The phonetics and phonology of Dutch mid vowels before /l/

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Abstract

This paper addresses the claim that Dutch /l/ triggers laxing of preceding tense mid vowels (/e ø o/), and that this leads to a phonetic length contrast between tense and lax vowels, e.g., tense speel [spɪːɫ] *'play' vs. lax* spil [spɪɫ] *'pivot'. The production experiment reported in this paper shows that this claim is incorrect. We find instead that /l/ triggers retraction of both tense and lax mid vowels, which leads neither to complete neutralization of quality nor to complete neutralization of length.*

1. Introduction

Gick and Wilson (2006) observe that a sequence of a high tense vowel and a dark liquid involves an 'articulatory conflict' between an advanced dorso-lingual target for the vowel and a retracted target for the liquid. According to Gick and Wilson, languages may select one of two strategies to resolve this conflict, viz. schwa excrescence (for this term, see also Levin 1987; Hall 2006; Botma et al. 2008) and laxing. The former strategy is found in many varieties of English, where the realization of words like *feel* and *fire* results in the percept of an intervening schwa, giving listeners the impression of an extra syllable or half-syllable (i.e., *feel* [fiəɫ], *fire* [faɪəɹ]). The latter strategy has been claimed to occur in Pittsburgh English, where laxing of /iː uː/ before dark /l r/ and /g/ has apparently led to neutralization of such pairs as *feel* and *fill*, which are both realized as [fɪɫ] (Walsh-Dickey 1997). Laxing thus resolves the articulatory conflict by reducing or eliminating the advanced target of the vowel (cf. Gick and Wilson 2006: 634).

According to some descriptions in the phonological literature, Dutch is another example of a laxing language. The transcriptions used in, e.g., van Oostendorp (2000) and van der Torre (2003) suggest that before dark /l r/, the Dutch tense mid vowels /e ø o/ undergo qualitative neutralization with their lax counterparts /ɪ ʏ ɔ/, with the contrast between the two sets of vowels realized in terms of length (e.g., tense *speel* [spɪːɫ] 'play' vs. lax *spil* [spɪɫ] 'pivot'). This interpretation of laxing is

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i			y				u
	e	<u>ɪ</u>		ø	<u>ʏ</u>	o	<u>ɔ</u>
		<u>ɛ</u>					
			a	<u>ɑ</u>			

Figure 1. *Dutch tense and lax vowels.*

made against the backdrop of a phonological analysis of the Dutch vowel system in which the underlying contrast in monophthongs is one of tense vs. lax (see, e.g., Smith et al. 1989; van Oostendorp 1995, 2000; van der Torre 2003; Gussenhoven 2009), as in Figure 1 (lax vowels are underlined). A couple of comments are in order regarding Figure 1. First, the non-high tense vowels /e ø o a/ are phonetically long (i.e., [eː øː oː aː]) and /e ø o/ are diphthongized (i.e., [e^{i}ː ø^{y}ː o^{u}ː]), at least in Standard Dutch (e.g., Van de Velde 1996; Smakman 2006). The high tense vowels /i y u/ are usually described as 'half-long' (e.g., Cohen et al. 1963; Nooteboom 1972; Rietveld and van Heuven 2009), except before /r/, where they are long (e.g., Gussenhoven 1993, 2009). Second, /ɪ/ is classified as a mid vowel, for phonetic and phonological reasons. Phonetically, the vowel quality (F1, F2) of /ɪ/ is similar to that of /e/. Indeed, Slis (1963) observes that shortened, non-diphthongized versions of /e/ are frequently misperceived as /ɪ/; this is also supported by the results of our perception experiment (see Section 4). For phonological arguments for the mid-vowel status of /ɪ/, see Levelt (1994) and van Oostendorp (2000).

Some examples of contrasting tense and lax mid vowels are given in (1), where, following the sources cited above, we transcribe tense /e ø o/ as phonetically long and diphthongized (1a), and lax /ɪ ʏ ɔ/ as short and non-diphthongized (1b).

(1)	a.	streep	/strep/	[stre^{i}ːp]	'stripe'	b.	strip	/strɪp/	[strɪp]	'strip'
		keus	/køs/	[kø^{y}ːs]	'choice'		kus	/kʏs/	[kʏs]	'kiss'
		rook	/rok/	[ro^{u}ːk]	'smoke'		rok	/rɔk/	[rɔk]	'skirt'

Matters are less straightforward in the context of a following liquid. Van Oostendorp (2000: 85–86) states that before /r/, tense /e ø o/ are realized as [ɪː ʏː ɔː], as in (2).[1]

(2)	beer	/ber/	[bɪːr]	'bear'
	kleur	/klør/	[klʏːr]	'colour'
	stoor	/stor/	[stɔːr]	'disturb'

Similarly, van der Torre (2003: 22) provides such forms as in (3), where an underlyingly tense mid vowel precedes syllable-final dark /l/.

(3)	veel	/vel/	[vɪːɫ]	'many'
	geul	/xøl/	[xʏːɫ]	'ditch'
	pool	/pol/	[pɔːɫ]	'pole'

Implicit in these transcriptions is the claim that laxing leads to neutralization of the qualitative contrast, and that the distinction between tense and lax vowels before /l r/ is realized as a length contrast instead, with the underlyingly tense vowels being longer than the lax ones.

This account raises at least two questions. The first is that a phonetic length contrast would be unexpected if, as van Oostendorp and van der Torre assume, the underlying contrast in vowels is one of tense vs. lax (with the non-high tense vowels predictably long, and the lax vowels predictably short). Given the data in (2) and (3), such an analysis must account for the fact that the relationship between length and quality is apparently not surface-true. The second, more basic, question is whether the transcriptions in (2) and (3) are phonetically justified. The problem here is that phonological approaches to the Dutch vowel system have been less than explicit about the phonetic characteristics of laxing, nor have they been very clear about the correlates of the terms 'tense' and 'lax' themselves.

Focussing on mid-vowel colouring before /l/, and in particular on the vowel pair /e/-/ɪ/, this paper describes the results of a production experiment which attempts to address this problem. The results of the experiment suggest that, for Dutch at least, the term pre-/l/ laxing is a misnomer. The phenomenon can be more appropriately termed retraction, and affects tense and lax vowels alike. The results further show that tense and lax mid vowels before /l/ are subject to substantial but incomplete neutralization of both quality and length. This leads us to conclude that transcriptions such as tense *speel* [spɪːɫ] 'play' vs. lax *spil* [spɪɫ] 'pivot' are incorrect.

The paper is organized as follows. Section 2 outlines the main arguments that have been advanced for a tense/lax approach to the Dutch vowel system and examines briefly the problematic status of the labels 'tense' and 'lax'. We suggest that tenseness can be reasonably described in terms of relative peripherality (vs. centrality). Section 3 describes the results of a production experiment that was carried out to ascertain the phonetic characteristics (F1, F2 values and duration) of the effect of /l/ on mid vowels. Section 4 describes the results of a perception experiment that was carried out to ascertain the extent to which pre-/l/ retraction in *speel*-*spil* pairs leads to neutralization of tense and lax mid vowels. Section 5 concludes and offers directions for further research.

2. The tense/lax approach to the Dutch vowel system

2.1. *Phonological arguments for a tense/lax approach*

A long-standing issue in the phonology of Dutch concerns the nature of the phonological contrast in vowels. As was noted in Section 1, Dutch monophthongs display a phonetic correlation between tenseness and length, such that non-high tense vowels are long and all lax vowels are short. The traditional position in the generative literature is that the underlying contrast is one of length, which is supported by the observation that tense/long vowels pattern with diphthongs (e.g., Zonneveld 1978; Booij 1995). Both can occur in stressed word-final open syllables (4a), while lax/short vowels cannot (4b):

(4)	a.	la	/la/	‘drawer’	b.	*/lɑ/
		kei	/kɛi/	‘cobble’		*/kɛ/

In addition, both tense/long vowels and diphthongs can be followed by at most one non-coronal consonant in word-final position (5a), while lax vowels can be followed by two consonants in this context (5b):

(5)	a.	raap	/rap/	‘turnip’	(*/ramp/)	b.	rap	/rɑp/	‘quick’
		rijp	/rɛip/	‘ripe’	(*/rɛimp/)		ramp	/rɑmp/	‘disaster’

For discussion of this asymmetry, see van Oostendorp (2000) and references therein.

Despite these observations, some analyses take the underlying contrast in the Dutch vowel system to be one of tense vs. lax. Van Oostendorp notes that such an analysis is supported by evidence from stress assignment, syllable markedness, and vowel typology. First, the pattern of stress assignment in Dutch suggests that closed syllables count as heavy while open syllables count as light. If vowels in light syllables, which are necessarily tense/long, are treated as phonologically long, then Dutch would violate the universal that quantity-sensitive stress systems always treat CVV syllables as heavy (e.g., Hayes 1995). Second, from the perspective of markedness, the problem with a length-based account is that Dutch would then lack the universally unmarked CV syllable type, given that lax vowels (in word-final position at least) are obligatorily followed by a consonant (cf. [4b]). Third, an analysis in terms of underlying length would imply that Dutch has more long than short vowels in its inventory. This, too, would be unexpected from the perspective of markedness. Indeed, as van Oostendorp observes, the distributional generalization in (4) is the *only* argument for underlying length – but this generalization, he argues, can also be captured by the condition that lax vowels be contained in a branching rhyme.

A further problem with underlying length concerns the status of what Smith et al. (1989) call the ‘French’ (i.e., non-native) tense and lax vowels, viz. /iː yː uː/ and /ɛː œː ɔː/. These vowels are marginal; they occur in superheavy syllables and penultimate syllables preceding schwa only, as in (6a) (data from van Oostendorp 2000: 123):

(6)	a.	expert	[ɛk'spɛːr]	‘expert’
		controle	[kɔn'trɔːlə]	‘check’
	b.	expertise	[ɛkspɛr'tiːzə]	‘expertise’
		controleer	[kɔntro'lɪːr]	‘check-1SG-PRES’

The French vowels in (6a) occur under primary stress only. In the absence of primary stress, for example when an autostressed suffix is added, as in (6b), they are realized as short tense or lax, depending on whether they occur in an open or closed syllable. Following van Oostendorp and Smith et al., we assume that the French vowels are most appropriately analysed as phonologically long. This would also explain why these vowels attract stress.

In what follows, we restrict our attention to the native Dutch vowels; however, notice that an analysis of the French vowels as underlyingly long would seem to rule out a similar analysis for the native tense vowels.

2.2. *Phonetic correlates of 'tense' and 'lax'*

In Section 2.1, we considered a number of phonological arguments in favour of a tense/lax analysis of the Dutch vowel system, but sidestepped what is perhaps the most problematic aspect of this approach, viz. the phonetic underpinnings of tenseness. Phonologists working on Dutch have tended to take an agnostic view on this. This seems justified to the extent that, phonologically, the key observation is that Dutch has two sets of vowels with different behaviour – an observation which holds irrespective of the vowels' exponence. Nevertheless, it is clear that a tense/lax analysis of the Dutch vowel system would gain support if the labels 'tense' and 'lax' were grounded in phonetics.

In this section, we suggest that, for Dutch at least, a feasible articulatory characterization of tense and lax vowels is in terms of relative peripherality, such that lax vowels are less peripheral, i.e., more centralized, than tense ones (see also Lindau 1979; Harris & Lindsey 1995). Compare in this respect the formant frequencies (F1, F2) of the tense and lax vowels as measured by van Nierop et al. (1973) in Figure 2 (lax vowels are represented in boxes). Given Figure 2, we suggest that the lax vowels of Dutch are closer to what we hypothesize is the 'neutral position' of the vocal tract. For the (female) speakers investigated by van Nierop et al., this position would be characterized acoustically by the vowel space in the region of around 650 Hz (F1) and 1500 Hz (F2).[2] This corresponds reasonably well to part of the articulatory definition of tenseness in Chomsky and Halle (1968: 324–325), who assert that, as compared to lax vowels, tense vowels "are executed with a greater deviation from the neutral or rest position of the vocal tract", and that "the greater articulatory effort in the tense vowels is . . . manifested by their greater distinctiveness and the markedly longer duration during which the articulatory configuration remains stationary".[3] While no consistent correlate of this increased effort has been found, at least not for English (cf., e.g., Durand 2005), we believe that the first part of Chomsky and Halle's definition – tense vowels having a greater deviation from the neutral position – is appropriate for Dutch.[4]

An account in terms of relative peripherality has been criticized on the grounds that this would make tenseness the only phonological feature whose exponence is defined in relative terms (cf. van Oostendorp 2000). However, this does not appear

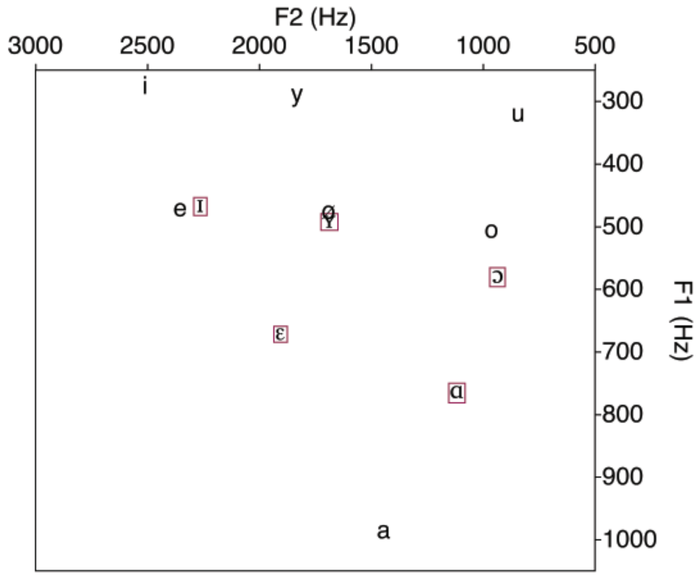

Figure 2. *Dutch tense and lax vowels (adapted from van Nierop et al. 1973).*

to be a problem in the type of approach assumed in Harris & Lindsey (1995), where the representation of vowels includes a 'centrality' element that is more prominent in lax vowels than in tense ones, with relative prominence formalized in terms of head/dependency relations (which are also used to encode other contrasts, e.g., that between high-mid and low-mid vowels). What is clear, however, is that our account requires a more precise characterization of the notion of 'neutral position' than is offered in this paper. Here we note only that this position is unlikely to correlate with schwa, whose acoustic signature varies greatly according to the phonetic context in any case, but which we expect is on average higher in the vowel space than the neutral position.

This problem notwithstanding, we believe that an account in terms of relative peripherality is more appropriate than one which subsumes tenseness under the feature 'advanced tongue root', or [ATR] (e.g., Stewart 1967; Halle and Stevens 1967; Perkell 1971; for Dutch, see Smith et al. 1989). As is shown by MacKay (1977), tense vowels in English are not necessarily produced with an advanced tongue root; the best that can be said is that they show tongue-root advancement as compared to lax vowels with the same height and frontness. MacKay further observes that English /o/ is realized with tongue-root retraction, even though it patterns as tense. The relation between tongue-root advancement and tenseness is also tenuous in German, where /ɪ/ involves a greater degree of tongue-root advancement than /i/ (Ladefoged and Maddieson 1996). More generally, Ladefoged and Maddieson observe that the nature of tongue-root advancement in English and

German differs from that in West African languages like Akan and Igbo, for which [ATR] was originally proposed. Tongue-root position is a separately controlled variable in Akan and Igbo (both languages display ATR-harmony) but not in English, where it is correlated with tongue height.

While we do not know of any X-ray tracings or ultrasound images contrasting Dutch tense and lax vowels, we believe that there are good grounds to be suspicious of accounts which implicate the tongue root. Examples of such accounts are Smith et al. (1989), where tense vowels are specified in terms of [ATR] (which is assumed to correlate with pharyngeal expansion) and van Oostendorp (2000), where the feature [lax] correlates with tongue-root retraction. However, notice that the formant values in Figure 2 do not provide any evidence for what is considered to be the main correlate of tongue-root involvement, viz. a change in F1 (the same is true of our own formant measurements; see Section 3). In addition, any approach that implicates the tongue root is at pains to explain why, in non-high vowels, it is the tense series that is phonetically long. As far as we know, there is no intrinsic relation between tongue-root advancement and increased duration. On the other hand, if tense vowels involve a greater articulatory deviation from the neutral position than lax ones, their greater length would seem to follow from this.

2.3. *Summary and research questions*

We have seen that there are good phonological grounds for taking the underlying contrast in the Dutch vowel system to be between a series of tense vowels and a series of lax ones. We have also seen that the phonetic exponence of tenseness is a matter of contention. Rather than assume a correlation between tenseness and tongue-root advancement, for which there is little support, we suggest that the lax vowels of Dutch are closer to the neutral position of the vocal tract than their tense congeners. If so, the ‘laxing’ of tense /e ø o/ before /l/ as suggested in the phonological literature should involve centralization of these vowels, causing them to overlap with their lax counterparts /ɪ ʏ ɔ/. This then leads to the following research questions:

(i) Do tense mid vowels undergo laxing before /l/? Specifically:
   - Is there qualitative neutralization to the corresponding lax vowels?
   - Is the tense/lax contrast before /l/ expressed by length?
   - Are there any differences between speakers in their production strategies?

(ii) What is the relationship between production and perception? Specifically:
   - If there is neutralization, then how does this affect the ability of listeners to differentiate between tense and lax vowels?
   - If there are differences between speakers in their production strategies, then how does this affect the ability of listeners to differentiate between tense and lax vowels?

Section 3 describes the details of a production experiment that was carried out to answer (i). Section 4 presents the results of a perception experiment that addresses (ii).

3. Production experiment

3.1. *Methodological background*

3.1.1. *Speakers* 15 female speakers of Dutch between the ages of 18 and 24, all of whom were students majoring in English Language and Culture at the University of Leiden, were recorded for the experiment. Most of them were raised in the province of South Holland, which is part of the area in the Netherlands where the largest cities are, The Hague and Rotterdam in particular. None of the speakers spoke with any obvious regional or other marked features, and their accents could be classified as Standard Dutch according to the criteria in Smakman (2006). A single-sex group of speakers facilitates comparison as it largely obviates vowel normalization (Adank 2003); any inter-speaker differences are also filtered out by the incorporation of speaker as a random effect within the statistical model (see Section 3.2). A further reason for limiting the speaker group to women is that female speakers are generally more inclined to speak a prestige variant (e.g., Fischer 1958; Romaine 1978), in our case Standard Dutch.

3.1.2. *Recording quality* The recordings were made in the digital language laboratory of the University of Leiden, using Sanako Lab 250 software. They were saved as mp3 files (256 kbps, 44.1 kHz) and later converted to .wav files. Formant measurements on decompressed speech recordings with an original bitrate higher than 192 kbps deviate only minimally from CD quality audio recordings (van Son 2005). The subjects were recorded in booths set off by soundproof screens, and a maximum of 9 students were recorded at a time. To reduce interference from other subjects during the reading task, one booth was left empty between speakers.

3.1.3. *Phonetic/phonological context of vowels* Vowels were measured in stressed syllables, in both single-syllable and two-syllable words. The speakers read 25 carrier sentences (each containing one of the relevant words) in 9 different, randomized orders, of the form *Ik ga nu het woord* [. . .] *zeggen* (‘I will now say the word [. . .]’). The words in question were existing Dutch words containing one of the six vowels under investigation (/e ø o ɪ ʏ ɔ/) followed by /l/ or /s/, or one of the peripheral vowels (/i u a/) followed by /t/. The peripheral vowels were included to measure the boundaries of the vowel space for each speaker; the other vowels were described in relation to these vowels. In addition to the test items, the word list contained 7 distracters. All speakers produced three repetitions of the full word list, yielding three tokens of each word per speaker. The list of items is given in Table 1.[5]

Table 1. *Vowel types and their phonetic/phonological contexts.*

Vowel category	IPA	-Vs/-Vt	-Vl	-Vlən
tense mid vowels	/e/	*Kees*	*speel*	*spelen*
	/ø/	*keus*	*peul*	*peulen*
	/o/	*Koos*	*pool*	*Polen*
lax mid vowels	/ɪ/	*mis*	*spil*	
	/ʏ/	*mus*	*pul*	
	/ɔ/	*mos*	*pol*	
peripheral vowels	/i/	*Piet*		
	/u/	*moet*		
	/a/	*maat*		

3.1.4. *Isolating vowels* Using Praat (Boersma and Weenink 2008), the vowels of all obstruent-final words were extracted from running speech and saved as separate files. The same was done with the vowel+/l/ sequences in words where /l/ was syllable-final. Given that there is considerable co-articulation between a vowel and a following dark /l/, no attempt at segmentation was made, as this would have involved too high a degree of arbitrariness. Acoustic information of surrounding segments was removed, e.g., the release burst of a preceding /k/ or /p/. (Since most of the preceding consonants were labial, lingual co-articulation effects were negligible.) Where formant transitions were clearly visible (e.g., in /m/-initial words), the segmentation was done at the end of the transition. Figure 3 shows a sample image of a segmented vowel token (/ø/ in *keus*).

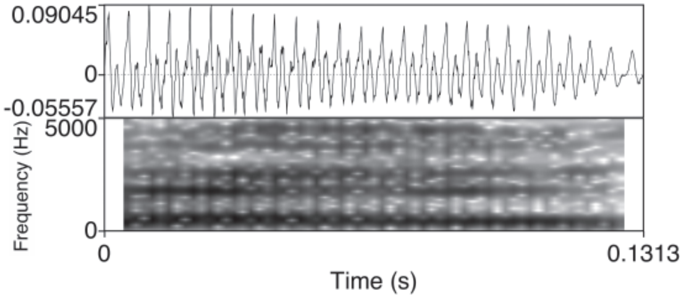

Figure 3. *Sample image of a segmented vowel token (/ø/ in* keus*).*

3.1.5. *Selection of formant measurements* Formant measurements were used to characterize the vowels of the closed-syllable words (i.e., all items in Table 1 except those in the rightmost column). We restricted our attention to F1 and F2, as these are the main acoustic correlates of vowel quality, and sufficient for plotting the vowels in a two-dimensional space (e.g., Pols et al. 1973; Deterding 1997).

Acoustic measurements were done using Praat. F1 and F2 values were automatically extracted at three equidistant points of the vowel or vowel+/l/ sequence, using the Burg algorithm (default settings: time step: 0.0; max number of formants: 5; max formant = 5500 Hz; window length = 25 ms; pre-emphasis = 50 Hz). In addition, the total durations of all vowels and vowel+/l/ sequences were measured. A second script, run on the vowel+/l/ sequences only, measured the formant values at nine equidistant time points. In both sets of measurements, not all time points returned results. For the shortest vowels (target vowels /ɪ ʏ ɔ/ and the peripheral vowels /i u/) in the pre-obstruent condition, only the measurement at 50% of the vowel's duration was used for analysis, as the measurements at 25% and 75% were usually missing or, if present, proved unreliable owing to the proximity of the preceding/final consonant. For all vowels in the pre-/l/ condition, the measurements at points 1 and 9 (10% and 90% into the vowel+/l/ sequence) did not return results, as their proximity to the neighbouring consonant/pause made them too weak for reliable detection.

In view of this, it was decided to use the measurements at 50% (midpoint) of /e ø o/ and /a/ in pre-obstruent context only, as these correspond most closely to those of the short vowels (where, as noted, only the midpoint measurements were reliable in this context). For the vowel+/l/ sequences the formant measurements at 25% were used, as these correspond most closely with the midpoint of the vowel (the measurements at 50% corresponded to the transition between the vowel and the liquid; the measurements at 75% represented formant values well into the /l/).

All 15 speakers produced 3 repetitions of the 18 target items, yielding a total of 810 vowel and vowel+/l/ tokens. All 810 duration measurements were successful, as were all but 23 of the 1,620 formant value measurements. In 10 cases, Praat did not return a result for either the F1, F2, or both; in an additional 13 cases, post-screening revealed measurement errors. The 23 unsuccessful measurements were either manually corrected on the basis of visual inspection of the spectrograms, or discarded. For more information on the relevant tokens, see Appendix 1. Eventually, 12 tokens were discarded altogether, yielding a total of 798 in the dataset.

3.2. *Results*

3.2.1. *Formant measurements* The F1 and F2 values (in Hz) of the vowel and vowel+/l/ tokens are shown in Table 2. The percentages reflect the points in time at which the measurements were taken (as a percentage of the total duration of the vowel or vowel+/l/sequence). Included in the table, and in the analysis below, are the mid vowels before obstruents and the vowel+/l/ sequences in the /l/-final (single-syllable) words. This subset of the data consists of 528 tokens (15 speakers × 3 repetitions × 12 items, minus the 12 discarded tokens). We observe in Table 2 that dark /l/ conditions a substantial difference in the F2 of a preceding vowel, which in the pre-/l/ tokens is systematically lower by some 150–500 Hz.

Table 2. *Average F1 and F2 of /e ø o ɪ ʏ ɔ/ in pre-obstruent and pre-/l/ context (means).*

Vowel	Item	F1		F2	
		mean	stdev	mean	stdev
/e/	*speel* (25%)	461	50	2125	201
	Kees (50%)	456	50	2463	157
/ɪ/	*spil* (25%)	483	50	1834	157
	mis (50%)	468	72	2342	172
/ø/	*peul* (25%)	481	53	1526	125
	keus (50%)	478	57	1831	140
/ʏ/	*pul* (25%)	469	44	1371	156
	mus (50%)	462	69	1832	164
/o/	*pool* (25%)	469	32	805	115
	Koos (50%)	487	59	1085	121
/ɔ/	*pol* (25%)	472	39	806	67
	mos (50%)	532	74	963	107

Table 3. *Summary of effects. Coefficients refer to the log odds of the following sound being an /l/. Number of observations: 528.*

Fixed effect	Estimate	Standard error	*z*-value	*p*-value
F1 (Hz)	0.006	0.01	0.96	0.338
F2 (Hz)	−0.001	0.00	−2.60	0.009
Duration (ms)	137.53	14.91	9.22	0.000
Random effect	**Variance**	**Standard deviation**	**N**	
Speaker	8.69	2.95	15	

This is in line with the cross-linguistically observed effect of dark /l/ on preceding vowels (e.g., Ladefoged and Maddieson 1996). Table 2 further shows that differences in F1 are minor and much less systematic.

A statistical analysis was performed using the lme4 package (Bates and Maechler 2008) in R, version 2.13.1 (R Development Core Team 2008). A generalized linear mixed-effects model was fitted to the data, the response variable being whether the following sound is an obstruent or /l/. The effect of speaker was treated as random, and the fixed effects in the model were F1, F2, and duration. Table 3 presents a summary of the model. While there is no effect of F1, F2 is significantly lower before /l/ than before obstruents. In the process of modelling, differences in F1 and F2 were also considered within individual vowels, but no significant interactions were found (i.e., F1 and F2 differences are similar for all vowels). Notice also that length differences are not meaningful here, since the relevant measurements were done on differently sized portions of the speech string, viz. vowel-only vs.

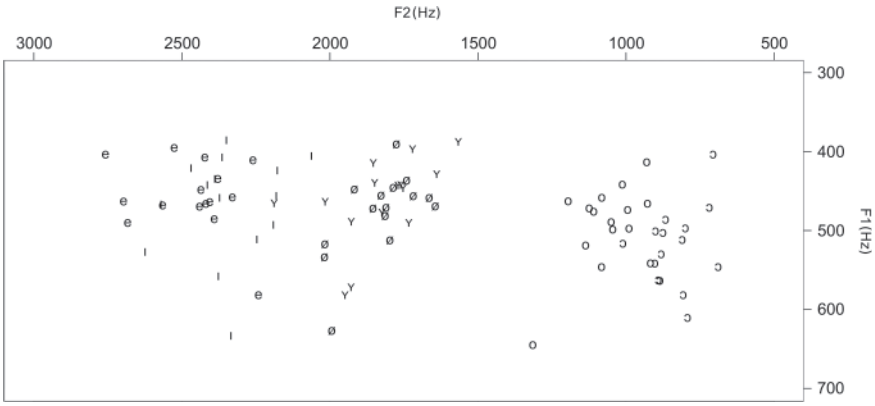

Figure 4. *Individual formant values in pre-obstruent context (means per speaker).*

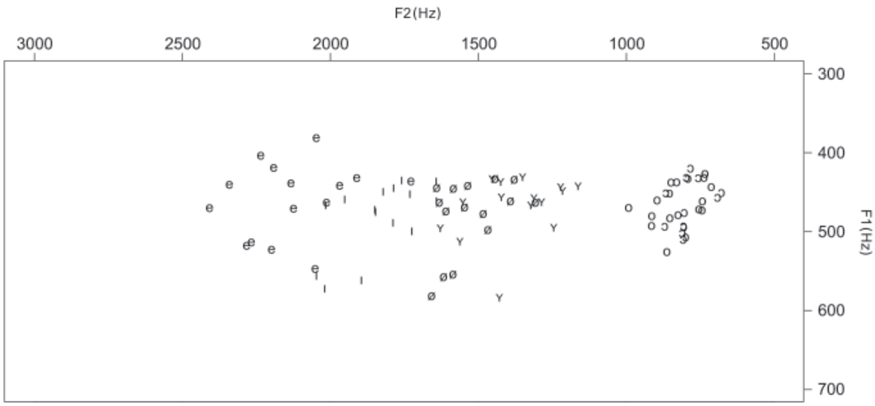

Figure 5. *Individual formant values in vowel+/l/ sequences (means per speaker).*

vowel+/l/ sequences. (Duration was included in the model, however, as it accounts for a large amount of the variance in the data.)

The retracting effect of /l/ is illustrated in Figures 4 and 5, where speakers' average formant values are plotted in a two-dimensional vowel space (F1 on the ordinate, F2 on the abscissa; points of measurement are as above, i.e., at 25% into the vowel+/l/ sequences and at 50% into the vowels in pre-obstruent context). The means of each speaker's individual vowel tokens (three per speaker) are represented by their respective phonetic symbols. For each of the three vowel pairs, the formant values at the midpoint of the tense and lax vowels are very close together, both before /s/ and when part of a syllable rhyme with dark /l/. Figure 5 shows that all the vowels have been shifted rightwards, which indicates that dark /l/ triggers retraction of both tense and lax vowels. This means, therefore, that the transcriptions

Table 4. *Duration of /e ø o ɪ ʏ ɔ/ in vowel+/l/ sequences and in pre-obstruent context.*

Item	Duration (ms)		Item	Duration (ms)	
	mean	stdev		mean	stdev
spil	205	31	*mis*	74	18
speel	226	40	*Kees*	156	27
	(ratio 90.7%)			(ratio 47.4%)	
pul	203	33	*mus*	83	19
peul	229	42	*keus*	158	24
	(ratio 88.6%)			(ratio 52.5%)	
pol	198	29	*mos*	85	14
pool	225	36	*Koos*	163	28
	(ratio 88.0%)			(ratio 52.1%)	

in the phonological literature (e.g., [spɪːɫ] vs. [spɪɫ]) are phonetically inaccurate, in that they suggest a qualitative change in tense mid vowels only, to the values of lax vowels. Instead, our data show that both tense and lax vowels are affected by a following /l/, and that the effect of /l/ on both types of vowels is similar.

3.2.2. *Duration measurements* We next consider the question of whether tense and lax mid vowels differ in length before /l/, as is suggested by transcriptions like [spɪːɫ] vs. [spɪɫ]. Table 4 shows the average durations (in ms) of the vowel+/l/ sequences and of the vowels before /s/; for each pair, we also provide the ratio of the duration of the lax vowel to that of the tense vowel. The results show that before obstruents, the length of lax mid vowels is roughly half that of tense vowels (i.e., between 47.4% and 52.5% of the length of tense vowels), while the length of lax vowel+/l/ sequences is between 88.0% and 90.7% of that of tense vowel+/l/ sequences. These differences are illustrated in Figure 6. (Note again that the durations of the vowels before /s/ and the vowel+/l/ sequences cannot be compared directly, as they consist of differently sized portions of the speech string.)

A Welch two-sample t-test shows that the durational difference between tense and lax mid vowels is significant in both contexts (pre-obstruent: $t = -5.7565$, $p = 0.000$; pre-/l/: $t = 28.6679$, $p = 0.000$). These measurements show that mid vowels before /l/ display a more complex relationship in terms of their relative duration than a straightforward 'long' vs. 'short.' The durations of sequences with lax vowels+/l/ are on average shorter than those of tense vowels+/l/, but this difference is considerably smaller than the length difference between tense and lax vowels before obstruents, where (in tense/lax approaches at least) length is not usually indicated. Thus, our data show that contrary to the transcriptions in the phonological literature, syllable-final /l/ does not *introduce* a length contrast between tense and lax mid vowels. Rather, the durational difference between the

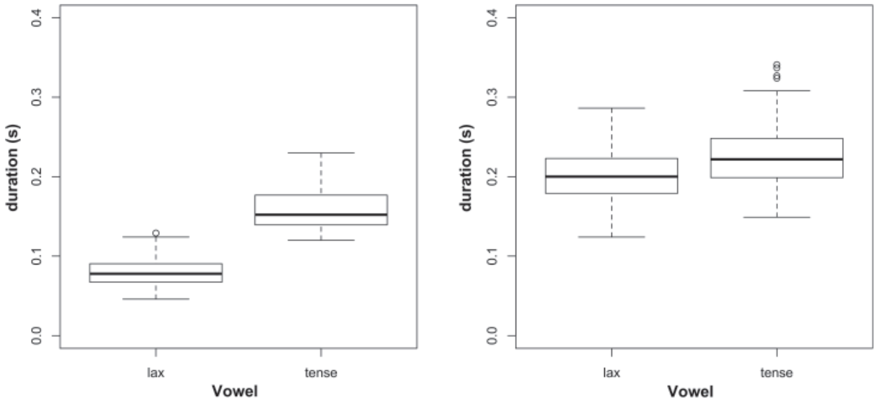

Figure 6. *Duration of /e ɪ/ before obstruents (left) and in vowel+/l/ sequences (right).*

two sets of vowels *decreases* before /l/, relative to the length difference before obstruents.

3.2.3. *Neutralization* We now turn to the claim that syllable-final dark /l/ triggers neutralization of the underlying tense/lax contrast. If F2 lowering before /l/ occurs with both tense and lax mid vowels, there is no reason to assume that this will lead to tense vowels taking on the qualitative features of their lax counterparts. Indeed, as Figure 5 shows, /o/-/ɔ/ is the only vowel pair for which /l/ retraction causes the tense and lax vowels to overlap more strongly in the vowel space. For the other two vowel pairs, the tense and lax members would seem rather to dissimilate: for /e/-/ɪ/, the average F2 difference (per speaker) of 119 Hz before obstruents increases to 291 Hz before /l/, while /ø/ and /ʏ/ show some overlap before obstruents but have an average F2 difference of 155 Hz before /l/. It should be noted, however, that Figures 3 and 4 show average formant values per speaker, and so do not enable us to assess directly whether neutralization has taken place.[6] To determine this, a statistical analysis was performed on the pre-/l/ data.

A generalized mixed-effects model was fitted to the pre-/l/ data subset, consisting of 262 tokens (15 speakers × 3 repetitions × 6 items, minus 8 discarded tokens), where the response variable was whether the vowel was tense or lax. The effect of speaker was treated as random; the fixed effects were F1, F2, and duration, as well as interactions between these effects and the vowel pair (front: /e/-/ɪ/, front-round: /ø/-/ʏ/, back: /o/-/ɔ/). Table 5 provides a summary of the model. Table 5 shows that the model can distinguish tense and lax vowels on the basis of F1 and F2, but not duration (as a main effect). It further shows that the effect of F1 is due to the front vowel pair /e/-/ɪ/, but is absent for the other vowel pairs. There is also a significant interaction between F2 and vowel pair. While there is no effect of F2 for /o/-/ɔ/, for /e/-/ɪ/ we find that lax /ɪ/ is associated with a lower F2. Finally, the significant

Table 5. *Summary of effects and significant interactions. Coefficients refer to the log odds of a lax vowel. Number of observations: 262.*

Fixed effect	Estimate	Standard error	*z*-value	*p*-value
F1 (Hz)	0.019	0.01	2.47	0.013
F2 (Hz)	−0.013	0.00	−4.72	0.000
Duration (ms)	−6.18	11.47	−0.54	0.560
F1: back	−0.024	0.01	−2.19	0.028
F1: front-round	−0.019	0.01	−2.05	0.040
F2: back	0.013	0.00	2.87	0.004
Duration: back	−33.54	13.97	−2.40	0.016
Random effect	**Variance**	**Standard deviation**	***N***	
Speaker	0.87	0.93	15	

interaction of duration and vowel pair shows that while duration is on the whole non-significant, it does play a role in distinguishing /o/ from /ɔ/.

The results of the analysis confirm that Dutch has no general qualitative neutralization of tense and lax vowels before /l/. What the results do show, however, is that there is substantial *durational* neutralization in this context (except for the /o/-/ɔ/ pair). In fact, the results show various significant differences between the three vowel pairs, with only /o/-/ɔ/ showing an effect for duration, and only /e/-/ɪ/ showing an effect for F1 and F2. In other words, the terms 'laxing' and 'lengthening' seem most appropriate for /o/-/ɔ/, and least appropriate for /e/-/ɪ/. The model cannot distinguish between /o/ and /ɔ/ on the basis of F1 and F2, but does show an effect of duration. In contrast, /e/ and /ɪ/ can be distinguished on the basis of F1 and F2, but not on the basis of their duration. (The members of the front-rounded pair /ø/-/ʏ/ are differentiated by F2 only.)

It is important to note, however, that the figures in Table 5 do not tell the whole story. There is in fact no doubt that the quality of the members of the tense/lax mid vowel pairs is perceptually more similar before /l/ than before obstruents – but the reason for this is obscured when we compare vowel formants measured at a single point in time, as we have been doing up to now. A comparison of the formant *tracks* of tense and lax mid vowels, on the other hand, reveals that these are very similar to each other before /l/, and very different from those before obstruents.

In order to get a better insight into the formant tracks, we measured the isolated vowels and vowel+/l/ sequences at 9 equidistant points. We focussed on the front vowel pair /e/-/ɪ/, whose members are, as we have seen, more distinct from each other than the members of the other two pairs. Figure 7 shows the average tracks of the F1 and F2 of /e/ and /ɪ/ in *Kees* and *mis*. Owing to the short duration of /ɪ/ (74 ms on average), only the measurements at 40%, 50%, and 60% of the total duration of the vowel tokens of *mis* were successful. For *Kees*, whose vowel is on average roughly twice as long (156 ms), only the measurements closest to the surrounding obstruents were unsuccessful (i.e., at 10% and 90%). While the formant

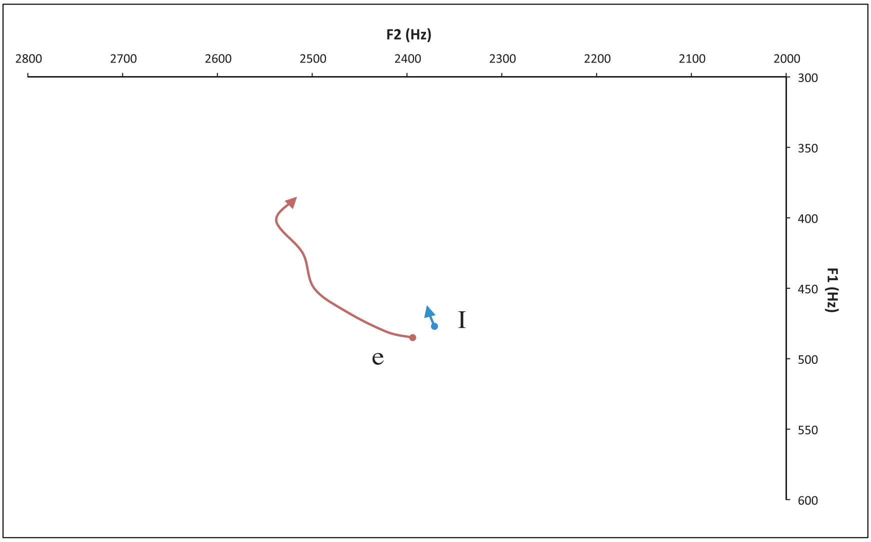

Figure 7. *F1, F2 tracks of /e/ and /ɪ/ in pre-obstruent context.*

tracks of /ɪ/ are fairly straight, those of /e/ display a gradual glide, with F1 and F2 moving away from each other (F1 range: 485–385 Hz, F2 range: 2394–2538 Hz). This shows that before obstruents, /e/ is phonetically a diphthong which glides towards [i]. (The average formant values at the midpoint of the peripheral vowel /i/ are very close to the endpoint values of pre-obstruent /e/ for these speakers, at 338 Hz and 2542 Hz respectively.) Contrary to what the midpoint measurements in Table 3 and Figure 5 suggest, the tense and lax members of the /e/-/ɪ/ pair are therefore perceptually quite distinct. Not only is /ɪ/ on average half as long as /e/ (see Table 4) but /e/ is also phonetically a closing diphthong, while /ɪ/ is a short monophthong. These results are in line with those reported in the literature (see, e.g., Gussenhoven 1992).

When we compare these results to those of /e/ and /ɪ/ before /l/, as in *speel* and *spil*, we observe that here the formant tracks are much more similar. In Figure 8, both /e/ and /ɪ/ glide from their mid-front vowel positions, with an F2 that is slightly lower than their midpoints before obstruents, towards values typically associated with back rounded vowels (and with dark /l/).

3.3. *Production experiment: preliminary conclusions*

The results of the formant and duration measurements indicate that the members of each of the three tense and lax mid-vowel pairs (/e/-/ɪ/, /ø/-/ʏ/, /o/-/ɔ/) are highly similar before dark /l/ but clearly distinct before obstruents. This suggests, therefore, that in pre-/l/ context, tense and lax mid vowels are subject to a high degree

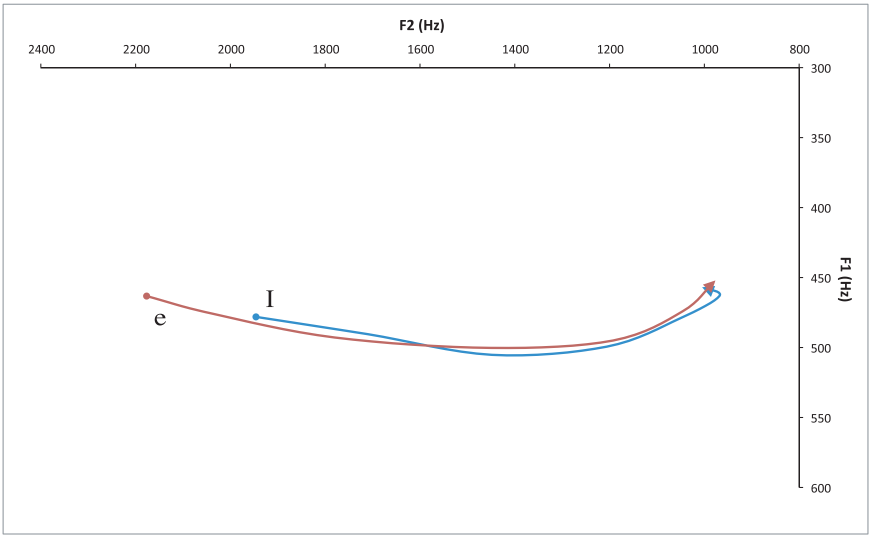

Figure 8. *F1, F2 tracks of /e/ and /ɪ/ in vowel+/l/ sequences.*

of neutralization. However, our data show that this neutralization is of a different kind than is suggested by the transcriptions in the phonological literature. Instead of complete neutralization of vowel quality and a surface length contrast (as in [spɪːɫ] vs. [spɪɫ]), the speakers in our experiment display, on average, substantial but incomplete qualitative *and* quantitative neutralization. The results of our experiment further show that the perceptual similarity of tense and lax mid vowels before /l/ is caused by two factors: a decrease in their length distinction (as compared to pre-obstruent position), and a diphthongal realization that involves retraction rather than raising.

3.4. *A note on interspeaker variation*

While there are too few data points per speaker per vowel per context to filter out individual variation statistically, informal inspection of the /e/-/ɪ/ data appears to reveal some systematic speaker variation in duration and F2. Of the 15 speakers, some showed relatively large differences between *speel* and *spil* tokens in terms of both length and F2. These speakers can thus be said to be ‘non-neutralizing’. Other speakers’ length and F2 differences were smaller, for some to the point of (near-)neutralization. These speakers reduced the contrast between /e/ and /ɪ/ before /l/ either by having no or a below average durational difference coupled with an average difference in F2 (i.e., neutralization of length only), or by having no or below average differences in both length and F2 (i.e., neutralization of both length and quality). Interestingly, there are no speakers in our corpus with a below average difference in F2 (291 Hz) and an above average difference in duration (22 ms). In other words, for the pair /e/-/ɪ/ at least, a difference in length never occurs in the absence of a difference in vowel quality. This is not unexpected if, as we assume, the greater length of tense vowels results from their greater articulatory deviation from the neutral position.

4. The relationship between production and perception

The results of the production experiment described in Section 3 show that tense and lax mid vowels in pre-/l/ context have similar durations and formant tracks, making them less distinct from each other before /l/ than before obstruents. In this section, we examine whether this increased similarity leads to perceptual confusion on the part of listeners – and if so, whether this is due primarily to the absence of a salient contrast in quality, length, or both. To this end a follow-up perception experiment was carried out, once again using the front-mid vowel pair /e/-/ɪ/, in *speel* vs. *spil*.

4.1. *Methodological background*

4.1.1. *Speakers* To obtain a better insight into the issue of perceptual confusion of /e/ and /ɪ/ before /l/, three speakers (A, K, and L) were selected from our corpus. The speakers in question display different patterns of contrast. Speaker A displays systematic (near-)neutralization of the distinction between *speel* and *spil*, in that her average differences in both length and F2 are below average for the speaker group. Speaker K neutralizes the length difference (in fact, she displays a small difference in the opposite direction), but has a relatively large qualitative distinction between her *speel* and *spil* tokens. Finally, speaker L displays relatively little or no neutralization, neither in terms of length nor F2. The average durational and F2 differences for speakers A, K, and L are given in Table 6.

Table 6. *Durational and F2 differences between* speel *and* spil *for speakers A, K, and L.*

Speaker	Length difference (ms)	F2 difference at 25%
A	8	(−)32
K	(−)22	326
L	51	460

4.1.2. *Listeners* A total of 30 listeners participated in the experiment: 15 female and 15 male speakers of Standard Dutch, aged 18 to 21. They were all students of English Language and Culture at the University of Leiden, in the same year as the subjects who participated in our production study. None of the speakers who participated in the perception experiment had participated in the production experiment. (The two groups of subjects were part of different tutorial groups; there was no indication that any of the listeners recognized the three speakers' voices, neither from informal post-test debriefing nor from our inspection of the results.)

4.1.3. *Stimuli* A stimulus recording was compiled using each of the selected speakers' three recorded tokens of *speel* and *spil* in their original carrier sentence. The resulting 18 sentences were split between two randomly ordered sound files of 9 tokens each and presented to the subjects, in such a way that half of them were presented with version A and half of them with version B (the two orders are given in Appendix 2).[7] The subjects were given a sheet of paper containing 9 numbered repetitions of the two items in Standard Dutch orthography (e.g., *1. speel – spil*). They were asked to listen to the recording containing the 9 carrier sentences (*Ik ga nu het woord speel/spil zeggen*, 'I will now say the word *speel/spil*') and, for each sentence, to mark which of the two words they heard. They were not told that there would be equal numbers of each item, nor that they would hear different tokens from the same three speakers. After listening to the recording once, and marking their responses immediately as they heard each sentence, they were asked to listen to the recording again and correct any response they felt necessary. Both the correct and the corrected responses were taken into account when scoring the response sheets.

4.2. *Data processing and results*

Processing of the results involved a simple count of *speel* and *spil* responses, and a further count of how many of these were correct. Table 7 presents an overview of the results. The results show that when listeners are confronted with tokens of *speel* and *spil* (in a frame sentence, but without further context) from a 'neutralizing' speaker such as A, their ability to classify them correctly is at chance level, as would be expected. A general linear model for these results shows that listeners do not fare significantly better when the tokens are produced by a 'length-neutralizing' speaker such as K ($Z = -0.746$, $p = 0.456$). That is, listeners find it difficult to

Table 7. *Results of perception experiment (*speel *vs.* spil*).*

Speaker	Item	Classified as:		% correct
		speel	*spil*	
A	*speel*	20	25	44.4
	spil	21	24	53.3
K	*speel*	27	18	60.0
	spil	24	21	46.7
L	*speel*	40	5	88.9
	spil	8	37	82.2

Table 8. *Summary of effects, perception study (GLM).*

Effect	Estimate	Standard error	*z*-value	*p*-value
Item (*spil*)	0.21	0.27	0.80	0.423
Speaker (A)	0.22	0.30	0.75	0.456
Speaker (L)	−1.65	0.37	−4.49	0.000

identify qualitatively different vowels if there is no accompanying quantitative distinction. It is only when both the F2 difference and the durational difference are sufficiently large – as is the case for L, a 'strongly non-neutralizing' speaker – that listeners reliably distinguish between /e/ and /ɪ/.[8] The results for speaker L's tokens are significantly different from both A ($Z = -5.099$, $p = 0.000$) and K ($Z = -4.490$, $p = 0.000$).

A summary of the general linear model is given in Table 8 (where *spil* is compared to *speel*, with *speel* taken as baseline). We observe that there is no significant difference between *speel* and *spil* items with respect to the number of correct/incorrect responses they elicit (i.e., there is no response bias). We may conclude, therefore, that for the vowel pair /e/-/ɪ/ at least, a length difference is a necessary condition for reliable distinction in pre-/l/ context.

5. Conclusion

We started this paper by noting that the effect of syllable-final /l/ on a preceding tense mid vowel has been described in the phonological literature as laxing. Laxing arguably neutralizes the tense/lax contrast in the direction of lax vowels, and results in a phonetic length contrast between tense and lax vowels (e.g., *speel* [spɪːɫ] vs. *spil* [spɪɫ]).

The data reported in this paper show that this view is incorrect. The results of our production experiment show that /l/ exerts a retracting effect on both tense and lax vowels, signalled acoustically by a lowered F2. This retraction does not lead to considerable overlap of tense and lax congeners in the vowel space (with the exception of /o/ and /ɔ/, which also overlap in pre-obstruent context). However, a comparison of the formant tracks (F1, F2) of tense /e/ and lax /ɪ/ reveals that these vowels are perceptually similar before /l/, since /e/ is not diphthongized in this context. Our data further show that the length difference between tense and lax mid vowels decreases before /l/, to the extent that there is (near-)neutralization of length in this context. Interestingly, for the vowel pair /e/-/ɪ/ none of the speakers in our corpus display a surface contrast in terms of length alone. This suggests that, for this pair at least, the presence of a quantitative contrast depends on the presence of a qualitative contrast. That we should find this relation between length and quality is not surprising if, as we suggest, the greater length of tense vowels results from the greater magnitude of their articulatory gestures. Further research is needed to determine whether the same relation obtains for other tense/lax pairs; this requires a larger corpus in which individual speaker variation can be filtered out statistically.

Another issue that requires further investigation is how pre-/l/ retraction relates to the 'colouring' effects triggered by other Dutch consonants, specifically /r j w/. The data in (7), taken from van Oostendorp (2000: 85–86), suggest that pre-/r/ colouring occurs regardless of whether /r/ is in the same syllable as the preceding mid vowel. (The examples in [7a] are repeated from [2] above).[9]

(7)	a.	beer	[bɪːr]	'bear'	b.	kerel	[ˈkɪːrəl]	'guy'
		kleur	[klʏːr]	'colour'		keurig	[ˈkʏːrəx]	'neat'
		stoor	[stɔːr]	'disturb'		koren	[ˈkɔːrən]	'corn'

However, while the transcriptions in (7) are identical to those used by van Oostendorp to represent /l/ laxing, the specifics of /r/ colouring are rather different. Phonetically, the effect of /r/ on mid vowels has been claimed to involve both lengthening and centralization ('t Hart 1969; Trommelen and Zonneveld 1989; Collins and Mees 1999), whereas our data show that /l/ triggers retraction. In addition, /r/ colouring of vowels appears to have become phonologized, since it is sensitive neither to the syllabic position of /r/ nor to its phonetic realization.

We do not know of any study that addresses the phonetic effects of /j w/ on mid vowels.[10] Our impression is that colouring is less frequent before /j/ than before /w/, and that at least some speakers have colouring regardless of whether /j w/ are in the same syllable as the affected vowel. We suspect that, as for /l/, the colouring effects of /j w/ are gradient and subject to speaker variation, and that the phonetic details will be different for each of the sounds concerned. Thus, while it is certainly possible to refer to the colouring triggers /r l j w/ as a natural class (e.g., that of 'non-nasal sonorants'), we feel that such a characterization does not lead to better insights, but rather obscures the quite varied effects triggered by its members.

Acknowledgments

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Appendix A: Unsuccessful automatic measurements

To detect unsuccessful measurements, Tukey's boxplots were generated plotting all vowels across speakers. Any outliers were considered as candidates for removal from the data matrix, as they may affect the averages in such a way that these would not represent typical formant values for a certain vowel by a certain speaker. There were no extreme outliers, and 14 weak outliers. 13 of these (0.8% of the total number of measurements) constituted measurement errors and were manually corrected on the basis of visual inspection of the relevant spectrograms, or discarded if no successful measurement proved possible. These tokens are given in Table A1.

Table A1. *Manually corrected or discarded tokens. The asterisks concern tokens for which Praat's automatic measurements did not return a result for one or both of the formants, and for which correction via manual measurement was impossible. For the other tokens, the automatic measurements returned unusual results (outliers); these were either corrected manually or, if this proved impossible, discarded.*

Context	Vowel	Speaker	# of tokens	Formant
-Vs/-Vt	/a/	M	1 corrected	F1
	/ɔ/	A	1 discarded	F2
		G	2 discarded	F2
		I	1 discarded	F2
-Vl	/o/	G	2 discarded**	F1, F2
		J	1 discarded*	F2
	/ɔ/	O	1 discarded	F1, F2
		B	1 discarded*	F2
		G	2 discarded**	F2
			1 corrected	F2
		I	1 corrected	F2
		J	1 discarded*	F2
			2 corrected	F2
		M	2 corrected	F2
		Q	1 corrected	F2

Appendix B: Word lists of perception experiment

No.	Version A		No.	Version B	
	Token	Speaker		Token	Speaker
1	*spil*	K	10	*spil*	A
2	*speel*	A	11	*speel*	L
3	*spil*	L	12	*speel*	K
4	*speel*	K	13	*spil*	K
5	*speel*	L	14	*speel*	A
6	*spil*	A	15	*speel*	L
7	*speel*	K	16	*spil*	L
8	*speel*	A	17	*spil*	L
9	*spil*	A	18	*spil*	K

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Notes

1. The data and transcriptions in (2) are originally from Trommelen and Zonneveld (1989: 148), who use the term 'colouring.' van Oostendorp (2000: 85) uses the term 'laxing,' noting that "the phonological [sic] representations [in (2)] have been somewhat idealized from the phonetic forms."
2. Clearly, the values depend on the vocal tract size of the speakers concerned.
3. Jakobson et al. (1952: 36) provide a complementary acoustic characterization of tenseness to the effect that in a tense vowel "the sum of the deviation of its formants from the neutral position is greater than that of the corresponding lax vowel."
4. The second part of the definition – that tense vowels have a markedly longer duration during which the articulatory configuration remains stationary – is not appropriate, since the tense mid vowels of Standard Dutch are phonetically diphthongized (cf. [1a]).
5. Glosses of the test items in Table 1: *Kees* 'id.' (first name), *speel* 'play-1SG-PRES', *spelen* 'play-PL-PRES', *keus* 'choice', *peul* 'pod', *peulen* 'pod-PL', *Koos* 'id.' (first name), *pool* 'pole', *Polen* 'Poland', *mis* 'mass', *spil* 'pivot', *mus* 'sparrow', *pul* 'tankard', *mos* 'moss', *pol* 'clump', *Piet* 'id.' (first name), *moet* 'must-SG-PRES', *maat* 'mate'.
6. We are grateful to an anonymous reviewer for pointing this out to us.
7. Subjects were presented with 9 (of the full set of 18) sentences to avoid exceeding their attention span.
8. An anonymous reviewer suggests that the possibility should be left open that listeners can distinguish the vowels in *speel* and *spil* tokens on the basis of duration alone. We did not test this possibility, since none of the speakers in our production experiment realized the /e/-/ɪ/ contrast in this way.
9. Gussenhoven (1993) observes that vowels before /r/ are long, provided they are in the same foot as /r/. Thus, the initial vowels in, e.g., *koren* (7b) and *Erica* 'id.' (first name) are long but the vowel in, e.g., *Europa* [ʏˈroᵘːpa] 'Europe' is not.
10. The articulatory conflict in /oj/ sequences is presumably that /o/ is phonetically [oᵘː], with the high-back tongue position conflicting with the high-front position of the following [j].

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