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Vowel Intrinsic Pitch in Connected Speech

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Abstract. We investigated whether 'intrinsic pitch' (IP) effects occur in connected speech. Fundamental frequency differences between German high and low vowels were measured in two different experimental conditions: (1) a typical laboratory task in which a carrier sentence served as a frame for test vowels; (2) a paragraph reading task in which test vowels occurred in a variety of prosodic environments. By comparing test vowels in comparable segmental and prosodic environments, it was shown that the IP effect does occur in connected speech, but that the size of the differences between high and low vowel fundamental frequency is somewhat smaller than in carrier sentences. Some tentative hypotheses are presented concerning the influence of prosodic environment on the magnitude of IP differences.

Introduction

One of the more distracting issues in testing and evaluating models of sentence intonation is the question of how to allow for differences of 'intrinsic pitch' (IP).[1] Since the fundamental frequency (F_0) differences attributable to IP vary greatly from study to study (and from speaker to speaker within studies), it is difficult to establish 'correction factors' for IP in raw F_0 data. Moreover, it is known that prosodic and segmental environment affect the size of IP differences (e.g. IP differences are larger in stressed vowls than in unstressed vowels) [*Reinholt Petersen,* 1979], but again the quantitative details are scarcely well enough understood to correct raw data in an empirically defensible way. As a result, it appears necessary for quantitative studies on intonation to control for IP by controlling the vowels in test utterances. This obviously constrains the kind of material that can be used in such studies, and in particular, it makes it difficult to use recorded natural dialogue.

[1] IP is the by now well-studied phenomenon whereby the fundamental frequency (F_0) of a high vowel is higher than that of a low vowel, other things being equal. This effect is known to occur in a wide variety of languages and under a considerable range of experimental conditions. For general discussion of IP see e.g. *Lehiste* [1970, pp. 68–71] and *Hombert* [1978, section 4].

In a recent report by *Umeda* [1981], the hypothesis is advanced that IP is at least partly an artifact of experimental methods that use isolated words and carrier sentences. Instead of this procedure, *Umeda* [1981] measured F_0 in a large number of vowel tokens, in various consonantal environments, taken from readings of a 20-min. connected text. On this basis she concluded that in connected speech vowel height has no consistent effect on F_0. If this conclusion could be confirmed, it would simplify the testing of quantitative models of intonation. Unfortunately, her finding is questionable, because she apparently made no attempt to control for the prosodic environment of the vowels she measured; she seems to have treated vowels taken from any position in intonation contours as comparable. Since the range of F_0 differences attributable to intonational features is considerably larger than that ascribable to IP, intonational effects could easily have overridden the IP effect *Umeda* [1981] was looking for.[2]

The main goal of the present experiment was to study IP effects in connected speech while at the same time controlling for differences of prosodic environment. The specific question investigated was whether *Umeda's* [1981] finding could be confirmed in a more rigorously controlled experiment. A secondary goal was to explore the influences of a variety of prosodic environments on IP. In particular we hoped to build on the studies of *Reinholt Petersen* [1979], *Steele and Godfrey* [1982], and *Shadle* [1983], in which it was found that various prosodic differences such as degree of stress affect the size of IP differences. (These studies will be discussed in the 'Results and Discussion' section.)

Method

Materials

In order to measure intrinsic pitch in connected speech, we constructed three paragraphs, each approximately 100 words long, representing three different written genres (crime novel, fairy-tale, and news bulletin). The three paragraphs contained a total of 14 locations where a test word with either a high vowel or a low vowel could be inserted. The test words were mainly names and numbers, chosen so that the substitution would affect the prosody and the sense as little as possible. The three paragraphs and the test words are given in 'Appendix A'.

In selecting pairs of test words for comparison, we had to strike a balance between the need to construct natural-sounding prose and the need to compare test vowels in identical phonetic environments. We used the following criteria. We ignored differences of backness and rounding among the high vowels, i.e. we compared /a/ with any of /i, y, u/. However, we did not ignore vowel length: there were seven long vowel pairs and seven short vowel pairs. These decisions were based largely on the results of *Antoniadis and Strube* [1981], who found no significant differences in IP among German vowels of the same height and length, but significant differences between otherwise identically specified short and long vowels. To minimize the effect of neighbouring consonants on F_0, we used test vowels preceded and followed by resonants wherever possible; in no case is a test vowel directly preceded by a stop. A few of the pairs are perfect minimal pairs, e.g. 'liegen/lagen', but in most there are slight differences of phonetic environment, e.g. 'zwanzig/fünfzig'.

[2] This possibility is further suggested by the amount of variation within *Umeda's* [1981] vowel tokens. Whereas the IP differences reported in other studies are commonly between 1 and 2.5 semitones, *Umeda* [1981, p. 351] reports a range of 7.4 to 14.7 semitones (80–200 Hz) variation between the F_0 of the same vowels in different positions in her prose passage. This F_0 variation corresponds in magnitude to that often produced by different intonational choices in normal, non-emotional speech.

In order to be able to interpret the magnitude of the IP effects obtained for each speaker, we included a second condition where test vowels in comparable segmental environments were embedded in carrier sentences. We designed a list of 14 pairs of words to be read in the frame *Er hat '...' gesagt*. These carrier sentence pairs are given in 'Appendix B'. We could not use the same words as in the connected speech condition, for two reasons. First, some of those words were not in citation forms (e.g. verb past tenses), which would have made for unusual sentences such as *Er hat 'rief' gesagt*. Second and more important, since the carrier sentences and the paragraphs were read in combined test sessions, the carrier sentences would have drawn the subjects' attention to the test words in the paragraphs, and thereby reduced the naturalness of the connected speech. As much as possible, we found pairs that matched environments exactly with test pairs in the paragraphs, e.g. 'Lage/Lüge' to match 'lagen/liegen'. But this was not always possible, and in some cases we matched preceding environments in one pair and following environments in another, e.g. 'knarrte/knurrte' was matched by 'knallen/Knüller' and 'warten/wirken'. Since we did not compare individual pairs with each other, but only averaged the magnitude of the IP effect across all pairs, we felt that this was a sufficient control.

Procedure

The materials were recorded by 4 educated native speakers of German, 2 males (A.K. and L.S.A.) and 2 females (E.G. and U.S.). There were two recording sessions several days apart. In each session each speaker read one version of the three paragraphs six times. The order of the paragraphs was varied, and in between the paragraph readings half of the carrier sentences were read in differing random orders. In this way, order effects were minimized and six repetitions of vowel in each test pair were obtained. Recordings were made in a sound-attenuated booth with a Sennheiser MD 421N microphone.

Speakers were not told the exact purpose of the experiment, but were asked to read the paragraphs in a manner appropriate to the subject-matter (e.g. as if they were actually reading the fairy-tale to a child or as if they were actually broadcasting the news). They were asked to read the carrier sentences as separate complete sentences, not as a list. They were told that there would be slight differences in the materials to be read at the second session.

For the F_0 analysis of the 2 female speakers, we digitized the recordings at 16 kHz and extracted F_0 with an autocorrelation-based program using a 31-ms window. For the male speakers we were able to use the analysis hardware at the University of Copenhagen Phonetics Laboratory. For purposes of data analysis, we took the F_0 of each test vowel to be the F_0 value at the energy peak of the syllable.[3]

Data were analysed separately for each speaker. For each test pair we calculated the difference in semitones between the mean F_0 of the six high vowel tokens and the mean F_0 of the six low vowel tokens. We then calculated average IP effects by taking the mean of these semitone intervals. This yielded, for each speaker, a mean IP effect for the connected speech condition and a mean IP effect for the carrier sentence condition. To test *Umeda's* [1981] hypothesis that IP is overridden in connected speech, we tested whether these effects were significantly different from zero, and whether they were significantly different from each other.

3 We also investigated an alternative measure of the F_0 associated with each vowel. Instead of taking the F_0 value at the energy peak, we took the value at the F_0 peak *of the syllable*. The F_0 contour nearly always reached its peak later than the energy peak of the vowel, in some cases even in the next phonetic segment. (This was particularly true when the vowel was followed by a nasal.) It was in these cases that the two resultant estimates of IP deviated most from each other. For example in the 'connected speech' condition the IP effect for speaker A.K. in the pair Mannheim/München according to the energy peak measure was 2.75 semitones, whereas for the F_0 peak measure it was 1.48 semitones. Nevertheless, despite such differences in individual vowels, the overall pattern of the results was almost the same for both measures. We have chosen to use the energy peak measure in this report because (i) it more clearly gives the F_0 value *within* test vowels, (ii) it allowed easier identification of the correct place to measure the F_0 in the raw extractions, and (iii) it usually produced less variance within the six repetitions of each test word.

Table I. High: low intervals in semitones in connected speech and carrier sentence conditions compared with zero (t test for single samples, two-tailed probabilities)

Speaker	Condition	Mean high : low interval	Standard deviation	t	Probability
A.K.	connected	1.25	0.92	4.899	$p < 0.001$
	carrier	2.19	1.72	4.764	$p < 0.001$
L.S.A.	connected	1.37	0.78	6.333	$p < 0.001$
	carrier	2.33	0.66	13.209	$p < 0.001$
E.G.	connected	0.69	0.64	3.887	$p < 0.01$
	carrier	1.59	1.40	4.249	$p < 0.01$

Results and Discussion

Testing Umeda's Claim

After the recordings were made, we found it necessary to make the following modifications to the procedure just described. First, the test pair 'saßen/schliefen' in the connected speech condition was excluded from the statistical analysis, because the speakers used different stress patterns with the two (they generally said 'als sie gerade zu TISCHE saßen' but 'als sie in ihren Betten SCHLIEFEN'). This means that the connected speech IP effects were calculated on the basis of 13, not 14, test pairs. Second, the carrier sentence data for speaker U.S. were excluded from further analysis, because despite several reminders she frequently fell into 'list intonation' in the carrier sentence condition (i.e. sustained or rising F_0 after the accent peak), instead of using a separate falling declarative contour on each sentence. We felt that this would make any mean F_0 value for the test vowels unreliable as a basis of comparison.

Mean IP effects for the carrier sentence and connected speech conditions are given for speakers E.G., L.S.A., and A.K. in table I. (Data for the individual test pairs are given in 'Appendices C' and 'D'.) In both conditions, for all speakers, the effects shown are significantly different from zero ($p<0.01$ or better). In other words, once prosodic environment is appropriately controlled, the IP effect is clearly present in connected speech as well as in carrier sentences. It appears that *Umeda's* [1981] conclusion should be rejected.

However, comparison of the effects also shows that IP differences are smaller in the connected speech condition than in the carrier sentence condition. This is shown graphically in figure 1. The difference was statistically significant for E.G. ($t = 2.07$, d.f. = 25, $p<0.05$) and L.S.A. ($t = 3.45$, d.f. = 25, $p<0.01$) and approached significance for A.K. ($t = 1.78$, d.f. = 25, $0.2>p>0.1$).

At least two explanations for this difference are possible. One is in effect that *Umeda* [1981] is partly right, and that IP differences, though not absent, are generally reduced in connected speech. This seems consistent with other findings about the difference between words in connected speech and words in carrier sentences or in isolation – e.g. that in the latter conditions vowel formants are farther from those of a centralized neutral vowel than in connected speech [*Stålhammar* et al., 1973; *Shearme and Holmes*, 1961]. The second possible explanation is that the smaller overall IP effect in the connected speech condition is due to the averaging together of very small IP effects in certain prosodic environments with normal (i.e. carrier-sentence-sized) effects in other environments. It might be, for example, that unstressed syllables show little or no IP effect, while stressed syllables show as much (or nearly as much) in the connected speech condition as in the carrier sentence condition; together these would yield a smaller mean effect.

Our data do not justify a clear choice between these two explanations, and of course, the two are not mutually exclusive. However, we do find some support for the second possibility. A one-way analysis of variance (with speakers as a repeated measure) indicated that there was consistent variation in the size of the intrinsic pitch differences in the test pairs in the connected speech condition ($F(12,36) = 2.211$, $p<0.05$), but only random variation in the carrier sentences ($F(13,26) = 1.760$, not significant). This suggests that the IP of at least some of the test pairs was being systematically influenced in the passages of connected speech. The nature of this influence is examined in more detail in the next subsection.

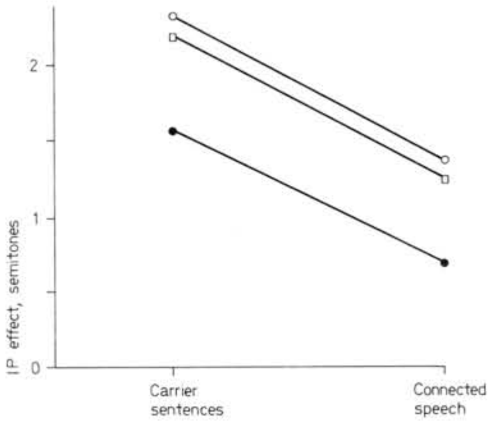

Fig. 1. Comparison of the IP effects in the connected speech and the carrier sentence conditions. See text for statistical tests of the differences within each speaker. ○ = L.S.A. (male); □ = A.K. (male); ● = E.G. (female).

Effects of Prosodic Environment on IP

Results reported by *Reinholt Petersen* [1979], *Steele and Godfrey* [1982], and *Shadle* [1983] show that the size of the IP effect is reduced in certain prosodic environments. *Reinholt Petersen* [1979] has shown clearly that IP is smaller in unstressed syllables than in stressed syllables, and that the size of the effect also appears to decrease during the course of an utterance. *Steele and Godfrey* [1982] and *Shadle* [1983] have shown that IP is sharply reduced in syllables after the last major accent of the intonation contour. However, none of these results permit clear differentiation among the roles of pitch level, degree of stress, and position in sentence or clause in affecting IP.

In designing the test paragraphs for our experiment, we located test pairs in different prosodic environments in order to try to distinguish these different effects on IP. We included the following comparisons:

Phrase-final, post-nuclear, low (pair 5) versus phrase-final, post-nuclear, high (pair 11)

Phrase-final, post-nuclear, low (pair 5) versus phrase-final, nuclear, low (pair 7)

Phrase-final, post-nuclear, low (pair 5) versus phrase-medial, post-nuclear, low (pair 3)

Phrase-final, post-nuclear, high (pair 11) versus phrase-final, nuclear, high (pair 13)

Table II. Mean IP effect per test pair across speakers in the connected speech condition

	Word pair	Mean IP, semitones
1	Müller/Meyer	2.23
2	fünfzig/zwanzig	1.62
3	rief/sprach	0.53
4	knurrte/knarrte	1.15
5	Müller/Meyer	0.25
6	Ulrich/Albrecht	0.89
7	Wilhelm/Walter	1.26
8	krumm/krank	0.56
10	Münchener/Mannheimer	0.95
11	Lokomotivführer/LKW-Fahrer	1.20
12	einundfünfzig/neunundzwanzig	1.88
13	München/Mannheim	0.81
14	liegen/lagen	0.68

Pair number 9 ('sassen/schliefen') was not included in the analysis, and so is not shown in the table.

Table II shows the mean intrinsic pitch effects across speakers for each test pair in the connected speech condition. None of the above comparisons showed statistically significant differences between the IP of the pairs, although the second (pair 5 versus pair 7) neared significance ($F(1,12) = 3.503$, $p = 0.08$). However, while no very clear pattern emerged from these comparisons, the following speculative generalizations appear justified. The clearest result was that post-nuclear, low pairs (3 and 5) had a smaller average IP difference than other environments (Scheffé post hoc comparison of pairs 3 and 5 with the remaining eleven pairs: $F = 29.86$, $p < 0.05$). In particular, the IP difference in these cases was generally smaller than the high post-nuclear pair (11). (See 'Appendix C' for the individual speaker data.) This pattern of results points to the conclusion that low pitch, rather than low-stress or phrase-final position per se, is the relevant factor in *Shadle's* [1983] and *Steele and Godfrey's* [1982] results.

However, the stipulation 'low pitch' cannot stand unqualified, since for all speakers the low phrase-final nuclear pair (7), unlike the low phrase-final post-nuclear pair (5), showed a normal-sized IP effect. This is so despite the fact that the absolute F_0 level in the two pairs is comparable within speakers. However, in most descriptions of intonation the nuclear syllable in pair 7 would be analysed as an underlying falling accent or high-low sequence. This phonological high, rather than the actual F_0 low, may be relevant for determining the size of the IP effect.

Inspection of the data for each subject ('Appendix C') shows that there was a considerable amount of variation across speakers within test pairs in both experimental conditions, and across test pairs within speakers in the carrier sentence condition. This suggests that individual production differences and differences of segmental environment have a considerable effect on the magnitude of IP. Since the planned comparisons in this section of the paper did not control for segmental differences and were based on only six repetitions of each test vowel, any potential pattern in the results was susceptible to being masked by such extraneous factors. It is clear that any study of the influence of prosodic environment on IP must control more carefully for both the influence of segmental environment and interindividual variation in production.

Conclusion

This study has several methodological implications for the investigation of sentence intonation. Most important, by controlling for prosodic environment, we have shown that intrinsic pitch differences do occur in connected speech. This refutes *Umeda's* [1981] hypothesis that IP is an artifact of experiments based on carrier sentences, and makes it seem highly probable that IP effects are present in natural speech as well.

However, our data do not suggest any simple means of 'correcting' raw F_0 data. On the contrary, it appears that both prosodic and segmental environment have a considerable influence on the size of IP differences, and that these environmental effects vary from speaker to speaker. Until the role of all these factors is better understood, the best procedure for experimental studies of sentence intonation is probably not to correct F_0 data post hoc, but to control the segmental content of experimental speech material in advance. This procedure has been followed by e.g. *Cooper and Sorensen* [1981] and *Liberman and Pierrehumbert* [1983].

As for investigating the effects of prosodic and segmental environment on IP, it appears necessary to use experimental procedures – like those of *Reinholt Petersen* [1979], *Steele and Godfrey* [1982] and *Shadle* [1983] – in which all these variables are carefully controlled. Such studies do not of course need to be restricted to single sentences, and indeed we believe that paragraphs of the sort we have used here will be very useful in creating certain types of prosodic environments. But our results seem to lay to rest the suspicion that IP is an artifact of the very means used to investigate it.

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Appendix A

Paragraphs for 'connected speech' condition. Test words are shown in their locations, with the test vowels indicated.

Crime Novel

Plötzlich wurde M*e*yer / M*ü*ller ganz still. Keine f*ü*nfzig / zw*a*nzig Meter vor ihm bewegte sich ein Schatten. Er zog seine Pistole aus dem Halfter und wartete. Der Schatten bewegte sich wieder. «Wer geht da?» r*ie*f / spr*a*ch er den Fremden drohend an. Aus der Dunkelheit kn*a*rrte / kn*u*rrte eine unbekannte Stimme. «Hände hoch, M*e*yer! / M*ü*ller! Polizei!» Ein grelles Licht blitzte auf. Eine Falle!

Fairy-Tale

Vor vielen hundert Jahren lebten in einem dunklen Wald zwei Brüder namens *U*lrich / *A*lbrecht und W*a*lter / W*i*lhelm. Sie wohnten allein mit ihrem treuen alten Hund und arbeiteten den ganzen Tag im Wald. Nach so vielen Jahren waren sie alt und kr*u*mm / kr*a*nk geworden, doch sie lebten gerne in der Einsamkeit und waren glücklich. Eines Abends, als sie gerade zu Tische s*a*ßen, / in ihren Betten schl*ie*fen, kam jemand durch den Wald gelaufen. Der Hund fing an zu bellen. Es klopfte heftig an die Tür.

News Bulletin

Vor knapp einer Stunde ist im Münchener / Mannheimer Vorort Maisach / Vorort Wallstadt ein vollbesetzter Nahverkehrszug mit einem Lastwagen zusammengestossen. Dabei sind mindestens vier Menschen, darunter der LKW-Fahrer, / Lokomotivführer, ums Leben gekommen. Weitere neunundzwanzig / einundfünfzig Fahrgäste wurden mit zum Teil schweren Verletzungen in Krankenhäuser eingeliefert. In München / In Mannheim gab ein Sprecher der Bundesbahn bekannt, der Lokführer habe offensichtlich ein Haltesignal nicht beachtet. Weitere Angaben liegen zur Zeit / lagen bis jetzt nicht vor.

Appendix B

Test words used in the carrier sentence condition. Carrier sentence was: *Er hat '...' gesagt.*

führen	fahren
Umfang	Anfang
wirken	warten
Lüge	Lage
kritzeln	Kratzer
Mühle	Maler
muffig	Masse
schlimm	Schrank
fünfzig	zwanzig
Müller	Meyer
füllen	feiern
minder	Mandel
Brief	Schach
Knüller	knallen

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Appendix C.

Mean F_0 (in Hertz) and standard deviation across six repetitions for each test word in the connected speech condition, and interval between high and low vowel in each test pair (in semitones).

Words	E.G.			A.K.			L.S.A.			U.S.		
	F_0	SD	high: low	F_0	SD	high: low	F_0	SD	high: low	F_0	SD	high: low
1 Müller	218.5	8.3	1.34	133.2	4.5	1.76	142.5	3.3	2.36	248.6	23.8	3.46
Meyer	202.2	12.5		120.3	5.4		124.3	3.1		203.5	12.4	
2 fünfzig	246.7	21.9	0.41	166.3	4.9	2.50	161.7	6.7	2.00	271.7	20.6	1.58
zwanzig	240.9	14.8		144.0	5.8		144.0	4.0		248.0	3.8	
3 rief	227.3	8.8	0.58	139.5	5.7	1.11	137.7	3.8	0.43	217.4	10.0	0.01
sprach	219.8	13.6		130.8	2.6		134.3	2.3		217.2	15.6	
4 knurrte	229.0	5.6	0.85	144.2	3.3	1.48	150.8	3.3	2.01	249.3	4.8	0.26
knarrte	218.0	8.9		132.3	3.7		134.3	6.9		245.6	7.1	
5 Müller	204.6	8.6	– 0.03	128.0	2.8	0.09	139.5	4.8	1.72	233.3	4.8	– 0.78
Meyer	205.0	6.7		127.3	5.1		126.3	3.6		244.0	4.4	
6 Ulrich	210.7	19.9	0.42	125.3	7.7	– 0.36	148.5	5.7	1.91	213.1	12.0	1.57
Albrecht	205.6	6.0		128.0	5.2		133.0	1.1		194.6	8.9	
7 Wilhelm	211.7	4.9	1.52	136.0	8.7	1.09	137.7	4.7	1.31	209.9	5.9	1.12
Walter	193.9	7.4		127.7	15.0		127.7	2.7		196.8	7.8	
8 krumm	224.7	23.5	0.57	144.7	6.9	0.55	141.3	6.9	1.47	236.5	15.2	– 0.34
krank	217.4	26.5		140.2	3.0		129.8	3.9		241.3	13.2	
10 Münchener	253.9	6.0	0.66	148.3	9.2	1.80	139.7	4.3	0.31	255.8	6.7	0.97
Mannheimer	244.4	11.5		133.7	5.8		137.2	1.9		241.9	11.1	
11 Lokomotivführer	258.4	11.4	1.16	139.2	2.0	0.72	134.7	2.0	1.15	253.7	3.2	1.78
LKW-Fahrer	241.6	4.3		133.5	7.8		126.0	6.6		228.9	9.4	
12 einundfünfzig	251.1	9.6	1.82	141.2	6.1	2.06	163.6	1.1	2.25	264.3	6.9	1.40
neunundzwanzig	226.1	18.2		125.3	2.1		143.7	6.4		243.7	6.4	
13 München	253.9	15.5	– 0.16	170.3	6.5	2.75	144.0	7.0	– 0.10	263.2	11.1	0.79
Mannheim	256.3	9.1		145.3	4.8		140.8	8.9		251.6	3.1	
14 liegen	210.4	24.7	– 0.22	125.2	5.2	0.68	146.2	4.0	0.97	226.3	4.2	1.27
lagen	213.1	10.0		120.3	5.0		138.2	9.5		210.2	12.0	

A negative value indicates that the mean F_0 for the low vowel was higher than the mean F_0 for the high vowel. Pair number 9 was not included in the analysis and so is not shown in the table.

Appendix D.

Mean F_0 (in Hertz) and standard deviation across six repetitions for each test word in the carrier sentence condition, and interval between high and low vowel in each test pair (in semitones).

	Words	E.G.			A.K.			L.S.A.		
		F_0	SD	high: low	F_0	SD	high: low	F_0	SD	high: low
1	führen	271.7	12.9	0.43	170.0	6.6	3.61	152.5	5.1	1.42
	fahren	265.0	22.9		138.0	7.2		140.5	8.7	
2	Umfang	276.7	12.5	3.52	153.5	7.0	2.44	163.5	1.8	2.44
	Anfang	225.8	18.5		133.3	4.5		142.0	5.3	
3	wirken	235.6	14.6	1.12	142.2	7.7	1.75	147.5	5.1	2.43
	warten	220.8	11.0		128.5	8.8		128.2	3.5	
4	Lüge	301.4	11.6	2.35	159.2	3.3	4.32	149.3	7.3	1.47
	Lage	263.2	19.7		124.0	3.7		137.2	3.1	
5	kritzeln	287.4	15.7	– 0.23	171.3	5.0	3.07	157.8	4.9	1.71
	Kratzer	291.3	13.7		143.5	4.1		143.0	6.0	
6	Mühle	269.7	26.9	0.59	144.8	7.1	2.57	160.7	6.6	3.12
	Maler	260.7	13.8		124.8	2.4		134.2	4.1	
7	muffig	281.5	21.9	1.22	171.0	6.5	4.29	166.0	5.9	2.95
	Masse	262.3	19.0		133.5	2.2		140.0	4.9	
8	schlimm	267.2	17.4	1.20	153.0	10.9	1.91	149.5	3.8	1.94
	Schrank	249.3	14.5		137.0	5.9		133.7	5.4	
9	fünfzig	296.6	14.7	4.88	155.3	5.5	1.59	163.5	1.4	3.68
	zwanzig	223.8	11.2		141.7	6.3		132.2	2.2	
10	Müller	263.8	7.9	0.55	149.2	10.8	2.69	151.0	6.2	2.66
	Meyer	255.5	5.0		127.7	4.3		129.5	3.5	
11	füllen	303.3	11.5	3.13	156.0	1.8	0.74	157.2	1.8	2.42
	feiern	253.1	15.9		149.5	12.8		136.7	2.7	
12	minder	262.9	23.3	0.17	148.5	10.8	2.78	150.0	4.8	2.13
	Mandel	260.3	23.5		126.5	2.8		132.7	4.5	
13	Brief	294.6	9.0	1.37	145.5	6.2	– 2.56	156.5	8.7	1.66
	Schach	272.2	7.7		168.7	6.2		142.2	7.4	
14	Knüller	290.1	7.4	1.90	151.5	4.7	1.41	156.2	1.6	2.54
	knallen	259.9	12.6		139.7	7.4		134.8	2.8	

A negative value indicates that the mean F_0 for the low vowel was higher than the mean high F_0 for the high vowel.