Comparison of lip rounding in German and English Vowels

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Abstract

This paper describes an experiment which was designed and conducted to test three hypotheses: first, that German back vowels are more rounded than their English counterparts, second, that the degree or type of lip rounding of a given vowel or set of vowels varies with different consonantal contexts, and third, that German back vowels are more rounded than front rounded vowels. The results of the Analysis of Variance suggests strongly that the first claim is true. No contextual variation was detected. The results also give some indication that the third claim is true.

Introduction

Standard German has vowels that English does not have, namely the front rounded vowels [y] and [?] (as well as short (or lax) counterparts) and a long low back vowel. English has a low front vowel which the Standard dialect of German does not (for most speakers). However, German and English are generally considered to share many vowels, that is, similar vowels in English and German are transcribed with the same symbol. For example, the vowel in "Bude" [budn̩] is transcribed with an [u] as is the English vowel in "booed" [bud]. Although these German and English vowels are transcribed the same, they do not sound the same to many ears. Thus, for example, if a native English speaker produces German words, the vowels might not sound "quite right" to a native German speaker, and vice versa.

The overall vowel quality of vowels in the two languages might be similar enough to warrant their being transcribed with the same symbol, but other details must account for the lack of total identity. One possibility is that German vowels might have slightly more (or less) extreme formant values (i.e., tongue positions would reach more (or less) towards the periphery of the vowel space). While this would have been interesting to pursue, we were more interested in collecting our own data, and we wanted to approach this problem from an articulatory perspective and not an acoustic one, so we considered another possibility.

It has been suggested that German back vowels are more rounded than their English counterparts (Disner 1983 quotes some sources). If this were true, it could account in part for the subtle differences in the vowel qualities of German and English vowels. Since a study of lip rounding would lend itself to collecting data with available equipment (a camcorder, a VCR), we decided to test the hypothesis.

It was also suggested to us that German and English vowels might behave differently from one another in similar contexts. This could also account for the perception that a German vowel spoken by a native English speaker was different from that produced by a native German speaker. It has been claimed that languages with more vowels will manifest less contextual variation than languages with fewer vowels [Keating and Huffman, 1984]. Keating and Huffman suggest that languages with fewer vowels vary more to fill up the "empty" vowel space. One might also imagine that it would be more important for a vowel to reach its articulatory goal in a language with a more crowded vowel space, since if it were to vary more, it would overlap with some other vowel's space. Thus German would define a more crowded vowel space with less room for variation of a given vowel with different contexts than would English since German has four more (monophthongal) vowels than English. This contextual variation could conceivably be realized in the degree or type of lip rounding accompanying the vowel. We therefore decided to test the hypothesis that lip rounding in German vowels varied less in the context of bilabials than did that of English vowels.

Since we were measuring lip rounding, we considered testing one other claim related to this topic. Wood (1986 p.392) predicts that German front rounded vowels must be less rounded than back vowels of like height, so that an acoustically stable "quantal region" is created. With more extreme rounding, Wood's vocal tract models predict that minor variations in the positioning of the tongue in the pre-palatal region where [y] is formed will cause large changes in the second formant frequency associated with the vowel (thus yielding a vowel of inconsistent vowel quality). However, with moderate lip rounding, relatively large variations in tongue position in this region would not affect the second formant. Wood quoted only a single source for the empirical evidence to support his claim— "private communication from Eli Fischer-Jorgensen". We therefore decided to test this as well.

Method

Subjects

Three native English speakers and three native German speakers volunteered to be videotaped as they produced words of their native language which they read as they were presented, one at a time, on index cards. Subjects were seated against a wall and a mirror was placed at a 45 angle from the wall so that a view of the side of the face appeared in the reflection.

Material and Procedure

1 x 1 cm graph paper was hung on the walls behind the subject and opposite the mirror, so that all measurements of a given frame on the VCR screen could be converted to true millimeters.

Subjects were instructed to pronounce the words in a relaxed, normal way. They were also asked to keep their heads as still as possible, and a thick book was placed on the back of the chair so that they could press against it to help immobilize their heads. German speakers read a total of 240 words and English speakers read 160. These totals broken down consist of:

Language	vowels	bilabial context	other contexts
German	all vowels (14 + Käse & bäte)	8 tokens	8 tokens
English	all vowels (10)	8 tokens	8 tokens

For this study only 6 tokens of the 8 available tokens were measured and only the high and mid tense vowels were considered.

The wordlists used are given below in Table I To minimize future measuring time, we chose to precede vowels with only two contexts, and we therefore chose what we considered to be the two most extreme consonantal contexts, that is, one which might be expected to affect the lip rounding in the vowel greatly (bilabials) and one which might be expected to exert little influence on this gesture (velar). We determined to use only real words since subjects would be getting no practice and we wanted no confusion about how something ought to be pronounced in the middle of the taping session. We therefore had to substitute on occasion an alveolar consonant for a velar in the German list. Our preference would have been to use words of CV structure; however, we considered it more important to use words for like pairs in German and English which resembled each other as closely as possible. An alveolar final consonant was selected, preferably voiced, so that the vowel would be longer. Some other minor exceptions were made.

Table I. German and English Wordlists

German vowels

bilabial environment			Other		
biete	müde	Bude	gieß	Güte	gut
bitte	Bütt	Butt	Tick	Küß'	Kuß
bete	Böte	Boot	geh'	töte	Tod
Bett	Pötte	Pott	Keß	Götter	Gott
bäte		bat	Käse		Tat
		Patt			Kacke

English vowels

bilabial environment		Other	
bead	booed	keyed	cooed
bid	put	kid	could
bade	bode	Kate	goad
bed	pawed	Keds	cawed
bad	pod	cad	cod

Measurement

Measurements were later made directly on the monitor while the tape was on "pause". A ruler was used whose smallest units were millimeters. For each vowel spoken, one frame was chosen which represented the apparent culmination of the vowel. For round vowels this was usually the point at which the lips were extended most forward, and for the unrounded vowels this was usually a frame before the jaw or lips began rising for the following consonant.

This approach differs from Linker (1982 p.3), who made a photograph of each vowel as the subjects produced them. Later, measurements were made from enlarged photographs. (Linker reports that a similar study done earlier by Fromkin was conducted in the same fashion.) We used the VCR because it was available, but we believe it is potentially the superior way to study lip movement. Since we could slow the tape down to frame- by-frame speed and reverse the picture as well, we could isolate the articulatory culmination of the vowel. Even with much experience, it was often necessary to reverse the tape to find this spot precisely and it was absolutely necessary to proceed as slowly as frame-by-frame would allow. Furthermore, often the vowel would reach this point in a single frame. But, imagine, there are 30 frames per second! We wonder how accurately one can pinpoint the achievement of an articulatory gesture by attempting to do it in real time, as Linker and Fromkin apparently did when they had to decide when to snap the picture as their subjects were producing vowels.

However, the VCR approach has drawbacks serious enough that until some way is found of circumventing them, it is perhaps no better than Linker's approach. The most important one has to do with the way measurements are made. Since Linker had hard copy, she could fix points reliably and measure distances more accurately probably than we could using a ruler on the video screen. The measures we made involved, for example, distances between a single point and several others. A point could not be marked in any way on the face of the monitor, so no point was fixed permanently. Each time we had to lift the ruler, we would have to determine again where that particular point might be. (We had consistent criteria, of course, and my feeling is that we were fairly accurate and consistent in identifying most points, although it would still be better to be positive.) Also, a point would appear to be in a different place depending on whether one was looking at it head-on or off to one side. Both of these problems could well have contributed to measurement error which was most likely avoided in Linker's approach.

The following points were defined on the lips, and various distances between them became the measures of lip movement. These particular ones were chosen because they seemed like good measures of lip protrusion and spread, lip approximation, and vertical and horizontal opening. Two variables were constructed which reflected the area enclosed by the outer boundary of the lips and by the opening between them. All variables except those involving the outer lip boundary were also chosen because Linker included them in her study.

Points		Distance between points
1,2	corners of the lips	HDO (horizontal distance-outside)
3,4	corners of the inner boundary of the lips	HDI (horizontal distance-inside)
5,6	point on the outer boundary of the lips half-way between 1 and 2	HFO (half-outside)
7,8	points on the inner boundary of the lips halfway between 3 and 4	HFI (half-inside)
9, 10	points halfway between the	FQO (first quarter-outside)
11,12	left corner and halfway point and right corner and half-way point, respectively	SQO (second quarter-outside)
13,14	points halfway between the left inside corner and the inside halfway point and likewise on the right side	FQI (first quarter-inside) SQI (second quarter-inside)

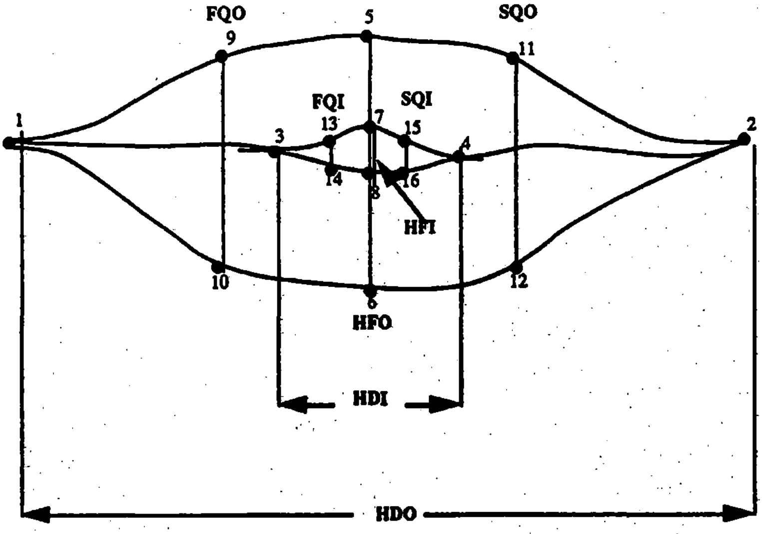

Figure 1. Frontal Measurements

<u>Constructed variables</u>

OAREA—the area enclosed by the outer boundary of the lips
IAREA—the area of the opening between the lips

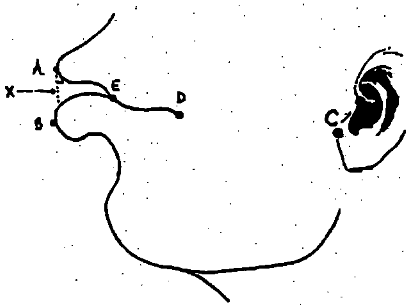

Figure 2. Side Measurements

<u>Points</u>

A	the furthest point out on the upper lip
B	the furthest point out on the lower lip
C	a stationary reference point: where the earlobe meets the face
D	the corner of the mouth
E	the point of forward-most contact of the lips
X	a line dropped vertically from A

Distances between points

AB	distance between the lower and upper lips
DC	distance between the corner of the mouth and the reference point
AC	distance between the upper lip and the reference point
BC	distance between the lower lip and the reference point
AD	distance between the upper lip and the corner of the mouth
BD	distance between the lower lip and the corner of the mouth
ED	length of contact between the lips
AE	distance between upper lip and forward-most contact of lips
BE	distance between lower lip and forward-most contact of lips
XE	distance between E and the reference line dropped from A

Analysis

Analysis of variance (ANOVA) procedures were used to analyze the data collected. Three different models were constructed. The first modeled each dependent variable (i.e., each of the measures identified above) as a function of the classificatory independent variables *round, language, speaker,* and a *round x language* interaction. The second modeled each dependent variable as a function of the independent variables *vowel, language, speaker*, and a *vowel x language* interaction. The third added *context* and the interactions *context x language, context x vowel*, and *context x vowel x language* to the independent variables of the second model.

The main effects of *round, vowel, language*, and *context* were examined for their significance. Here we would be asking if a significant amount of the variance in the dependent variable was being accounted for by that particular effect. However, we could interpret a significant result directly for a given dependent variable only if there were no significant interactions involving the independent variables.

The interactions were also examined for significance. By testing the significance of the *round x language* interaction, we are asking if the difference between the means for the German and English rounded vowels is different than the difference between the means for the German and English unrounded vowels. That is, a given measure might behave differently in German than in English for the different values of "round". In other words, does German implement "round" differently than English?

The results of the *vowel x language* interaction will indicate whether vowels which are transcribed the same in German and English differ in different ways from each other (e.g., round vowels might involve less vertical opening in German but unrounded vowels might involve more).

The test of the *context x language* interaction probes whether German vowels vary overall with context differently than English vowels. The test of the *context x vowel* interaction tells whether different vowels behave differently in different contexts across the two languages. And the *context x vowel x language interaction*, if significant, will say that some individual vowels interact differently with context in German than in English.

For measures with significant interactions, a Newman-Keuls test was performed to determine which simple effects were significant. If a simple effect was significant, the means were compared to determine the direction of the difference.

A one-way ANOVA was done for German front and back rounded high vowels and one was done for the front and back mid vowels, modeling the dependent variables as a function of *vowel*. Results were examined for significance levels.

Results

A summary of some results is given in Table 2. These include the significance of the interactions of language and other independent variables, the significance of the main effect of language, and a comparison of the means of German vowels (without the front rounded vowels) with the English vowels for each dependent variable for which there was at least one interaction which was not significant and for which the main effect of language was significant.

Table II. Summary of selected ANOVA results (dashes indicate a non-significant result)

variable	round x language	vowel x language	context x language	language	comparison of means
HDO	--	--	--	.0001	E > G
HDI	--	--	--	.0001	E > G
HFO	--	--	--	.0001	E > G
FQO	--	--	--	.01	E > G
SQO	--	--	--	.0001	E > G
AC	--	--	--	--	
BC	--	--	--	--	
AB	.01	.01	--	--	
DC	--	--	--	--	
ED	.0001	.0001	--	.0001	E > G
AD	--	--	.04	.0001	G > E
BD	--	--	--	.0001	G > E
XE	--	.0001	--	.0001	G > E
HFI	--	--	.02	.0001	E > G
FQI	--	.05	--	.005	E > G
SQI	--	--	--	.001	E > G
AE	.0001	.0001	--	.001	E > G
BE	.0001	.0001	--	--	
OAREA	--	--	--	.0001	E > G
IAREA	--	.05	--	.0001	E > G

Main Effects

1.- For all measures taken from the head-on view, English means are consistently larger for all vowels. These are measures of horizontal and vertical opening. The one exception is the variable *FQI*, which shows an interaction of vowel x language.

An analysis of the simple effects shows that the mean for this measure in the English vowel [o] is larger than that of the German, but for all other vowels, there is no significant difference. (The means themselves are given in Appendix A.)

2.- The only measures of lip protrusion which were made from a stationary reference point (AC, BC) are not significant for any measure.

3.- Other measures of lip protrusion, namely AD and BD, are consistently larger for all German vowels. There is an interaction of context and language for the variable AD; however, the means of the German vowels in each context are still larger than those of the English vowels in corresponding contexts.

4.- Two effects not listed in this Table 2 are context and *context x vowel*. Neither was significant for any dependent variable.

Interactions

1.- *round x language* This interaction was significant for 4 dependent variables. Graphs of the means are presented below in Figure 3. Significant differences between the means between languages was determined with Newman-Keuls tests and are marked with an asterisk. (All are significant at the $p < .05$ level.) Ignoring the differences in the unrounded vowels for the time being, only ED and BE show a significant difference for German and English back rounded vowels. ED is longer in German vowels and BE is shorter.

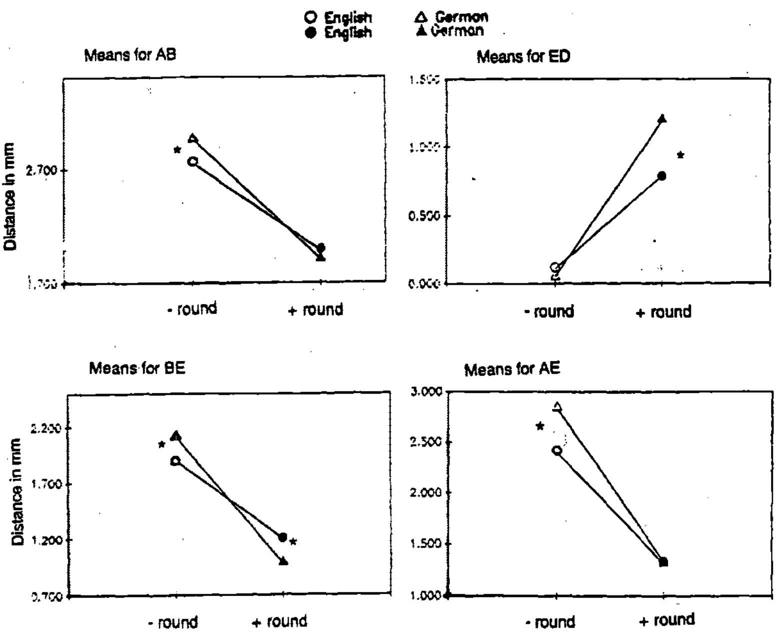

Figure 3. Significant Round x Language Interactions

2.- *vowel x language* This interaction was significant for 7 variables, 6 of which we will consider here. Graphs of the means for these are presented below in Figure 4. Again, differences between the same vowels in the two languages were determined by Newman-Keuls tests. All differences which are significant are significant at a $p < .05$ level and are marked with an asterisk.

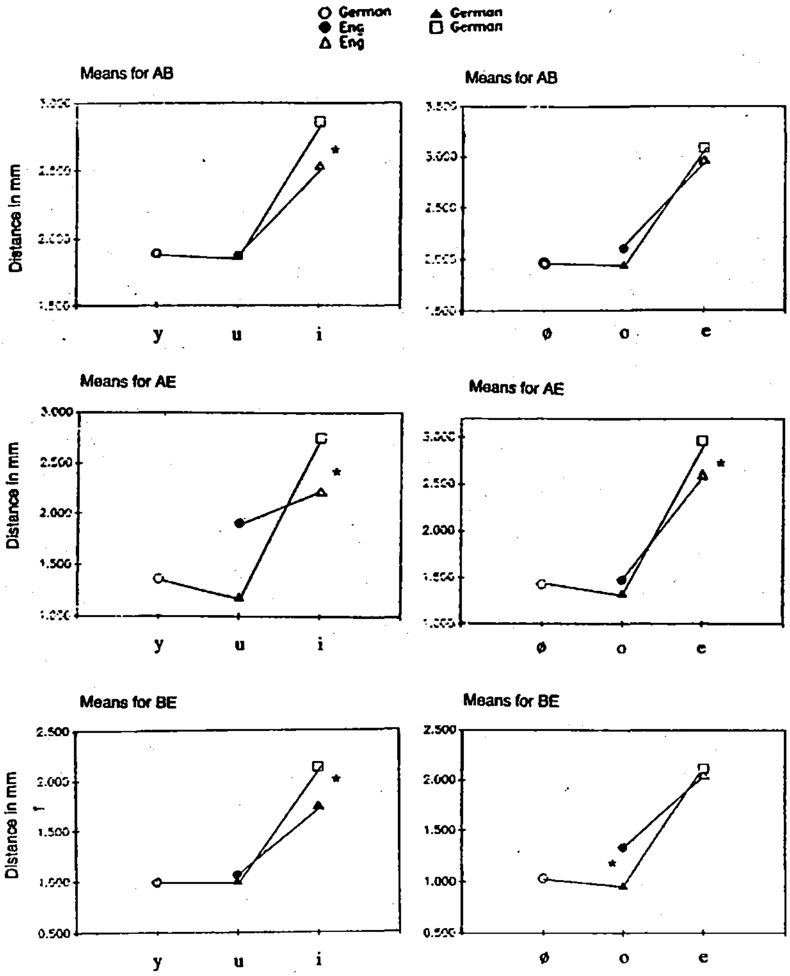

Figure 4. Significant Vowel x Language Interactions

Ignoring the unrounded vowels, it can be seen that the only consistent measures for distinguishing both the high and mid back German vowels from their English counterparts are ED and IAREA. German rounded vowels have larger

ED's and English vowels have greater IAREA. The only other significant result involving rounded vowels is that for the back mid vowel, BE is longer in English than in German.

3.- *context x language* This interaction was significant for two variables, HFI and AD. The means are presented below in the graphs in Figure 5. Apparently, HFI is shorter for German vowels in a bilabial context than the other context, and the reverse is true for English vowels. However, none of these simple effects within language is significant (and none even approaches significance). The means for AD are shorter for the German vowels in a bilabial context as well, and the reverse is true for English vowels. However, again none of these simple effects are significant. That of German bilabials versus other approaches significance at p < .08.

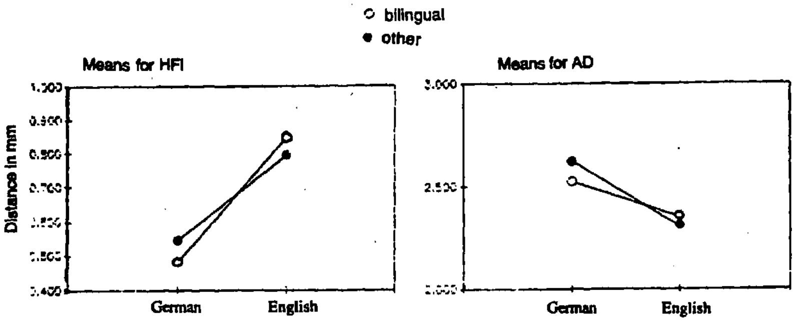

Figure 5. Significant Context x Language Interactions

German front rounded versus back rounded vowels

1. The same measures were not significant for the high and mid vowels. Only AE was significantly different for [y] and [u], and HDI and SQI were significantly different for [ø] and [o]. No other measures for either high or mid rounded vowels proved significant. A list of means for these significant measures is given in Table 3. Note that [y] has a significantly longer AE than [u] and that [ø] has significantly larger HDI and SQI. All were significant at the p < .05 level.

Table 3. Means for selected measures for German rounded vowels

AE		HDI		SQI	
[y]	1.36672176	[ø]	1.47731458	[ø]	18719131
[u]	1.19645537	[o]	1.22754611	[o]	15092589

Discussion

Main Effects

Returning to the first question posed in the introduction, it seems that German back vowels are indeed more rounded than their English counterparts. These

German vowels are firstly more closely approximated than in English, as they all involve significantly less vertical opening and horizontal opening. However, close approximation is only one component of rounding or one possible way of implementing this feature. It is possible that the these German vowels are more closely approximated but not more protruded. To determine this, we must consider the measurements taken from the side view and examine specifically measures of lip protrusion. Unfortunately, since the measures of protrusion measured from a fixed reference point proved to be not significantly different, i.e., AC and BC (probably because their variances were quite large), we must turn to other measures which perhaps do not provide this information as directly.

AD and BD were consistently longer for German vowels than for English vowels. Recall that these are distances between the outermost points on the upper and lower lip respectively and the corner of the mouth. If the lips are more protruded, A and B would be expected to extend more away from the face. However, as the lips move forward they are also being compressed sideways. This along with the protrusion shifts point D forward as well. As the lips extend forward, the length of AD and BD increases, and so, ultimately, these are measures of lip protrusion. But the means of these two measurements are most likely an underestimate of the degree of absolute lip protrusion. Thus, it is accurate to say that German back vowels are also more protruded than their English counterparts.

Interestingly, AD and BD are also longer for German spread vowels ([i] and [e]) as well. Here this longer distance seems not to be a reflection of greater lip protrusion, but rather of greater spread. As the lips are pulled farther back, the length of AD and BD should increase. See Figure 6 below.

<u>Interactions</u>

Some variables tested significantly for interactions. The results of the simple main effects within the round x language interaction for ED and BE support the conclusions in (A) above although it is not as easy to see how. BE is shorter in German back rounded vowels than in English back rounded vowels. While it seems as if BE is a similar measure to BD (and thus should be expected to lengthen if the lips were extending farther forward), it is really quite different. Recall that B is the point of forward-most contact of the lips. The longer the length of this contact, the less distance there is left over from the point where the lips separate (E) to the outermost points on the upper or lower lip. Note also that the length of the contact of the lips referred to above is the measure ED. When the lips are more protruded, it should be longer. (See Figure 7). Thus, one can conclude that German back vowels are more protruded than English back vowels, which supports the claims in (A).

The results of the *vowel x language* interaction don't tell much of a neat story about the way various identically transcribed vowels behave differently in the two languages. First, however, it can be said that the results of the tests of the simple effects within this interaction for the variables ED and IAREA lend further support to the claim that German back vowels are more rounded than English. ED is significantly longer for German [u] and [o], corresponding to greater upper and lower lip protrusion as discussed above. (See Figure 7). However, one wonders why there is no difference in the means of BE or AE. Could the lips be extended so far forward that a BE and AE distance is created equal to that of the English less protruded vowels?

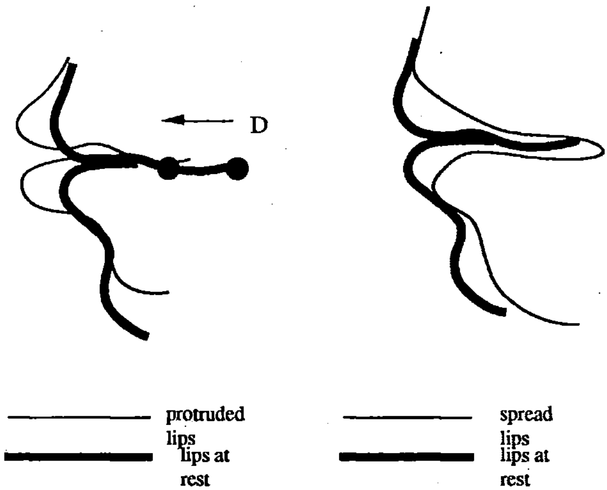

Figure 6. The Effect of AD and BD

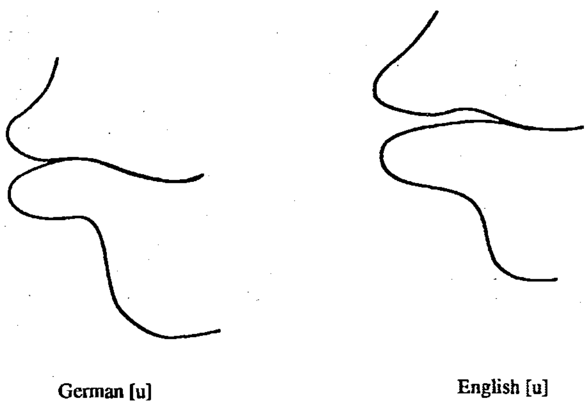

Figure 7. The Effect of BE and ED

Another possibility is that English back vowels are less protruded and more approximated at the same time. However, all measures of lip approximation show that English vowels are less approximated (except for AB, which is not significant). Means for the area of the opening between the lips (IAREA) are also greater for all English vowels. This also suggests that the lips are less approximated and less protruded in English back vowels. However, the spread English vowels also have greater area of opening than German spread vowels. Given that German non-round vowels seem to be more spread based on the interpretation of their greater AD and BD lengths, one wonders if increasing the spread of the lips decreases the area. It certainly does not seem as if it would. Furthermore, AE, BE and AB are all longer for German [i], suggesting that the upper and lower lips are more stretched out and the distance between the outermost points of the two lips are farther apart than in

English [i]. That is, it suggests that German [i] is more spread. Only AE is significantly longer for [e] in German than English, suggesting that the lower lip is not as stretched back in [e] as it is in [i] in German.

The results of the context models are not what we expected. There is no *context* effect whatsoever for any measure. This suggests that the lip rounding in vowels is no different in bilabial contexts than in velar ones, that is, vowels do not coarticulate in terms of the lip gesture with bilabial consonants. One might wonder about the significant interaction for the *context x language* effect found for variables HFI and AD. However, none of the simple main effects within language was significant. In other words, there was no difference in the means of the variables HFI or AD for English vowels in bilabial versus the "other" context. That is, the situation with these two variables is no different than for every other measure in terms of a relevant context effect.

This does not contradict the findings of Keating and Huffman, who noted that Japanese vowels varied with certain contexts. Their contexts were different; they compared prosodic contexts—word in wordlists versus words read embedded in prose. We just expected to see some effect of a bilabial environment on rounded vowels.

Turning now to the final question of whether German back rounded vowels are more rounded than front rounded vowels, the situation is also a bit murky. AE is significantly different for [y] and [u], and the mean of [y] is greater than that of [u]. This suggests that the upper lip is less protruded in [y] by reasoning analogous to that used in interpreting BE above (see Figure 7). However, all other measures are not significantly different from one another, most notably the area of the opening between the lips and the other measure of upper lip protrusion AD. We think that with either more data or more accurate measurements the problem might be resolved-most likely in favor of stronger support for Wood's claim.

Strange also is the fact that AE is not significantly different for [ø] and [o], so, apparently, [ø] does not involve more upper lip protrusion than [o]. Other measures-of horizontal opening (HDI) and vertical opening (SQI)—are significant, however, and this suggests that [ø] is less approximated than [o]. Of course, Wood didn't make any predictions about front rounded mid vowels in the 1986 paper.

At any rate, there are apparently some differences between German back rounded vowels and front rounded vowels.

Conclusion

We sought to answer three questions with this project. Are German back rounded vowels more rounded than English back rounded vowels? Do German vowels vary more with context than English vowels? Are German back rounded vowels more rounded than front rounded vowels?

We think it is very clear that the answer to the first question is a definite yes. The other two questions were answered less confidently. We could find no effect of context. Perhaps with more precise measurement techniques or more varied contexts, one would detect such an effect. We uncovered limited support of Wood's prediction. We would have expected other effects to be significant, but given that a consistent, although not unambiguous, measure of upper lip protrusion was significant for [u] and [y], cautious support of the claim that [y] is less rounded than [u] is extended. We suppose that with more precise measurements, stronger effects would be uncovered. In addition, something which has not been previously mentioned might have obscured some smaller effects. Measurements were not modified in any way to neutralize differences in shapes and sizes of speaker's lips. These differences certainly existed, the question is whether they were large enough to cover up effects. We think it would be a worthwhile question to pursue.

Finally, we suggest that some improvement of the method we used in this experiment in terms of making more accurate and precise measurements would make this approach far superior to those which involve making static records of a dynamic articulatory gesture.

*The original version of this paper was presented in the 119th meeting of the Acoustical Society of America, State College, Pennsylvania, 21-25 May 1990.

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Appendix A : Means for dependent variables by language

dependent variable	German	English
HDO	5.074465725	6.42247748
HFO	2.198813670	3.59766604
FQO	2.162718415	2.44257300
SQO	2.554385075	2.980625045
AC	10.8798038	10.60764903
BC	10.71210527	10.35472996
AB	2.272693475	2.37592131
DC	8.93014642	8.84531106
ED	0.83037591	0.457089875
AD	2.57639892	2.334414875
BD	1.91206837	1.71832825
XE	1.22180332	1.172476725
HFI	0.515213405	0.81974796
FQI	0.38512083	0.550455275
SQI	0.43835514	0.71371507
AE	1.84151771	1.874316315
BE	1.37503010	1.55356930
OAREA	7.00491681	9.09679273
IAREA	0.84705746	1.57053812