Norwegian retroflexion – licensing by cue or prosody?*

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1. Introduction

A common topic in recent literature on phonology is the question of whether phonological processes and segments are licensed by prosodic position or by perceptual cues. The former is the traditional view, as represented by e.g. Lombardi (1995) and Beckman (1998), and holds that segments occur in specific prosodic positions such as the coda. In a licensing by cue approach, as represented by Steriade (1995, 1999), on the other hand, segments are assumed to occur in those positions only where their perceptual cues are prominent, independent of the prosodic position. In positions where the cues are not salient, neutralization occurs.

The present article investigates the perceptual recognition of retroflexion in Urban East Norwegian (henceforth UEN)[1]. Previous studies on UEN retroflexes focussed either on their articulatory realization (see Simonsen et al. 2000) or their phonological distribution (see Kristoffersen 2000). The retroflex class in UEN is of interest for the discussion on licensing for two reasons. First, it occurs predominantly in coda position, which is an indication for prosodic licensing. Second, retroflexes in UEN and in general show an asymmetrical spread of cues, because they have strong transitions from the preceding vowel into the consonant (henceforth: VC cues). The asymmetrical spread of retroflex cues, illustrated by Steriade (2001) in her study on assimilation processes, can be taken as an indication for cue licensing.

The present study attests the strength of retroflex VC cues by an perception experiment in which both Norwegian and German listeners weigh the VC cues of retroflexes perceptually more important than the CV cues of denti-alveolars in Norwegian. Furthermore, it argues that these cues can account for the phonotactic restrictions on retroflexes.

The study precedes as follows. Section 2 gives the phonological data on retroflexes in Norwegian. In section 3, this data is discussed in the light of the two theories; prosodic licensing and cue licensing. It will be shown that the prosodic theory cannot account for the UEN data. The results of a

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[1] As defined by Kristoffersen (2000: 9f.).

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perceptual test with cross-spliced signals are presented in section 4. Section 5 concludes.

2. Retroflexion in UEN

In UEN, retroflex segments occur postvocalically within non-derived environments. These retroflexes stem diachronically from an /r/ plus a denti-alveolar [t, d, n, l, s], as reflected in the orthography of the examples in (1).[2]

(1) a.	bart	[bɑʈ]	'mustache'
	jarl	[jɑːɭ]	'earl'
	kors	[kɔʂ]	'cross'
	barn	[bɑːɳ]	'child'
b.	kartong	[kɑ.ˈʈɔŋ]	'cardboard'
	sardin	[sɑ.ˈɖiːn]	'sardine'
	ballong	[bɑ.ˈɭɔŋ]	'balloon'
	person	[pæ.ˈʂuːn]	'person'

(1a) provides examples with retroflex segments in syllable-final position, and (1b) with retroflexes in syllable-initial position.

In derived environments, retroflexes in UEN are the result of a retroflexion rule (Kristoffersen 2000: 88ff.) that merges /r/ and denti-alveolars across morpheme or word boundaries, cf. (2).

(2) a.	bar+en	[bɑːɳ]	'bar' + def. sg.	cf. [bɑːɾ]	bar
	bror+s	[bɾuːʂ]	'brother' + possess.	cf. [bɾuːɾ]	bror
b.	vår+lig	[ˈʋoː.ˌɭi]	'spring +like'	cf. [ʋoːɾ]	vår
	vår+dag	[ˈʋoː.ˌɖɑːg]	'spring day'	cf. [ʋoːɾ]	vår
c.	Per ser	[ˌpeː.ˈʂeːɾ]	'Per sees'	cf. [peːɾ]	Per

In (2a), retroflexion occurs across a stem-suffix boundary, in (2b) within a compound word, and in (2c) across a word boundary.

Three major exceptions exist to the diachronic development of retroflexes and the synchronic retroflexion rule. The first exception is the sequence *rd* within non-derived environments, which is mostly not retroflexed when preceded by a short vowel, see e.g. *sverd* [sʋæɾd]

[2] As minimal pairs such as *kat* [kɑt] – *kart* [kɑʈ] exist in UEN, the present article assumes that retroflexes in lexical words are not derived but underlying phonemes. For a detailed discussion of this point and alternative proposals that all retroflexes are derived see the articles in Jahr & Lorentz (1981).

'sword'. After long vowels, however, *rd* is mostly turned into a retroflex (Braunmueller 1991: 129).[3]

The second exception is the retroflex fricative [ʂ], which can occur in word-initial position without a preceding rhotic in the input, cf. (3).[4]

(3)	sjø	[ʂøː]	'sea'
	ski	[ʂiː]	'ski'
	skje	[ʂeː]	'spoon'

The origin of the retroflex in the examples in (3) is a palatalized /s/, still indicated in the orthography by a following *k* or *kj* before front vowels and a *j* elsewhere. According to Popperwell (1963), these segments used to be pronounced as [ʃ], but merged with the retroflex [ʂ].[5]

Thirdly, the laminal lateral [l] and the retroflex lateral [ɭ] stemming from the sequence r plus denti-alveolar show exceptional behaviour. Both segments are in the process of merger into a 'slightly retroflex' variant (Vanvik 1972). Therefore, [ɭ] can also occur word-initially in non-derived environments, see the examples in (4) from the Oslo accent of UEN (Vanvik 1972: 141).

(4)	lat	[ɭɑːt]	'lazy'
	lord	[ɭɔːɖ]	'lord'

All retroflex segments in UEN cause progressive assimilation of following coronals, a process described as '[apical] spreading' in Kristoffersen (2000), cf. examples in (5).

(5)	a. Ernst	[æɳʂʈ]	name
	barsel	[bɑʂɭ̩]	'childbirth'
	b. perlen	[pæː.ɭɳ̩]	'pearl'+ def. sg.
	c. slå	[ʂɭoː]	'to beat'
	firfisle	[ˈfiːɾ.ˌfɪʂ.ɭə]	'lizzard'

[3] See Kristoffersen (2000: 88f.) for a full description and discussion of the data on *rd* sequences. The *rd* exception in Norwegian seems to be a singular phenomenon, no other language could be found that shows this exceptional behaviour in retroflexion.

[4] I wish to thank Ove Lorentz for pointing out this exception and its historical explanation to me.

[5] There is no consensus in the literature on the phonetic status of this sound. Vanvik (1972) e.g. states that the formerly postalveolar sound is still pronounced as [ʃ]. The present study follows Popperwell and Kristoffersen in assuming that both historically distinct sounds merged into one, retroflex category.

As can be seen in (5b), progressive assimilation of retroflexion is not restricted to a lexical word context, but occurs also across morpheme boundaries.

The examples in (5c) show the spread of retroflexion of the fricative onto the lateral (assuming the lateral is not fully retroflexed, recall the explanation above).

One exception to progressive spreading of retroflexion in UEN exists, namely the retroflex fricative /ʂ̺/, which can spread its retroflexion rightwards, see the examples in (5). [6]

(6)	kanskje	[ˈkɑɳ.ʂ̺ə]	‘perhaps’
	lunsj	[lœɳʂ̺]	‘lunch’
	lys-sky	[ˈlyʂ̺.ˌʂ̺yː]	‘photophobic, furtive’
	fall-skjerm	[ˈfɑɭ.ˌʂ̺æɾm]	‘parachute’

3. Cue or prosody?

To decide whether retroflexion in UEN is licensed by prosody or by cue, the following subsections 3.1 and 3.2 will apply both theories subsequently to the data presented in section 2.

3.1 Prosodic account

Looking at retroflexes in non-derived words in (1a) only, one could assume that retroflexes are licensed by coda position. This assumption is quickly falsified by the fact that bisyllabic words as in (1b) can have a retroflex in the onset of the second syllable, e.g. [pæ.ˈʂ̺uːn] ‘person’.[7] Furthermore, the retroflex fricative and the retroflex lateral can occur in word-initial position, cf. the examples in (3) and (4). Thus, the coda cannot be the licensing position for retroflexion in UEN.

An alternative prosodic account is to consider the foot as a possible licensing domain. Foot-medial position favours certain elements such as geminates, but is also a site of lenition, see e.g. flapping in American English. According to Kristoffersen (2000), the foot in UEN is a moraic trochee, i.e. it consists of two moras, and is assigned from right to left.

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[6] A full discussion of the specific process of retroflexing *n* before [ʂ̺], and its exceptions, is given in Vanvik (1979: 51f.).

[7] Hannele Nicholson and Andreas Hilmo Teig suggest that these cases could be interpreted as a spreading of retroflexion from a coda to a following onset position. There is no synchronic evidence for such a process. Diachronically, the alveolar flap in coda position merged with the denti-alveolar segment in onset position to a retroflex segment. One could assume an intermediate stage in this development with a retroflex flap in coda position, which then spread its retroflexion rightwards. However, such an intermediate stage is not attested.

The non-retroflexion of /rd/ in UEN can be described in terms of foot position. Foot-medially, this sequence is almost always realized as [rd], cf. (7a), whereas foot-initially it is a [ɖ], cf. (7b) (brackets indicating foots).

(7) a. garde [(ˈgɑɾ.də)] 'royal guard' b. gardist [gɑ.(ˈɖist)] 'guardsman'
verdig [(ˈʋæɾ.di)] 'worthy' fordi [fɔ.(ˈɖiː)] 'because'

Foot-finally, there is some incongruence for /rd/ sequences, compare e.g. *sverd* [(ˈsʋæɾd)] with *Edvard* [(ˈɛd.ʋɑɖ)].

The occurrence of the retroflex segments [ʈ, ɳ, ɭ, ʂ] in UEN is not as easily described in a foot account. Bisyllabic words such as [(ˈʋoː.ɭi)] and [(ˈpæː.ɭn̩)] or trisyllabic words such as [(ˈfiːɾ).(ˌfɪʂ.ɭə)] and *karneval* [(ˈkɑː.ɳə).(ˌvɑl)] 'carnival' suggest that retroflexion occurs foot-medial. Monosyllabic words such as [(kɑʈ)] or [(kɔʂ)], however, spoil the picture, as they have a retroflex in foot-final position. Furthermore, retroflexes occur also foot-initial in cases like [pæ.(ˈʂuːn)] 'person' or [(ˌpeː).(ˈʂeːɾ)] 'Per sees'. These contexts cannot be unified by reference to a foot position.

Thus, there is no prosodic category, neither coda nor foot position, that can account for the occurrence of retroflexes in UEN.

3.2 'Licensing by cue' account

Before showing that UEN retroflexes are dependent on cues, the phonetic cues of retroflexion have to be established. According to Stevens (1997), retroflex consonants are articulatorily characterized by a sublingual cavity that introduces a zero formant between the second and third formant transitions in the acoustic signal. This zero formant causes a clustering of second and third formants. As Ohala & Ohala (2001) point out, the raising of the second formant is typical for all constrictions made with the tongue tip or blade and depends very much on the vowel context. The lowered third formant, however, seems to be genuine to retroflex articulations. Retroflexes show a lowered F3 both in the VC and the CV transitions, i.e. both if a retroflex is preceded and if it is followed by a vowel. The degree of format lowering differs between the two positions, it is more prominent in VC cues (if a vowel precedes). Steriade (1995) argues that the VC cues for dentals and retroflexes differ strongly, whereas their CV cues are very similar. In his study on Gujarati, Dave (1977) found that the CV cues for retroflexes are still distinguishable from those of dentals but that they are very similar to those of velars. Whether CV cues of retroflexes are more similar to dentals or to velars is in fact not a point of importance here. Noticeable is that these cues are not sufficient to distinguish retroflex from other places of articulation, whereas VC cues are.

To distinguish between denti-alveolar and retroflex, the third formant is not a reliable cue in all contexts. In their study on Hindi, Ohala & Ohala (2001) found that there is a clear difference in VC cues for dental and retroflex in an /a/ vowel context. No difference occurs in an /i/ vowel context, where the transitions of F3 in VC are the same.

VC cues are not the only ones that distinguish retroflex from dental. Steriade (1995) also lists CV cues, burst spectrum, burst amplitude and VOT, but none of them is as prominent as the VC cues. Regarding the manner of articulation, further aspects have to be taken into account. Ohala & Ohala (2001) show that the inclusion of burst noise is essential for a proper identification of stops. Sonorants, on the other hand, have very strong internal cues such as friction spectrum, which make VC cues less important for sonorants than for stops, cf. Steriade (1995: 20).

Taking this information into account, the data in (1) - (3) can be described in the following way. Retroflexion in UEN (both in derived and non-derived environments) occurs after vowels only. This is in accordance with the prominence of VC cues for retroflex segments, as VC cues are only available to the listener if a vowel precedes a consonant.

Two exceptions to the postvocalic occurrence of retroflexes exist. The first are the retroflex fricatives in (3) and the retroflex laterals in (4). Both classes can occur word-initially independent of the preceding segment. As was shown in section 2, both laterals and fricatives differ diachronically from their post-vocalic counterparts, neither was a retroflex in former stages. Thus there could be a lexical explanation for these exceptions: as a result of simplifying the phoneme inventory, these segments became retroflex but did not change their phonotactic occurrence to that of retroflexes. These exceptions then were lexicalized. But there is also a cue explanation why only these retroflex manners can occur word-initial if no vowel precedes. Both fricatives and laterals have very strong internal cues: besides the transitional VC and CV cues, fricatives and laterals show cues such as friction noise or formants during the segment.

The second exception to the generalization that retroflexes in UEN occur post-vocalically are those retroflexes that emerge from progressive assimilation. But also this process retroflexion via progressive assimilation can be accounted for by the strong VC cues of retroflexes. Regressive spreading of place is cross-linguistically far more common than progressive assimilation marked.This observation is phonetically grounded in the fact that most places of articulation have strong CV cues,[8] which are only

[8] For the notion of phonetic grounding in phonology, see Archangeli & Pulleyblank (1994).

available for the second consonant in a sequence of two consonants. Therefore the place of the second consonant will spread onto the preceding one. Retroflexes, on the other hand, have prominent VC cues, like all apicals, and thus undergo progressive assimilation, see Steriade (1995, 2001) for a detailed discussion of this.

The exception to the progressive assimilation of retroflexes is again the fricative, which shows regressive assimilation. As shown above, this fricative stems historically from a postalveolar, and its regressive spreading might be a remnant of the phonological behaviour of the postalveolar which then was lexicalized.

Summing up, the prosodic account failed to cover the data on retroflexion in UEN, whereas licensing by cue can account for both the postvocalic occurrence and the regressive assimilation. Even the exceptional behaviour of retroflex laterals and fricatives that can occur in onset position can be accounted for when referring to the cues of this class.

4. Perceptual test of cues

In the perceptual test conducted in this study, dental and retroflex segments in intervocalic position were cross-spliced and presented to listeners who had to judge to which category these sounds belong.

According to Steriade's licensing by cue approach it was expected that the first half of a retroflex segment dominates the perception of the whole signal, whereas the second half is consistently ignored. Thus, the listeners were expected to classify the cross-spliced signal according to the place of articulation of the consonant occuring in the first half, not the second.

Section 4.1 describes the results of previous perception studies on retroflexes in Swedish and Hindi. In contrast to the present study, the signals in these tests were not cross-spliced. The implementation of the present test is described in section 4.2, and its results in 4.3.

4.1 Previous studies

Öhman (1966) tested all Swedish stops (including dentals and retroflexes) in the context of the vowel /a/. Listeners had to judge four types of signals; the whole, the VC part, the CV part, and the release only. In his test, the CV signals for retroflexes were perceived poorly. Öhman explains this with "the non-Swedish syllable structure of these utterances" (1966: 988),[9] but

[9] Gårding (1967) gives evidence for the fact that distributional cues can override phonetic ones. In her syllabification test for Swedish the burst cue of retroflexes is overridden by the distributional cue that retroflexes cannot occur syllable- or word-initial. "Being forced to divide a sequence such as [vaːʈoːr] into *var tår* or *vart år*, a listener will prefer the latter inasmuch as no words begin with [ʈ] and a large number end with it" (1967: 38).

the results could also be taken as evidence for the dominance of VC cues for retroflexes.

Krull (1990) constructed a test similar to Öhman's, she tested Swedish voiced stops only, with the same four types of signals. Her results are 11.8 percent misperception of retroflex VC signals as dental, whereas only 7.3 percent of the retroflex CV signals were miscategorized as dentals. This test seems to indicate that CV cues are slightly more reliable for retroflexes than their VC cues. Furthermore, Krull shows that the release alone is an insufficient cue for distinguishing the place of articulation, as on average 24 percent of the signals were misperceived in this condition.

Ahmed & Agrawal (1969) tested the perception of CVC words with all Hindi consonants. The words were presented to Hindi listeners as CV and VC signals. Their results show that CV cues are more reliable for retroflexes, as they yielded only one percent of misclassification, opposed to 7.5 percent of retroflex misclassification in VC condition.

Ohala & Ohala (2001) also tested Hindi, they used pVC syllables with the vowels [i, a, u] and the consonants [p, t̪, ʈ, tʃ, k]. The listeners were presented with the whole stimuli and with stimuli that were cut off before the release. Though their study cannot contribute to the question of the relevance of VC or CV cues for retroflexes, as they only tested VC cues, the results are interesting in two other respects. Firstly, Ohala & Ohala show that the stop burst is an important additional cue, as the correct classification for retroflexes and dentals dropped from an average of 84.9 percent to 66.4 percent when the release was cut off. Furthermore, the vowel context contributed largely to the classification task. In /a/ context, there was nearly no difference in performance for dental and retroflex in the cut-off signal, and in the whole signal they differed only slightly, as [t̪] was miscategorized as [ʈ] in 9.5 percent of the cases, cf. table 1.

The tables 1 and 2 give the presented signal in the first column and the listeners categorization in the first row. Shaded fields indicate the correct responses.[10] The left half of all the following tables always presents the results for the whole signal condition, the right half those of the shortened signals.

/a/, whole	t̪	ʈ	/a/, shortened	t̪	ʈ
t̪	90.5	9.5		81.0	6.3
ʈ	0.0	95.2		6.3	87.3

Table 1. Confusion matrix (in percent) for stops in an /a/ context.

[10] The columns in this and the following table do not add up to 100%, as the listeners had further choices of place of articulation, which are not included here.

For the /i/ context, there was an asymmetry in the perception of the whole signals in Ohala & Ohala's results. Whereas the retroflex was never misclassified as dental, the dental was misclassified in 23.8 percent of the cases. The shortened signals provided totally different results. Correct identification was with 36.5 percent lower than chance. Interestingly, the retroflex was classified as dental in 39.7% of the cases, cf. table 2.

/i/, whole	t	ʈ	/i/, shortened	t	ʈ
t	71.4	23.8		36.5	6.3
ʈ	0.0	92.1		39.7	36.5

Table 2. Confusion matrix for stops in an /i/ context.

From this one can conclude that the VC cues for retroflexes are less distinguishable from the dental in an /i/ context, which leads to a poor classification in cases where additional information such as the burst is missing.

Summing up the studies, there is a large inconsistency in the results. Only Öhman (1966) suggests the dominance of VC cues, whereas the results of Krull (1990) and Ahmed & Agrawal (1969) indicate the dominance of CV cues. These results are not language-related, as the two opposing results for the tests on Swedish (Öhman 1966; Krull 1990) show. Ohala & Ohala (2001) indicate the necessity of the burst for correctly identifying a stop. Furthermore, they point out a vowel-dependence of transitional cues, which will be relevant for the following evaluation.

4.2 Implementation of the present study

A male, native speaker of UEN was recorded reading a list of nonce V_1CV_1 words where the consonants were [t, ʈ, n, ɳ] and the vowels [i] and [a] respectively. Word pairs with a retroflex and a denti-alveolar in the same manner and the same vowel context were then manipulated (with the PRAAT programme) to have the same pitch and same length of consonant and vowel. The word pairs were then cross-spliced; the first half of one word (cut in the middle of the consonant, i.e. before the burst for the plosives) was paired with the second half of the other and vice versa. In addition to these signals, further versions without release and following vowel were generated. This resulted in the following stimuli, cf. (8), where the first row lists the whole stimuli and the second the shortened ones.

(8) aʈta, atʈa, aɳna, anɳa, iʈti, itʈi, iɳni, inɳi
aʈt˺, atʈ˺, aɳn, anɳ, iʈt˺, itʈ˺, iɳn, inɳ

The stimuli in (8) were grouped according to the vowel context and manner of articulation, yielding four stimuli groups. Each group contained four repetitions of each stimulus in randomized order. These stimuli were played to six Norwegian and six German native speakers. All listeners had a short training session before each group to familiarize themselves with the denti-alveolar – retroflex contrast. This training session was particularly important for the German speakers, as German has no retroflex segments. Presented with a signal over headphones, the listener had to indicate whether this signal sounded like a denti-alveolar, a retroflex, or neither (to exclude forced choice).

4.3 Results of the perception experiment

The results of the present study for the voiceless plosive in an /a/ context judged by Norwegian listeners are presented in table 3. As in the previous two tables, the first column gives the signal presented to the listeners, and the first row the resulting categorization. The shaded columns indicate the expected answer, assuming VC cues are more prominent. The third answer column stands for ‘neither’.

/a/, whole	t	ʈ	∅	/a/, shortened	t	ʈ	∅
tʈ	90	10	0		100	0	0
ʈt	0	100	0		0	100	0

Table 3. Confusion matrix (in percent) for stops in an /a/ context, Norwegian subjects.

The results correspond strongly with the expectations, i.e. the VC cues for both whole and shortened signals determine the classification. In the whole signal condition, the retroflex burst influences the categorization (10 percent of the tʈ˺ signals were classified as retroflex), whereas the denti-alveolar burst does not have any influence at all (all ʈt˺ signals were categorized as retroflex). This is in accordance with Ohala & Ohala’s (2001) findings for non-cross-spliced signals.

The results of the German subjects in an /a/ context are presented in table 4.

/a/, whole	t	ʈ	∅	/a/, shortened	t	ʈ	∅
tʈ	71.4	28.6	0		100	0	0
ʈt	28.6	71.4	0		14.3	80.9	4.8

Table 4. Confusion matrix for stops in an /a/ context, German subjects.

The German subjects are influenced by the presence of the CV cues and the burst in both denti-alveolar and retroflex cases, as 28.6 percent of the signals are classified according to these cues. In signals with missing burst, the denti-alveolar VC cues always dominates the perception. The retroflex VC cues however are not perceptually strong enough to mask the contradictory information of the denti-alveolar cues. This lead the listeners in 14.3 percent of the cases to select 'denti-alveolar' and in 4.8 percent to select 'neither' as answers.

The responses to stop signals in an /i/ context are presented in tables 5 and 6. In table 5, the results for the Norwegian listeners are given. The categorization is rather clear for the shortened signals (right part of the table 5), but the whole signals (left part) yielded some confusion. Though the retroflex – denti-alveolar signal is never perceived as denti-alveolar, it is classified as 'neither' in 20 percent of the cases. The denti-alveolar – retroflex signal is classified as retroflex and 'neither' in 13.3 percent of the cases, each.

/i/, whole	t	ʈ	∅	/i/, shortened	t	ʈ	∅
tʈ	73.3	13.3	13.3		90	10	0
ʈt	0	80	20		0	100	0

Table 5. Confusion matrix for stops in an /i/ context, Norwegian subjects.

Thus, the Norwegian listeners in the present study perform similar to Ohala & Ohala's (2001) Hindi speakers with respect to the whole signal in an /i/ context. That the results for the Norwegian subjects in the shortened signals are more in accordance with the expected performance than for the whole signal is however not in conformity with Ohala & Ohala's findings. A reason for this difference is that in the present study the burst yielded contradictory information on the place of articulation, so its lack actually simplified the categorization task.

The results for the German listeners are given in table 6. They show clearly that the /i/ vowel context makes the distinction between retroflex and denti-alveolar VC cues more difficult. Like the Norwegian subjects, they classify more consistently when the burst is missing from the signal.

/i/, whole	t	ʈ	∅	/i/,shortened	t	ʈ	∅
tʈ	47.6	52.4	0		71.4	28.6	0
ʈt	28.6	61.4	10		19.0	76.2	4.8

Table 6. Confusion matrix for stops in an /i/ context, German subjects.

The responses to nasal signals are presented in the following tables. The signals in an /a/ context judged by Norwegian listeners, cf. table 7, show a clear dominance of retroflex VC cues in both conditions (see lower row), but the denti-alveolar VC cues are overridden by the cues of the retroflex, especially if the CV transitions are given (see upper row).

/a/, whole	n	ɳ	∅	/a/, shortened	n	ɳ	∅
nɳ	54	46	0		80	20	0
ɳn	0	100	0		0	100	0

Table 7. Confusion matrix for nasals in an /a/ context, Norwegian subjects.

German listeners are also strongly influenced by the retroflex VC cues, but they took the information of the denti-alveolar VC cues slightly more into consideration than the Norwegian listeners, see the higher percentage for denti-alveolars in the first row of table 8 compared to table 7.

/a/, whole	n	ɳ	∅	/a/, shortened	n	ɳ	∅
nɳ	57.1	38.1	4.8		85.7	14.3	0
ɳn	14.3	85.7	0		14.3	85.7	0

Table 8. Confusion matrix for nasals in an /a/ context, German subjects.

The general result for nasals in an /a/ context differs from that for stops in the same context, in as far as the VC cues are less dominant. This is probably due to the strong internal cues of nasals, which give contradictory information of two places of articulation to the listener.

Surprisingly, the results for nasals in an /i/ context correspond more to the expectations, see tables 9 and 10. For the Norwegian subjects, the retroflex cues influence the categorization more than the denti-alveolar cues. In table 9, the classification of the [ɳn] signal is 100 percent retroflex in both the whole and the shortened context. The [nɳ] signal is classified as denti-alveolar in 66.7 percent of the whole signals and in 53.3 percent of the shortened signals.

/i/, whole	n	ɳ	∅	/i/, shortened	n	ɳ	∅
nɳ	66.7	13.3	0		53.3	20	26.7
ɳn	0	100	0		0	100	0

Table 9. Confusion matrix for nasals in an /i/ context, Norwegian subjects.

The German listeners are more influenced by the VC for both denti-alveolars and retroflexes in the /i/ context than in the /a/ context, compare table 10 to table 8.

/i/, whole	n	ɳ	∅	/i/, shortened	n	ɳ	∅
nɳ	95.2	4.8	0		90.5	9.5	0
ɳn	4.8	80.9	14.3		14.3	76.2	9.5

Table 10. Confusion matrix for nasals in an /i/ context, German subjects.

Comparing the influence of the VC cues with that of the CV cues in the whole experiment, a clear result emerges. Norwegian listeners always classify retroflex – denti-alveolar signals as retroflex, thus they are strongly influenced by retroflex VC cues. The German subjects perform slightly differently. They do not always classify a signal with retroflex VC cues as retroflex but are influenced by the denti-alveolar CV cues in 17.2 percent of the cases. This different performance indicates that the Norwegian subjects are more trained to focus on the VC cues. This focus is probably due to their phonological knowledge on the occurrence of retroflexes in post-vocalic position, which provides these VC cues. When presented with a signal with retroflex VC cues, the contradicting CV cues are overridden for Norwegian subjects.

Denti-alveolar VC cues are dominated by retroflex CV cues in 8.33 percent of the stop cases for Norwegian subjects. In sum, the Norwegian listeners clearly attest the dominance of VC cues for both retroflexes and denti-alveolars compared to the respective CV cues.

The German subjects show a dominance of retroflex CV cues over denti-alveolar VC cues in 27.4 percent. This result might indicate that denti-alveolar VC cues are not as strong as retroflex CV cues for this subject group. But it could also indicate that German listeners are simply less trained in distinguishing the two categories, and thus perform by chance.

When the contradicting information from burst and following vowel is lacking in the presented signals, this generally raises the number of expected answers by 13.4 percent, with the only exception being the nasal front vowel context, were it drops by 5.7 percent.

Between stop and nasal signals there is no difference, the results for stops generally corresponded in 82.0 percent of the cases to the expectations, whereas the nasals did so in 81.9 percent of the cases.

The vowel context has some impact on the results. Generally, the results rise compared to the expectations from 78.9 percent for an /i/ context to 85.12 percent for an /a/ context. The nasals are less influenced by the vowel context because of their strong internal cues.

5. Conclusion

Section 3 provided evidence for the fact that the licensing by cue approach can account better for the occurrence of retroflex segments in UEN than a prosodic approach: the prominent VC cues of retroflexes and the strong internal cues of fricatives and laterals can correctly predict retroflex phonotactics in UEN. No prosodic category, however, can combine their sites of occurrence.

The perception test conducted in this study attested the dominance of VC cues in perception, for both retroflexes and dentals. Not only Norwegian native speakers, who might have been guided by their phonological knowledge on the occurrence restriction on retroflex segments, categorized a cross-spliced signal as retroflex if the VC cues were retroflex. German native speakers, who do not have any phonological knowledge on retroflexion, performed similarly.[11] The perception experiment further showed that in a high front vowel context denti-alveolars and retroflexes are easily confused, and further cues are necessary for a correct categorization.

Future studies on the perception of cross-spliced retroflex segments should test different modi. Fricative signals seem to be of special interest, as they have very dominant internal cues that are not context-sensitive. An inclusion of velars could furthermore test the claim that velars and retroflexes have similar CV cues.

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[11] Ove Lorentz pointed out to me that both the German and the Norwegian listeners have probably been exposed to the retroflex vowels in English (like the one in *bird*). This could influence their preferential perception of a retroflex in a postvocalic position.

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