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The [+spread] of the Northern Cities Shift

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Abstract

Sociolinguistic research has been greatly enriched by the application of instrumental acoustic methods. This is especially true in the study of vocalic changes where formant frequencies offer detailed pictures of subtle shifts of vowel quality. In the usual shorthand, F1 and F2 are accepted as correlates of vowel height and frontness respectively though most researchers recognize that formant frequencies are affected by other articulatory factors than just tongue position. In this research, we examine one of the most significant of these factors: lip configuration. This articulatory factor plays a key role in many vowel changes including the Northern Cities Shift (NCS), the focus of our study.

Traditional accounts of the NCS (e.g. Labov 1994) describe the changes in terms of tongue position. Some role for labiality is often acknowledged in the latter case which involves unrounding. We argue, however, that lip configuration is also implicated in centralization.

We examine the effects of lip configuration in the NCS through a video study of subjects from the St. Louis region. Speakers were recorded on digital video reading prepared materials. The experimental set-up allows us to precisely measure articulatory landmarks (e.g. vertical and horizontal lip distance, lip protrusion) from a display. The audio output from the recording was subjected to acoustic analysis so that comparisons between lip configuration and acoustic outcome could be made. Preliminary results confirm our hypothesis that speakers participating in the NCS demonstrate significant lip spread.

To make sense of these findings we consider the acoustic consequences of lip rounding and spreading. By lengthening the vocal tract, rounding acts to lower formant frequencies, while unrounding and spreading have the opposite effect. In this way the changes in lip configuration observed in the NCS serve to enhance the acoustic effects of the changes in tongue position. These observations also shine light on some previously puzzling findings in our work on the NCS: fronted tokens often show extremely high F1 values in addition to the expected higher F2 values. In some cases, the formant data suggested that the primary direction of movement for this vowel was lowering rather than fronting. The present study leads us to reconsider this articulatory interpretation and suggest that increased F1 (and F2) values may indicate that lip spreading is being employed by NCS speakers as a complement to shifting tongue positions. Finally, we also weigh the possibility that lip configuration could be adopted by some NCS participants as an alternative to lingual positioning.

The [+spread] of the Northern Cities Shift

Tivoli Majors and Matthew J. Gordon

1 Introduction

For over forty years the study of language change has held a prominent position at the top of the sociolinguistics agenda. Variationist research has explored new territory investigating language changes, not just after the fact but while they are in progress. In the arena of sound change, new windows on the inner workings of the change process have been opened by incorporating theories and methods from laboratory phonetics. Most influential in this regard have been the methods of instrumental acoustics and particularly, in North America anyway, formant frequency measures used to study variation in the pronunciation of vowels. Formant data is enormously helpful in tracking vowel changes in progress where F1 and F2 are taken as correlates of the articulatory dimensions of height and backness. At the same time, researchers recognize that a vowel's formant structure is affected by more than just tongue position. Any articulatory gesture that lengthens the vocal tract tends to lower formant frequencies, while gestures that shorten the vocal tract have the opposite effect.

This project explores one site for such gestures by considering the effect of lip configuration on formant frequencies. The basic distinction under study here involves positioning of the lips from rounded and protruded on one end of a continuum to spread apart and retracted on the other end of that continuum. The protrusion of the lips during rounding serves to lengthen the vocal tract and so to lower formant frequencies, while spreading shortens the vocal tract and has the opposite acoustic effect.

What we are reporting on here are results from a pilot study that sought to explore the relationship between articulatory data on lip configuration and acoustic data on formant frequencies. This relationship is of particular importance in the study of the Northern Cities Shift (NCS), the linguistic phenomenon examined here. The NCS has been well described in the sociolinguistics literature (see, e.g., Labov, Ash, and Boberg 2006; Gordon 2001). It involves an apparently coordinated series of changes to six vowels and is heard across the Inland North dialect region. The present study focuses on the movements associated with two vowels participating in the NCS: /ɔ/, which tends to be lowered and fronted, and /a/, which tends to be fronted. Note that this is a pilot study and our limited sample of speakers prevents us from drawing strong conclusions. Still, we hope to demonstrate the promise of this kind of multimodal exploration for the study of the NCS and other sound changes in progress.

2 Methodology

To capture both a visual and auditory perspective on vowel production, four speakers (1 male and 3 female) were recorded on digital video while reading aloud a list of words. The speakers were all natives of St. Louis, Missouri and ranged in age from 21 to 28. Each speaker sat directly in front of the camera (Sony DCR-TRV320), and a mirror was placed about six inches to the right of the speaker's face at roughly a 45˚ angle in order to reflect a side view of the face back to the camera. The subjects sat with their backs to a wall, and a book was placed between their heads and the wall. They were asked to hold the book in place with their heads during the recording. This technique reduced the amount of head movement and thus helped them maintain a consistent distance from the camera. This recording set-up as well as some of the measurement techniques were inspired by Jun (1994) and Pan (1994).

The visual analysis involved measuring five variables: 1) Openness: the distance between the centers of the upper and lower lips, 2) Spread (front): the horizontal distance from one corner of the mouth to the other, 3) Upper lip protrusion: the position of the upper lip on the front-back dimension, 4) Lower lip protrusion: the position of the lower lip on the front-back dimension, and 5) Spread (side): the position of the corner of the mouth on the front-back dimension. The first two of these measurements were taken from the head-on view and the other three from the side view. For these side-view measurements, a mark was drawn on the speaker's upper cheek prior to recording and the distance between this stable mark and the variable point (i.e. the corner of the mouth or the outside edges of the upper and lower lips) was measured. Figure 1 illustrates the five visual measurements taken. As might be expected, the two measures of spread, one from the front and the other from the side, were found to be largely redundant, and our analysis here considers only the front-view data, which we judged to be more reliable because of better image quality.

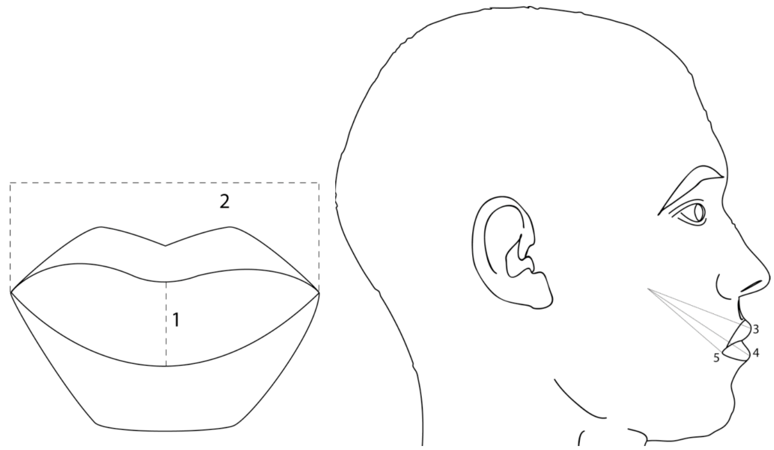

Figure 1: The five facial measurements taken for visual analysis

The visual measurements were taken from stills captured using Apple iMovie software. We scrolled through the video of each target vowel being spoken and captured a still of the frame in which the mouth achieved its maximum point of rounding (for rounded vowels) or openness (for unrounded vowels). The five distance measurements were taken from the still images using the line drawing function in Adobe Illustrator.

The acoustic analysis involved measuring the frequencies of the first and second formants (F1 and F2) by examining spectrographic, LPC, and FFT displays. Measurements were generally taken from the LPC display. In cases of LPC and FFT mismatch, however, FFT measurements were recorded. Measurements for both formants were taken at the maximum F1 point corresponding to the maximum opening of the non-round vowel. Because lip rounding has the effect of lowering formants, the vowel target of the round vowels may not correspond to the maximum F1, so the spectrograms of the round vowels were examined to determine the vowel target, and measurements were taken at the point of F1 "deflection", the point at which F1 reached a maximum or minimum and began moving in the opposite direction. In case no such deflection was detectable, measurements were taken at the steady-state portion of the vowel deemed to correspond to the vowel target, roughly at the temporal midpoint.

The word list was constructed to include 26 different words featuring all six of the vowels involved in the NCS, along with /u/ and /o/. The words contained the target vowels in various phonological contexts, and each word was repeated in the list three times, though not consecutively, as the list was randomized. The number of tokens of each phoneme varied. Since we were primarily interested in the lower half of the NCS, we analyzed 15 tokens of /ɔ/, 18 tokens of /a/, and 11 tokens of /æ/ for each speaker, but we examined as few as 6 tokens for other vowels. Because of slight differences in the positioning of the camera, direct comparison of the visual measurements across the speakers is not possible. We did not perform any normalization of the acoustic data; thus, all statistical comparisons are done on an intraspeaker basis.

3 Results

Based on our previous research (e.g., Gordon and Majors 2006; Majors 2006), we judged two of the speakers examined as representing "typical" St. Louis vowel systems showing some participation in the Northern Cities Shift (NCS) and distinct low vowels. Acoustic analysis of the other two speakers suggested they were participating in the low back vowel merger. Due to limited space, we present only the results of the speakers who are not participating in this merger so that we may examine the relationship between lip configuration and the acoustic realization of the low vowels.

3.1 Acoustic Results

Figures 2 and 3 present the vowel plots of the non-merged speakers, Melody and Mark.

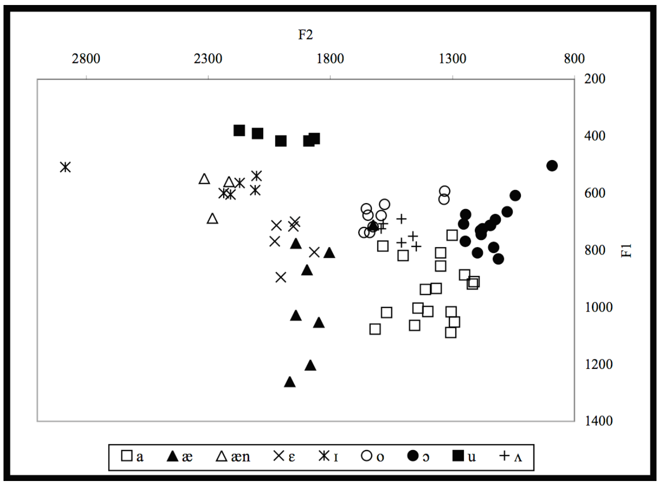

Figure 2: Melody's vowel plot

Melody's plot indicates some participation in the NCS, with some lowering and centralization of /a/ and at least some tokens of /ɔ/ lowered into the /a/ range. She has considerable variance in the acoustic realization of /æ/ with some very low tokens along with some raised tokens, especially those in pre-nasal contexts. Also of note is the fronting of /u/ with tokens overlapping the frontness of /ɪ/. Such fronting is common in many dialects of American English, especially when the vowel appears after coronal consonants as it did in our word list.

In Mark's vowels (Figure 3) we see hallmarks of the NCS with raising of /æ/, centralization of /a/, and some apparent lowering of /ɔ/. We note that some of the centralized tokens of /a/ show particularly high F1 measurements, which suggests the vowel is lowered as well as fronted.

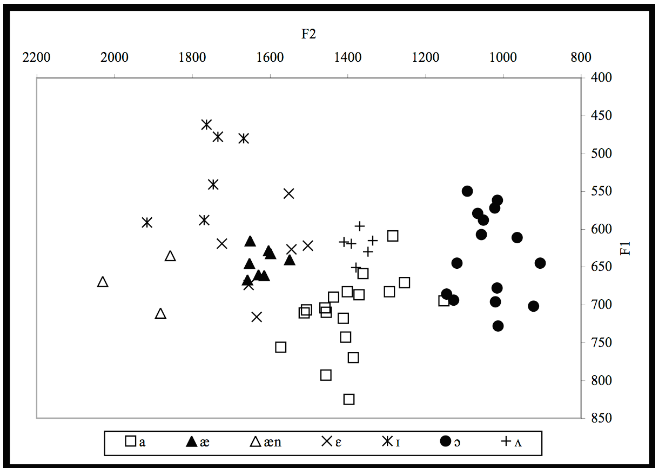

Figure 3: Mark’s vowel plot

3.2 Overview of Lip Gesture Results

The results of the visual analysis for the speaker Melody are presented in Figure 4. These bar graphs provide a convenient overview of how the four main distance measurements relate to vowel production. Each graph provides the mean values observed for each vowel for one of the visual measurements. All these measurements are shown in centimeters. The absolute values are not important; what matters are the relative values across the vowels. Figure 4a provides the results for lip opening (measure 1 in Figure 1).

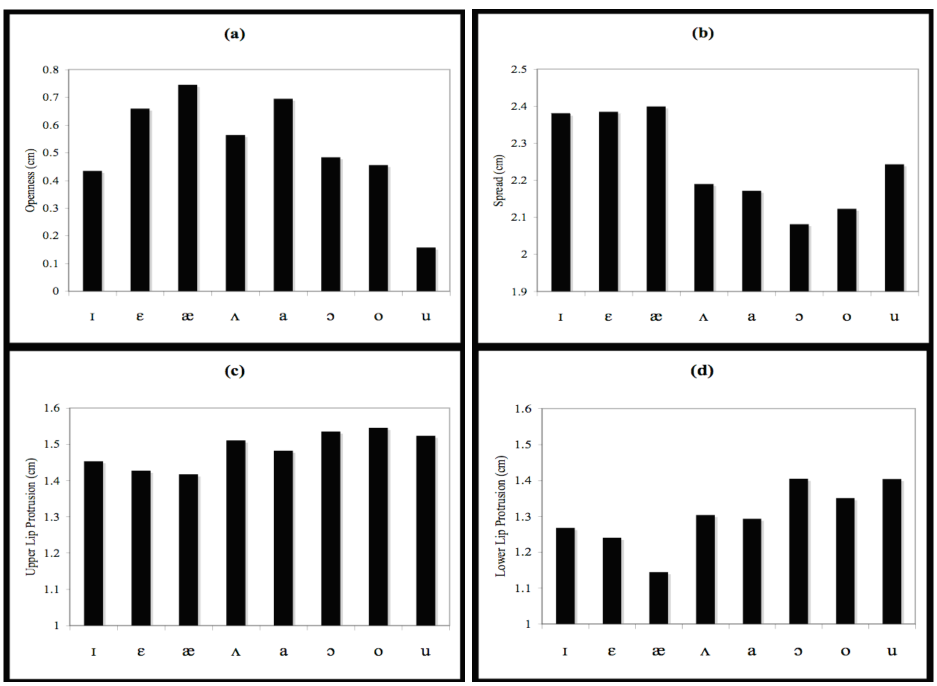

Figure 4: Mean lip gesture distances for Melody in centimeters; (a) lip opening, (b) spread (c) upper lip protrusion (d) lower lip protrusion

As we should expect, the low vowels /æ/ and /a/ have the greatest lip opening, followed closely by the historically mid /ɛ/, which overlaps in acoustic space with /æ/, while the high vowels /ɪ/ and /u/ show the least degree of openness. The extremely low mean openness for /u/ comes from the fact that lip rounding also serves to reduce the distance between the upper and lower lip. In Figure 4b, we see the results for lip spread (measure 2 in Fig. 1), and a clear distinction between the front vowels /ɪ/, /ɛ/, and /æ/, which show high degrees of spread, and the other vowels. The relatively high value for /u/ is noteworthy and may be related to the fact that this historically back vowel was apparently quite fronted (see Fig. 3). The two measures of protrusion, for the upper and lower lips (measures 3 and 4 in Fig. 1) are shown in 4c and 4d respectively. The rounded vowels /ɔ/, /o/, and /u/ exhibited the greatest lip protrusion and the front vowels /ɪ/, /ɛ/, and /æ/ exhibited the least protrusion. This was particularly evident on the lower lip. We note that despite the apparent fronting of [u], lip protrusion is pronounced, indicating that in the fronted position, [u] retains its rounding.

Results for Mark were generally similar to those of Melody, but there were some notable differences. The vowel /a/ exhibited the overall greatest lip opening, which is not unexpected since acoustically this vowel was lower than any other. Also, the lip spread measure for Mark's /a/ was on par with that of the front vowels rather than the central or back vowels.

3.3 Relationship between Acoustic and Articulatory Gestures

Traditionally, F1 and F2 are thought to be acoustic correlates of tongue position. In our study, we examine the relationship of lip gesture with these acoustic measures. We conducted linear regression analyses to determine the correlation and strength of association between each lip gesture and the acoustic measures of F1 and F2. In this section we present a series of graphs showing the results of our regression tests. The strength of the association between the acoustic and gestural measures is determined by the slope of the line (generated by the regression formula) in each figure, and the R^2 value is a representation of the goodness of fit to that regression line. Higher slopes and R^2 values generally indicate a stronger association between variables. Because our study has no direct measure of tongue position and also because the acoustic and articulatory measures were not time-synched, we do not expect especially high correlations, and we will generally consider correlation factors above $R^2 = .30$ to be a good correlation for our purposes.

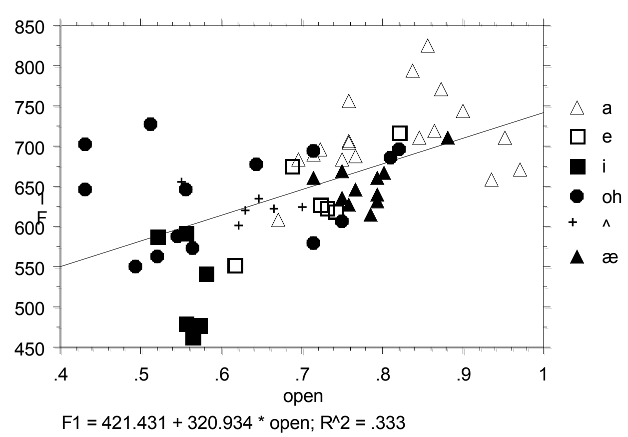

Figure 5: Lip opening as predictor of F1 (Mark) [NB: In all these regression plots, <e> = /ɛ/, <i> = /ɪ/, <oh> = /ɔ/]

Figure 5 plots values for our measure of lip opening against the F1 values for Mark. The regression line suggests a fairly good association with a substantial slope and an R^2 of .333. We interpret this to mean that lip opening serves as a good predictor of F1 value. Although we have no direct measure of tongue position per se, a lower tongue position is generally accomplished with a lowering of the jaw, which in turn causes a greater distance between the lips. This result is in keeping with the traditional view that F1 is an acoustic correlate of tongue height. We also examined the relationship between lip opening and F2 frequency but found no indications of a meaningful correlation (R^2 = .064). This result is not surprising given that F2 is generally influenced by variations in the front-back dimension not in openness.

Turning now to the effects of lip spreading, Figure 6 plots the regression between the measure of spread and F1 for Mark. The fairly flat slope of the line and the R^2 value of .042 suggest there is almost no relationship between lip spread and F1.

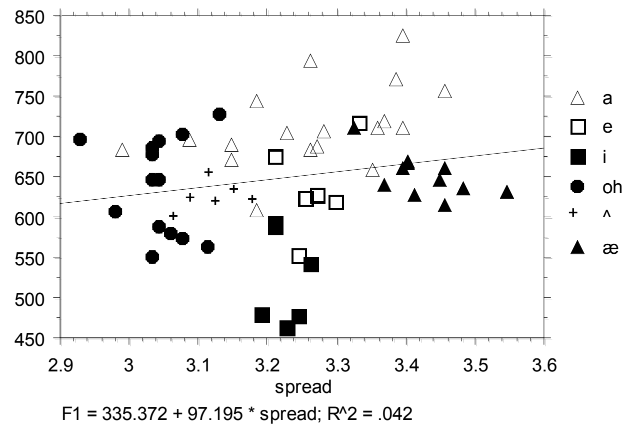

Figure 6: Lip spread not a predictor of F1 (Mark)

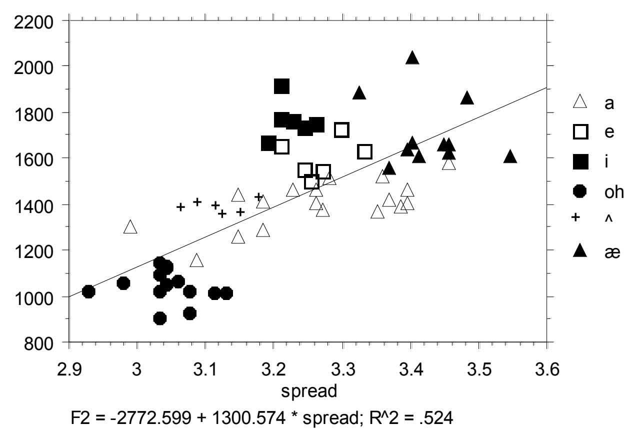

Figure 7: Lip spread is a predictor of F2 (Mark)

While lip spread does not appear to affect F1, it does show a strong correlation with F2 as seen in steep slope of the regression line and the R^2 of .524 in Figure 7. We observe that the vowels with the highest F2 generally have higher degrees of lip spread. This was especially true for the vowel /æ/. Conversely, the vowel /ɔ/ has the lowest F2 values and the lowest degree of spread.

In previous work on the NCS in St. Louis, we have often found extremely high F1 values for /a/ which we have usually interpreted as indicating that the vowel is undergoing lowering in addition to fronting. The visual measures in this study allow us to explore the articulatory dimensions of this phenomenon in more detail. Specifically, we can examine whether increased F1 values correlate with greater opening, suggesting lowering, or with some other gesture. The data from Mark offer an opportunity to pursue this question. As seen in Figure 3, Mark showed several apparently very low (and fronted) tokens of /a/. In discussing Mark's lip gesture results above, we noted that he showed the highest mean opening for /a/ and that his spread values for this vowel were more in line with those of his front vowels than his central and back vowels. Thus, his average /a/ is quite low and quite spread. Still, there is a good deal of variation in the F1 values across his /a/ tokens, and we wondered whether those tokens at the upper extreme for F1 were produced by extreme lowering, by extreme spread, or perhaps by both.

To explore this question we ran separate regression analyses on the data for /a/ alone. Figure 8 shows the correlation of F1 with lip opening and lip spread for Mark's /a/ tokens. We saw above that overall F1 was positively correlated with lip opening but not lip spread. When looking at just /a/, however, we find that lip spread is a better predictor of F1 than lip opening as indicated by the higher slope and greater R^2 for right side of Figure 8. Moreover, if we focus on the tokens of /a/ with the highest F1 values, those marked with solid dots in Figure 8, we see that these examples, which the acoustic picture suggests are the lowest in vowel space, are spread along the mid-range of lip opening but are on the higher end of the measures of lip spread. In other words, the acoustically lowest vowels are not the most open, but are among the most spread. We interpret this finding as evidence that the extreme "lowering" of many of the /a/ vowels found in the NCS in St. Louis can be accomplished by exaggerated lip spread, which like other gestures that shorten the vocal tract has the effect of raising the frequencies of all of formants.

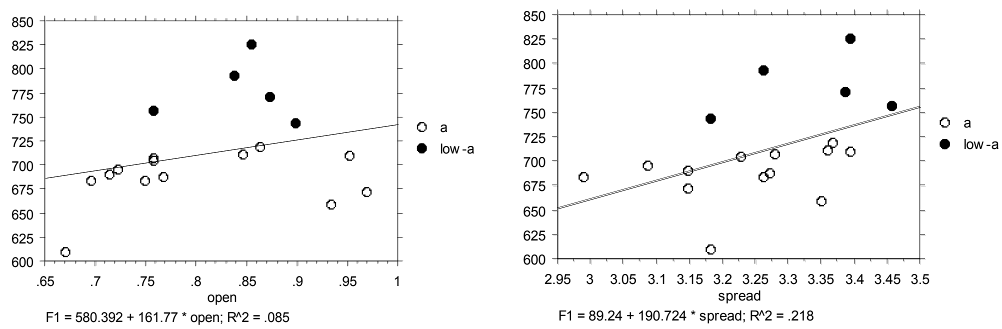

Figure 8: correlation between lip opening (left) and spread (right) for the vowel /a/ (Mark)

We turn now to an examination of lip protrusion as it relates to the acoustic realizations of F1 and F2. Table 1 gives the correlation formulae and R^2 for lip protrusion and formant values for both Mark and Melody. Neither upper nor lower lip protrusion appears to be a predictor of F1 for either speaker as indicated by the very low R^2 values. Lip protrusion was, however, a much better predictor for F2. Also, in both speakers, the lower lip was more highly correlated with F2 than the upper lip, a finding likely due to the greater mobility of the lower lip.

Mark			
Gesture		Regression formula	R^2
Protrusion upper	F1	F1 = 778.31-34.398 * upper-protrusion	.001
	F2	F2 = 10713.61-2470.89 * upper-protrusion	.402
Protrusion lower	F1	F1 = 874.228-61.751 * lower-protrusion	.012
	F2	F2 = 7334.261-1620.34 * lower-protrusion	.559
Melody			
Protrusion upper	F1	F1 = 1312.774-373.772 * upper-protrusion	.022
	F2	F2 = 4251.001-1772.795 * upper-protrusion	.114
Protrusion lower	F1	F1 = 1567.841-623.082 * lower-protrusion	.103
	F2	F2 = 4215.595-1999.521 * lower-protrusion	.241

Table 1: Correlations between lip protrusion and formant values

The regression plots showing the strongest correlation, that between lower lip protrusion and F2, are given in Figure 9. The downward slopes indicate a negative relationship between the two measures; as the lip protrusion increases, F2 values decrease. This stands to reason since greater protrusion lengthens the vocal tract thereby lowering all formants. We see a stronger correlation effect for Mark than for Melody in the steeper slope of the regression line and the greater R^2 value on the right side of Figure 9. Nevertheless, for both speakers, we find an expected general pattern in which rounded vowels, shown with round symbols on the regression plots, are the most protruded vowels. Unfortunately, the only rounded vowel examined for Mike was /ɔ/, because he read a preliminary version of the word list which lacked tokens of /o/ and /u/.

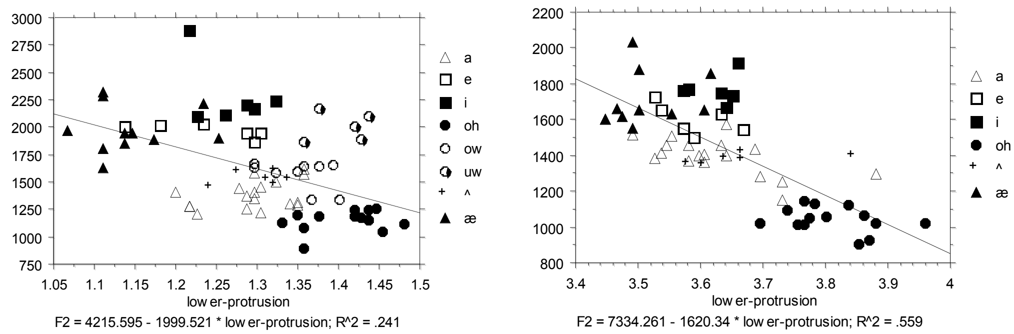

Figure 9: Correlation of lower lip protrusion and F2 for Melody (left) and Mark (right)

These results can shine some light on an important phonetic question related to the mechanics of several vowel changes including the NCS and the low back vowel merger: When rounded back vowels shift, do they retain their rounding? We have mentioned above the relatively straightforward case of /u/, which is fronted in many parts of the US. Figure 9 provides further support for the suggestion that fronting of this vowel does not involve unrounding. We see this in Melody's /u/ data for which the degree of lip protrusion is consistently high even though the high F2 values indicate fronted realizations. Thus, the vowel retains its rounding as it shifts forward.

A more complicated situation obtains in the case of /ɔ/. As it is usually described, the NCS causes /ɔ/ to undergo lowering and fronting. Acoustically, this would be suggested by increased F1 and F2 values. The end result of the shifting of /ɔ/ is typically something near [ɑ] which implies that the vowel undergoes unrounding, a process that would also show up acoustically as increased F1 and F2 frequencies. We might wonder, however, whether the shifting of the vowel in space occurs in concert with its unrounding or whether one precedes the other. This is a question that cannot be answered by acoustic data alone, and yet it is one for which the kind of visual data we examined might provide some insight. Indeed, our results suggest that the movement of /ɔ/ can proceed independently of unrounding. Melody's data in the left half of Figure 9 show that the vowel /ɔ/ is generally produced with a high level of lower lip protrusion which indicates that it can retain its roundedness even as it undergoes shifting forward and down. Still, her acoustic data (Figure 2) suggest that she does not have a great deal of shifting of this vowel anyway.

We saw stronger evidence of /ɔ/ shifting in Mark's vowel plot (Fig. 3) with the greatest dispersion in the F1 dimension suggesting lowering. To explore the correlation between lowering of /ɔ/ and lower lip protrusion as a measure of rounding we ran the regression shown in Figure 10 which plots only Mark's tokens of /ɔ/. The statistic shows no significant correlation between F1 and lower lip protrusion, and seeing the distribution of the individual tokens, this result is not surprising. It is striking that the six tokens with the highest F1 values, those that are the most lowered in acoustic space, vary greatly in terms of lip protrusion; In fact, the token with the least protrusion and the one with the most protrusion were within 20 Hz of each other on the F1 dimension. On the basis of these limited data, we suggest that the shifting of /ɔ/ in space can proceed independently of unrounding.

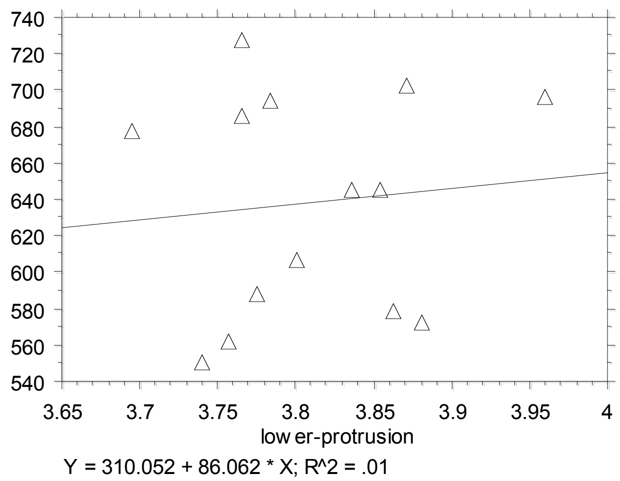

Figure 10: Regression plot of correlation of lower lip protrusion and F1 for /ɔ/ (Mark)

4 Conclusions

The study reported here has clear limitations, including the obvious fact that our observations are based on data from just two speakers. Moreover, the procedures for measuring variation in lip gestures are admittedly rather crude. Certainly much more precise measurements could be made by employing more technologically sophisticated techniques such as motion tracking using electromagnetic sensors placed on the face (e.g. Yehia et al. 1998; Kroos et al. 2002). One of our goals for this pilot study, however, was to demonstrate the fruitfulness of visual analysis even when conducted without specialized equipment.

We have learned several lessons of general methodological relevance:

- The front-view measure of lip spread is inversely correlated with the side-view measure (position of the corner of the mouth), and so only one measure is needed.
- The measure of lip opening (distance between the upper and lower lips) shows good correlation with articulatory vowel height and with degree of rounding.
- The lower lip shows greater variation in its movement (protrusion) than the upper lip, and so may serve as a more sensitive indicator of rounding.

We have also tried to point out some cases where incorporating visual analysis can shed some light on particular questions related to the NCS or other vowel changes. For example, it is well known that the effects of variable lip gestures are difficult to disentangle from those of changing tongue position on the basis of acoustic measures alone. Visual measures like those examined here offer a direct window on the degree of lip rounding and spread. Thus, we can literally see that /u/ remains rounded when it undergoes fronting or that /ɔ/ may also retain its rounding as it shifts down and forward in the NCS. Similarly, visual measures may also serve as a corrective to potentially false impressions given by acoustic data. We argued this might be the case for the NCS movement of /a/ which often shows extremely high F1 values, suggesting strong lowering of the vowel. Our data, however, indicate that this effect might be due instead to exaggerated spreading of the lips which would raise F1 frequencies as well as those of all formants. We certainly would not make sweeping claims that this happens with all NCS speakers; we are simply suggesting that it is a strategy adopted by some speakers and is perhaps more common in some areas (e.g., St. Louis) than others.

As this suggestion about the treatment of /a/ in the NCS underscores, one of the directions we hope to pursue in future research is an examination of the implementation of the shift in other locations. Our own experience as well as recent work by Labov (2007) raises the possibility that St. Louis represents a non-prototypical example of the NCS, and we would like to explore comparable studies of speakers from truly northern cities. We are also interested in applying the kinds of techniques tried here to other sociophonetic issues. As mentioned briefly above, direct measurements of rounding can be useful in the study of the low back vowel merger in helping uncover the mechanisms at play in the merger as well as its articulatory results.

In sum, we are encouraged by the results of this study, preliminary though they are, and we hope to build on this research. We also hope that researchers will take the effects of variation in lip gestures into consideration when interpreting acoustic data and perhaps consider incorporating gestural data into their analyses.

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