VARIABILITY IN DIRECTION OF DORSAL MOVEMENT DURING PRODUCTION OF /l/

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ABSTRACT

This paper presents articulatory data on the production of /l/ in various environments in Dutch, and shows that the direction of movement of the tongue dorsum varies across environments. This makes it impossible to measure tongue position at the peak of the dorsal gesture. We argue for an alternative method in such cases: measurement of position of one articulator at a time point defined by the gesture of another. We present new data measured this way which confirms a previous finding on the articulation of Dutch /l/.

1. INTRODUCTION

In articulatory research, it is usual to measure the location of points on the tongue (tip, body, or dorsum) at the peak of a particular gesture. For example, dorsum position might be measured at the peak of dorsal backing, or tip position at the peak of tip raising [1, 2, 4]. However, this method may not be effective if there is too much variation in the gestures for a particular sound across environments. If the tip rises in one environment but falls during the same sound in another, it will not be possible to measure position of the tip at the peak of either raising or lowering for all environments. While this might simply mean that vertical position of the tip is not relevant for the sound in question, the direction of tongue motion could legitimately vary in theoretically relevant ways. If there is such variation, this would have implications for the theory of Articulatory Phonology.

In this paper, we investigate the articulation of /l/ in Dutch under various circumstances. /l/ is a useful segment in which to investigate articulatory variability, because it shows a strong allophonic alternation between light /l/ in syllable-onset position and dark /l/ in coda position (similar to English). We manipulate syllable position of the /l/ (coda or onset) and quality of preceding vowel (front or back). This paper focuses on the motion of the tongue dorsum during /l/.

2. METHODS

2.1. Materials and data collection

Articulatory data and simultaneous acoustic data from six native speakers of Dutch was recorded using a Carstens Articulograph. Speakers produced words of the six types in Table 1, with each word embedded in a short phrase. Receivers of the articulograph were attached to the tongue tip, body, and dorsum, and a reference receiver was attached to the upper teeth. For two speakers (I and K), an additional reference receiver was placed on the bridge of the nose, and the angle of the bite plane was also recorded. For additional details of recording methodology, see [5].

Post-/l/ environment	Prec. front vowel	Prec. back vowel
Coda /l/	[fɪl̲mər] (6) ‘cameraman’	[xɔl̲vən] (9) ‘waves’
/l/ before epenthetic [↔]	[fɪl̲əmər] (6) ‘cameraman’	[xɔl̲əvən] (9) ‘waves’
/l/ before underlying [↔]	[brɪl̲əmakər](6) ‘optician’	[mɔl̲əvɑl] (9) ‘mole trap’

Table 1: Examples of materials. Number of items of each type appears in parentheses.

As shown in Table 1, the preceding environment for the /l/ could be either a back or a front vowel (restricted to /ɪ, ɛ/ and /ɑ, ɔ/ in our data). The following environment could put the /l/ in coda position (with a following consonant), or could put the /l/ in onset position by having one of two types of schwa following the /l/. The schwa could be either underlying (always present in the word) or epenthetic (only variably present). As shown in Table 1, the same words can be produced either with or without the epenthetic schwa, so the same words are used in the coda and epenthetic schwa conditions. Previous work using tongue tip data [5] has shown that /l/ before either type of schwa is produced as a light /l/, while /l/ in coda position is dark.

In order to obtain a production of each coda/epenthesis word from each speaker produced both with and without the epenthetic schwa, speakers were instructed as to whether to produce the "extra [ə] sound" or not. This allowed us to obtain a reasonably large number of matched items for each speaker. An additional recording, not reported here, was made before instructing the speakers about pronunciation. No consistent differences in articulation of the /l/ were found between the two recordings [5].

2.2. Data analysis

The articulograph data shows the position of each receiver (tip, body, and dorsum) in the horizontal and vertical dimensions over time. For speakers I and K, the data was rotated to make the dimensions vertical and horizontal relative to the world rather than relative to the articulograph helmet. (An articulograph records the distance of the receivers from magnets in a helmet the speaker wears.) For the remaining speakers, this correction was not possible, so for them, what appears to be an increase in vertical position may actually be both raising and fronting or raising and backing. For the purposes of this study, what will be important is not the absolute direction of movement, but whether the direction of movement is the same across environments.

For each speaker's production of each item, the movement of the tongue dorsum in the vertical dimension during the /l/ was examined, and classified as having the dorsum during the /l/ in a peak, a valley, or neither (Figure 1). For this purpose, the location of the /l/ was defined as the time of the tongue tip raising gesture, which was an obvious feature of almost all productions of /l/. Productions were classified as having neither a peak nor a valley of the dorsum position if the dorsum vertical position remained flat during and around the /l/, or if the dorsum was between a valley and a peak associated with sounds other than the /l/.

Furthermore, the vertical position of the dorsum at the time of the peak of tip raising was measured for each token. (Horizontal position will not be reported because previous research [5] indicated that there are no consistent fronting or backing gestures associated with the /l/ in Dutch.) Although it is typical in articulograph research to measure dorsum position at the maximum of a dorsal gesture, our results for classification of dorsal movement shape will make it clear why this is not possible in this case, and why measurement at the peak of tip raising is a useful alternative.

3. RESULTS

3.1. Shape of dorsal contour

The results of classifying each token for shape of the dorsum contour (peak, valley, or neither) appear in Tables 2 and 3. Three of the speakers (I, D, L) are more likely to have the dorsum in a valley during the /l/ if the /l/ is in coda position than if it is not. Speakers A and K show some tendencies in this direction, while Speaker G appears to have no effect of the post-/l/ environment. Four speakers (I, G, A, L) are considerably less likely to have the dorsum in a valley if /l/

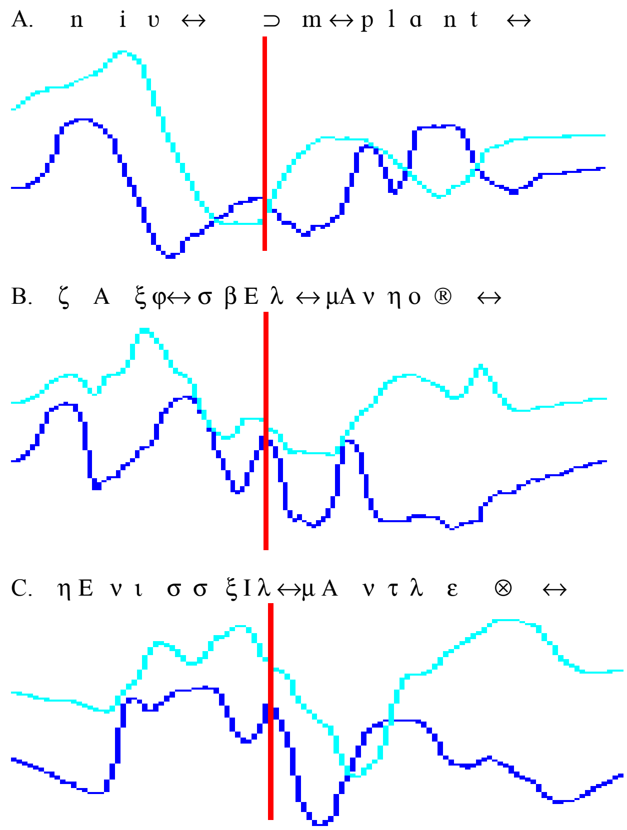

Figure 1: Examples from Speaker I of the dorsum in a valley (A), in a peak (B), and in neither (C) during /l/. The upper, light blue line is the dorsum vertical position, and the lower, dark blue line is tip vertical position. The vertical red line is at the peak of tip raising. (A) "nieuwe olmen planten" 'plant new elms' with /l/ in coda position after a back vowel. (B) "zachtjes bellenman horen" 'quietly hear the bell man,' with /l/ in onset position following a front vowel. (C) "Hennies schillenmand legen" 'empty Hennie's peel basket,' with /l/ in onset position after a front vowel.

Environment	I	K	D	G	A	L
Coda /l/						
valley	1.00	.80	1.00	.67	.67	.87
no valley or peak				.13		
peak		.20		.20	.33	.13
/l/ before epenthetic ↔						
valley	.53	.73	.33	.67	.53	.33
no valley or peak	.27	.07		.13	.07	.27
peak	.20	.20	.67	.20	.40	.40
/l/ before underlying ↔						
valley	.60	.40	.13	.73	.40	.20
no valley or peak	.27	.33	.20	.13	.13	.40
peak	.13	.27	.67	.13	.47	.40

Table 2: Proportion of items (out of 15 for each environment) with each dorsal contour, for each speaker (top row), by following environment. Cells with 0 tokens are left blank.

Environment	I	K	D	G	A	L
/l/ after front vowel						
valley	.44	.61	.44	.39	.22	.28
no valley or peak	.33	.22	.06	.28	.11	.17
peak	.22	.17	.50	.33	.67	.56
/l/ after back vowel						
valley	.89	.67	.52	.89	.74	.59
no valley or peak	.07	.07	.07	.04	.04	.26
peak	.04	.26	.41	.07	.22	.15

Table 3: Proportion of items (out of 18 for front vowels and 27 for back vowels) with each dorsal contour, for each speaker (top row), by preceding vowel frontness/backness.

follows a front vowel than if it follows a back vowel. Thus, for all speakers except K, the dorsum is more likely to be in a valley during /l/ either if the /l/ is in coda position, or if the /l/ is preceded by a back vowel. For some speakers (most clearly I and L), both of these factors seem to have an effect.

These results show that there is substantial variation in the shape of the dorsal vertical contour during production of /l/. As demonstrated in Figure 1 above, the dorsum can be located at a peak or in a valley during the production of /l/ (or occasionally in neither). This means that it is impossible to measure the height of the dorsum during /l/ at a point defined by the vertical motion of the dorsum: one cannot measure dorsum height at the extremum of dorsal lowering if a substantial number of tokens show raising rather than lowering during the /l/. However, vertical position of the dorsum may still be relevant to articulation of the /l/. If this is the case, the best alternative may be to measure dorsum height at the peak of a gesture which is more clear, such as the peak of tip raising in our data. As Figure 1 exemplifies, a clear peak of tip raising is present under a wide variety of conditions (coda /l/ after back vowel, onset /l/ after front vowel).

3.2. Dorsum height

The height of the dorsum might seem redundant with the data on shape of the dorsal contour presented above: if the dorsum is in a peak, it might well be higher than if it is in a valley. However, a small rise can occur at either an overall high or overall low position of the dorsum (e.g. a small rise can occur within a larger valley as in Figure 2), so conditions with many tokens showing peaks do not necessarily have the dorsum at a higher position than conditions with predominantly valleys. We therefore turn to data on the height of the dorsum measured at the peak of tip raising. Table 4 presents this data for each speaker, for each environment of /l/.

For all speakers except K, the dorsum is higher in /l/ before either type of schwa than in coda /l/ (for both front and back preceding vowels). The effect of vowel frontness is inconsistent for /l/ in coda position, but for /l/ before either type of schwa, the dorsum is higher after front than after back vowels. A 2-factor within-subjects ANOVA showed a significant main effect of both following environment ($F(2,10)=12.36$, $p<.02$ with the Greenhouse-Geisser correction) and preceding vowel frontness ($F(1,5)=11.67$, $p<.02$). The interaction was also significant ($F(2,10)=13.77$, $p<.01$). Tests of simple effects showed a significant effect of following environment for both types of preceding vowel (front vowels: $F(2,10)=16.45$, $p<.01$; back vowels: $F(2,10)=6.63$, $p<.05$ with Greenhouse-Geisser correction).

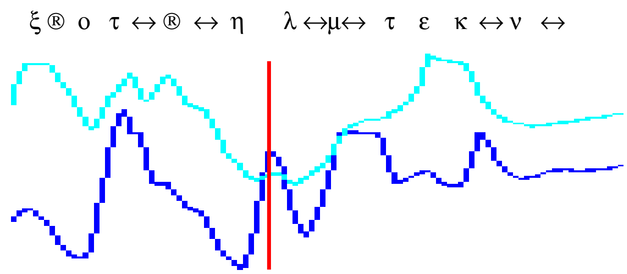

Figure 2: Small peak of dorsum position within a larger valley. Speaker I. “Grotere hol[↔]men tekenen” ‘draw bigger spiral ornaments,’ with /l/ before epenthetic schwa after a back vowel. See Figure 1 for other details.

Speaker	Prec. vowel	Coda /l/	Epen. ↔	Underl. ↔
I	front	14753	15175	15313
	back	14345	14781	14733
K	front	14018	13969	14011
	back	14082	14034	13907
D	front	930	1557	1652
	back	1040	1296	1308
G	front	1202	1788	1695
	back	1127	1339	1297
A	front	716	1350	1324
	back	789	1055	1036
L	front	705	1386	1687
	back	615	1172	1335

Table 4: Vertical position of dorsum at the peak of tip raising for each preceding and following environment of /l/ and for each speaker. For speakers I and K, position is in hundredths of mm from a fixed point on the articulograph helmet. For all others, it is in hundredths of mm from the upper teeth [5].

4. CONCLUSIONS

This data exemplifies a case in which the usual method of choosing measurement points in articulatory studies cannot be applied. The most common method of analyzing articulatory data is to measure the position of a particular articulator (either vertical or horizontal) at the peak of a salient gesture made by that same articulator [1, 4]. Thus, if tip raising appears to be important for the sound under investigation, the vertical position of the tip is measured at the peak of tip raising, and is compared across whatever conditions are of interest. If dorsum backing appears to be an important gesture, the horizontal position of the dorsum is measured at the peak of dorsal backing. The time difference between the peaks of such gestures may also be measured. In some papers that use this method, if a few tokens lack a clear realization of one of the gestures, that token is omitted from the data [4].

Our data, however, presents a different case. While past research on the articulation of /l/ in English [1, 2, 4] has found that /l/ (both in coda and onset position) has both a tip raising and a dorsal backing gesture, in our data, we find only a clear tip raising gesture. Any dorsal backing appears to be associated with the preceding vowel, and to have little to do with the /l/. In previous work [5]we found no consistent effects of post-/l/ environment on horizontal position. What we do see (as shown in Figure 1) is a very strong dorsal lowering gesture for many tokens. This is particularly the case for /l/ in coda position, and for /l/ following back vowels. We suspect that, especially when these two factors co-occur (in a coda /l/ after a back vowel), the /l/ becomes so dark as to be vocalized, forming a back diphthong together with the preceding vowel. /l/ vocalization is a well-known phenomenon cross-linguistically and in Dutch [4, 6].

If we saw at least some dorsal lowering gesture for all (or nearly all) tokens, we could measure dorsum height at the extremum of dorsal lowering, following the usual methodology for locating measurement points. We could then compare dorsum height across conditions, and would probably find greater dorsum lowering for coda /l/ than for onset /l/. However, as Figure 1 and 2 show, we do not see this. Instead, we have large numbers of tokens with a raising of the dorsum just at the time of the /l/ instead of a lowering, and so we cannot measure at the extremum of dorsal lowering. We cannot simply exclude such tokens, because there are quite a large number of them. More importantly, since the classification data in 3.1 above shows that the distribution of such tokens is not random across conditions, it would be misleading to exclude them. If there were a dorsal gesture in the horizontal dimension (this would be expected to be a backing gesture, as in English /l/), one could measure the position of the dorsum at the peak of that gesture. However, since the relevant dorsal gesture for Dutch /l/ appears to be lowering rather than backing, this is not possible either.

We suggest that in such cases, one should measure the position of the relevant articulator at the peak of whatever gesture is indeed consistently associated with the sound under investigation. In this case, we measure the height of the dorsum at the peak of tip raising because the tip raising gesture is a clear indicator of the /l/, and is the only one which is present for almost all tokens. (In this corpus, only one token by one speaker had an /l/ so vocalized that it lacked any trace of a tip raising gesture for the /l/. This single token was excluded.)

Previous research on English /l/ and other sonorants has shown that the timing of the two component gestures of the sonorant varies systematically with position in the syllable [1, 2, 4]. For English /l/, the tip raising gesture occurs later relative to the dorsal backing or lowering gesture if /l/ is in coda position than if it is in onset position. Therefore, the height of the dorsum measured at the peak of tip raising may not be equally close to the extremum of the actual dorsal gesture for all tokens. However, since there is no point which can be consistently identified as the extremum of the dorsal gesture, we must accept this consequence.

The theory of Articulatory Phonology [2-4] claims that words are represented in the speaker's lexicon as a collection of gestures, rather than as phonemes or features. It further proposes that all gestures which are present in the underlying form of a word must also be present in the surface form of a word. Gestures cannot be substituted, inserted, or deleted [4]. This is a strong claim, and various authors argue against it [5, 7, 8]. This claim might seem to go contrary to the classification data we present in 3.1 above, and exemplify in Figure 1: the dorsum sometimes has a peak and sometimes has a valley during the same sound, /l/, in our data. However, this difference in the shape of the dorsal contour in itself does not pose a problem for Articulatory Phonology. When the dorsum is at a peak during the /l/ (Figure 1B), the rise in dorsum height is generally small and closely timed to the tip raising gesture. The most likely explanation for this rise is that the dorsum is being dragged along by the rather extreme motion of the tongue tip, since the tongue tip and dorsum are not entirely independent articulators. The rise in dorsum position probably does not represent an active gesture of the dorsum. In fact, the small rise in dorsum position can sometimes occur in the middle of a larger valley of the dorsum position (Figure 2). This suggests that the active gesture being carried out by the dorsum is one of lowering even when there is a small rise, and this lowering gesture may extend throughout the vowel and postvocalic /l/. However, during the tip raising gesture of the /l/, the dorsum may also show a slight passive rise. Thus, there is probably no substitution of a dorsal raising for a dorsal lowering gesture, so this data can be accommodated within Articulatory Phonology.

Our data shows that the articulation of /l/ in Dutch can involve either a raising or a lowering of the dorsum, and that a lowering is most likely when the /l/ is in coda position (dark /l/), or follows a back vowel, or both. Furthermore, it shows that the dorsum is higher in /l/ before either type of schwa (in onset position) than it is in coda position, when dorsum height is measured at the peak of tip raising. This extends previous results [5] about the tip gesture to the dorsum, and strengthens the finding that Dutch /l/ before either type of schwa is light, while /l/ in coda position is dark. This data also leads to the methodological conclusion that there is sometimes such variability in gestures that one must measure the position of one articulator at a time point defined by the peak of a gesture of another articulator.

5. REFERENCES

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