(90) Speakers clarify hard words for listeners.

Evolutionary hypothesis:

(91) Listener accommodation does not exist for individual words.

(92) Hard words are produced differently because of their transmission history.

(93) Made up words have no transmission history.

⇒ Hard made up words should not be different from easy made up words.

14 Norwegian retroflexion

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

(94)	/ ʊintər-føːɾə /	→	[ʊintəføːɾə]	‘winter condition’
	/ ʊintər-jɑkə /	→	[ʊintəjɑkə]	‘winter coat’
	/ ʊintər-kʉl̠ə /	→	[ʊintəkʉl̠ə]	‘winter cold’

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

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

Retroflexion is optional for / s /:

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

Is the likelihood of retroflexion different for hard words in / s- /?

14.1 Norwegian retroflexion in the 19th century

No words or morphemes can begin with a retroflex consonant [ʈ ɖ ɳ ʂ] (Brekke 1881, Storm 1884, Western 1889):

(97)	/ teː /	‘behave	* / ʈeː /
	/ deː /	‘that’	* / ɖeː /
	/ neː /	‘decresence’	* / ɳeː /
	/ seː /	‘see’	* / ʂeː /

Retroflexion of / s- / to [ʂ-] provides a cue for listeners that the preceding morpheme ends in / -ɾ /:

(98)

/ ɭæːɾəɾ-sɑːl / ‘room for teachers’ ✓

↙

[ɭæːɾəʂɑːl]

↖

/ ɭæːɾə-sɑːl / ‘room for learning’ ×

If no retroflexion takes place, it is ambiguous for listeners whether the first morpheme ends in / -ɾ / or not:

(99)

/ ɭæːɾəɾ-sɑːl / ‘room for teachers’ ✓ ?

↙

[ɭæːɾəsɑːl]

↖

/ ɭæːɾə-sɑːl / ‘room for learning’ ✓ ?

Listener-oriented hypothesis:

(100) Speakers aim to reduce lexical ambiguity for listeners.

(101) Speakers apply phonological changes in hard words if they provide extra segmental cues for listeners (Scarborough 2003).

⇒ Retroflexion of / s- / should be more common for hard words.

Evolutionary hypothesis:

(102) Lexically unambiguous words are easier for listeners to identify.

(103) Lack of ambiguity plays a greater role for hard words.

⇒ Unambiguous hard words are more likely to survive transmission.

⇒ Retroflexion of / s- / should be more common for hard words.

⇒ Both hypotheses predict that retroflexion of / s- / should be more common for hard words.

14.2 Sound change in Norwegian

In the early 20th century, the palatalized sibilant / ʃʲ / merges with retroflex / ʂ / (Borgstrøm 1938, 1958, Vogt 1939):

(104)

/ ʃʲœn /	>	/ ʂœn /	‘judgment’
/ ʃʲæːɾə /	>	/ ʂæːɾə /	‘cut’
/ ʃʲɑːl /	>	/ ʂɑːl /	‘shawl’

Retroflexion of / s- / now creates ambiguity:

(105)

		/ ɭæːɾər-sɑːl /	‘room for teachers’	✓ ?
[ɭæːɾəʂɑːl]	←	/ ɭæːɾər-ʂɑːl /	‘teacher’s shawl’	✓ ?
		/ ɭæːɾə-ʂɑːl /	‘beginner’s shawl’	✓ ?

Suppressing retroflexion causes less ambiguity:

(106)

		/ ɭæːɾər-sɑːl /	‘room for teachers’	✓ ?
[ɭæːɾəsɑːl]				
		/ ɭæːɾə-sɑːl /	‘room for learning’	✓ ?

Listener-oriented hypothesis:

(107) Speakers aim to reduce lexical ambiguity in hard words for listeners.

⇒ Speakers should now suppress retroflexion of / s- / for hard words.

(108) History is not relevant – when conditions change, everything resets.

Evolutionary hypothesis:

(109) Inherited traits do not disappear immediately when conditions change.

(110) Enough time needs to elapse to allow inherited traits to be lost in transmission.

⇒ Retroflexion of / s- / could still be more common for hard words, because that is how they were inherited.

⇒ Speakers could treat individual words in a way that is harmful for listeners.

15 Experiments – retroflexion in easy and hard words

15.1 Experiment 3a – retroflexion in real words

(111) Material: 99 monomorphemic nouns in / sV- /:

- All words are highly familiar to Norwegian speakers.
- All words are native or very old loanwords.

⇒ All words date back to before the 19th century.

(112) Participants: 211 native speakers of Norwegian.

(113) The words in / sV- / followed a made up morpheme / bɛməɾ- /.

(114) Participants would rate on a 1-7 scale how likely they were to apply retroflexion to a word.

Listener-oriented hypothesis:

(115) Speakers apply less retroflexion in hard words.

(116) More retroflexion in hard words is not possible, since it harms listeners.

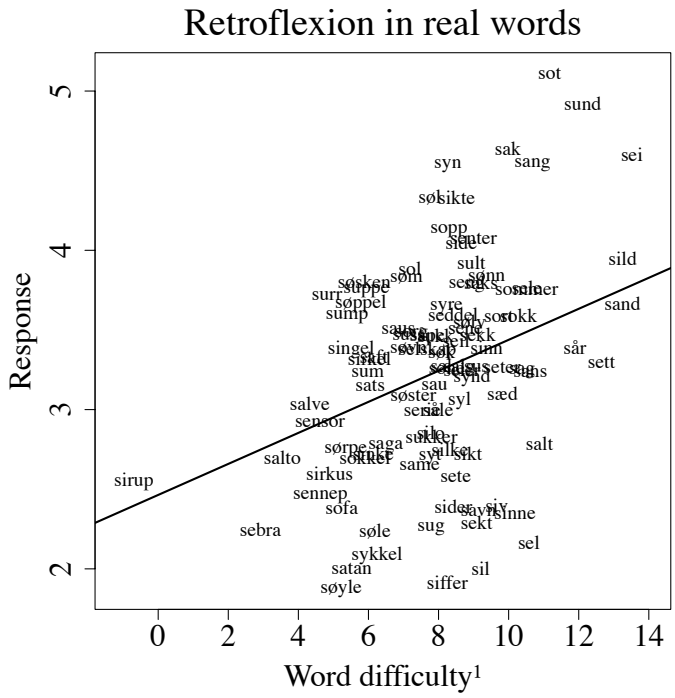
Evolutionary hypothesis:

(117) More retroflexion in hard words is plausible, given the history of retroflexion.

(118) Speakers do not accommodate listeners on individual words – harming listeners at this level is possible.

Results:

- More retroflexion in hard words (mixed effects linear regression, $p < .00001$).



⇒ Speakers do not accommodate the needs of listeners for individual words.

15.2 Experiment 3b – retroflexion in nonce words

(119) Material: 198 made up mono- and disyllabic nouns in / sV- /.

(120) Participants: The same 211 native speakers of Norwegian.

Listener-oriented hypothesis:

(121) Speakers accommodate listeners and apply less retroflexion in hard words.

Evolutionary hypothesis:

(122) Differences among individual words are due to inherited traits.

[1] Word difficulty = log transformed summed token frequency of words one phoneme substitution away from the word in / sV- /.

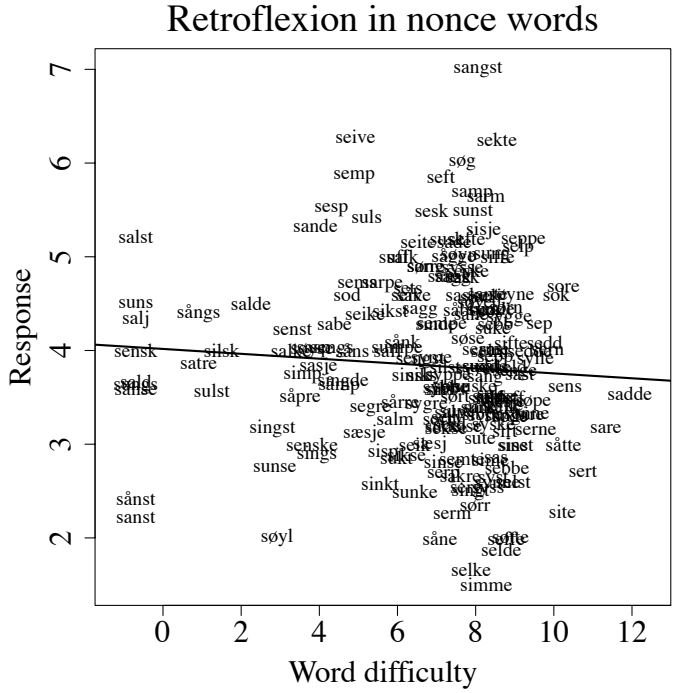
(123) Made up words have no evolutionary history.

⇒ Made up words have no inherited traits.

⇒ There should be no difference between easy and hard words.

Results:

- No difference between easy and hard words (p = .98).



⇒ Speakers do not accommodate the needs of listeners for individual words.

16 Conclusions

(124) Recent sound changes in Norwegian retroflexion have turned a beneficial pattern into a harmful pattern for listeners.

(125) Speakers maintain this pattern because the production of individual words is determined by evolution.

(126) Speakers do not extend this pattern to novel words.

(127) Novel words have no evolutionary history, so speakers treat all novel words the same.

(128) These findings argue against the hypothesis that speakers accommodate listeners in the production of individual words.

References

Borgstrøm, Carl. 1938. Zur Phonologie der norwegischen Schriftsprache (nach der ostnorwegischen Aussprache). *Norsk tidsskrift for sprogvidenskap* 9:250-273.

Borgstrøm, Carl. 1958. *Innføring i sprogvidenskap*. Oslo: Universitetsforlaget.

Bradlow, Ann R., Gina M. Torretta, and David B. Pisoni 1996. Intelligibility of Normal Speech I: Global and Fine-Grained Acoustic-Phonetic Talker Characteristics. *Speech Communication* 20:255-272.

Brekke, Knud. 1881. *Bidrag til dansk-norskens lydlære*. Kristiania: W. C. Fabritius.

Coetzee, Andries W. 2009. Learning Lexical Indexation. *Phonology* 26:109-145.

Eliasson, Stig. 1986. Sandhi in Peninsular Scandinavian. In H. Andersen, ed., *Sandhi Phenomena in the Languages of Europe*, 271-300, Berlin: Mouton de Gruyter.

Goldwater, Sharon and Mark Johnson. 2003. Learning OT Constraint Rankings Using a Maximum Entropy Model. In J. Spenader, A. Eriksson, and Ö. Dahl, eds., *Variation within Optimality Theory. Proceedings of the Stockholm Workshop on 'Variation within Optimality Theory', April 26-27, 2003 at Department of Linguistics, Stockholm University, Sweden*, Stockholm: Stockholm University.

Hayes, Bruce. 2004. Phonological Acquisition in Optimality Theory: The Early Stages. In R. Kager, J. Pater, and W. Zonneveld, eds., *Constraints in Phonological Acquisition*, 158-203, Cambridge: Cambridge University Press.

Kristoffersen, Gjert. 2000. *The Phonology of Norwegian*. Oxford: Oxford University Press.

Luce, Paul A. and David B. Pisoni. 1998. Recognizing Spoken Words: The Neighborhood Activation Model. *Ear & Hearing* 19:1-36.

Marslen-Wilson, William, Helen E. Moss, and Stef van Helen. 1996. Perceptual Distance and Competition in Lexical Access. *Journal of Experimental Psychology: Human Perception and Performance* 22:1376-1392.

McCarthy, John J. 1998. Morpheme Structure Constraints and Paradigm Occultation. In M. C. Gruber, D. Higgins, K. S. Olson, and T. Wysocki, eds., *CLS 34 Part 2: Papers from the Panels. The Status of Constraints. The Acquisition of Spoken Language. Acquisition and the Lexicon*, 125-150, Chicago, IL: Chicago Linguistic Society.

Munson, Benjamin and Nancy Pearl Solomon. 2004. The Effect of Phonological Neighborhood Density on Vowel Articulation. *Journal of Speech, Language, and Hearing Research* 47:1048-1058.

Nosofsky, Robert M. 1986. Attention, Similarity, and the Identification-Categorization Relationship. *Journal of Experimental Psychology: General* 115:39-57.

Pater, Joe. 2009. Weighted Constraints in Generative Linguistics. *Cognitive Science* 33:999-1035.

Pierrehumbert, Janet B. 2001. Exemplar Dynamics: Word Frequency, Lenition and Contrast. In J. Bybee and P. Hopper, eds., *Frequency and the Emergence of Linguistic Structure*, 137-157, Amsterdam: John Benjamins Publishing Company.

Scarborough, Rebecca Anne. 2003. Lexical Confusability and Degree of Coarticulation. In P. M. Nowak, C. Yoquelet, and D. Mortensen, eds., *Proceedings of the Twenty-Ninth Annual Meeting of the Berkeley Linguistics Society. February 14-17, 2003. General Session and Parasession on Phonetic Sources of Phonological Patterns: Synchronic and Diachronic Explanations*, 367-378, Berkeley, CA: Berkeley Linguistics Society.

Skoruppa, Katrin, Anna Lambrechts, and Sharon Peperkamp. (To appear). The Role of Phonetic Distance in the Acquisition of Phonological Alternations. *Proceedings of NELS 39*.

Smiljanić, Rajka and Ann R. Bradlow. 2009. Speaking and Hearing Clearly: Talker and Listener Factors in Speaking Style Changes. *Language and Linguistics Compass* 3:236-264.

Steriade, Donca. 1999. Phonetics in Phonology: The Case of Laryngeal Neutralization. In M. K. Gordon, ed., *UCLA Working Papers in Linguistics* 2:25-146.

Steriade, Donca. 2001. Directional Asymmetries in Place Assimilation. A Perceptual Account. In E. Hume and K. Johnson, eds., *The Role of Speech Perception in Phonology*, 219-250, San Diego, CA: Academic Press.

Steriade, Donca. 2009. The Phonology of Perceptibility Effects: The P-map and its Consequence for Constraint Interaction. In K. Hanson and S. Inkelas, eds., *The Nature of the Word. Studies in Honor of Paul Kiparsky*, 151-179, Cambridge, MA: The MIT Press.

Storm, Johan. 1884. Norsk Lydskrift med Omrids af Fonetiken. *Norvegia* 1:19-132.

Vogt, Hans. 1939. Some Remarks on Norwegian Phonemics. *Norsk tidsskrift for sprogvidenskap* 11:136-144.

Western, August. 1889. Kurze darstellung des norwegischen lautsystems. *Phonetische studien* 2:259-282.

Wilson, Colin. 2006. Learning Phonology with Substantive Bias: An Experimental and Computational Study of Velar Palatalization. *Cognitive Science* 30:945-982.

Wilson, Colin and Ben George. 2009. MaxEnt Grammar Tool [Computer Software]. Retrieved from http://www.linguistics.ucla.edu/people/hayes/MaxentGrammarTool/.

Wright, Richard. 2003. Factors of Lexical Competition in Vowel Articulation. In J. Local, R. Ogden, and R. Temple, eds., *Phonetic Interpretation. Papers in Laboratory Phonology VI*, 75-86, Cambridge: Cambridge University Press.