Contrast in German Monophthongs Pairs: Quality or Quantity?

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April 29, 2002

Abstract

In Modern High German there are seven pairs of two monophthongs that are traditionally referred to as tense/lax pairs, although the definition of what "tense" and "lax" actually mean is left disappointingly vague. In this experiment an operational definition for tenseness is formed based on perturbation theory. Tenseness should be reflected by distance of a vowel in acoustic (i.e., F_1, F_2) space from a uniform tube. This operational definition of tenseness leads to an unpleasant picture of the vowel space where the members of each pair bear no consistent relationship to each other. If the pairs are recast as long/short pairs, however, a relationship emerges where the long vowels are all approximately 2.5 to 3.5 times longer in duration than their short counterpart. The fact remains, however, that there is no clear connection between the qualities of paired vowels, leading to the suggestion that the connection between the pairs is more phonological and phonetic.

1 Introduction

Modern High German has 19 vowel phonemes, 16 monophthongs and three diphthongs. Among the monophthongs are seven pairs, shown in Table 1. Between the members of each pair are differences in both quantity and quality, but the quality difference is usually the more emphasized of the two. In the literature the members are referred to as tense/lax pairs (e.g., Hall, 1992, p. 76). The intuition is that the tense vowels are produced on the periphery of the vowel space whereas the lax vowels are formed in its interior.

It is inferable, then, that tenseness can be measure as a distance from some central point in the vowel space. It has often been claimed (e.g., as quoted below, Borden, Harris,

Tense Vowel	Example	Gloss	Lax Vowel	Example	Gloss
/iː/	iːgl̩	'hedgehog'	/ɪ/	ɪç	'I'
/eː/	eːbən	'even'	/ɛ/	ɛtvas	'something'
/aː/	aːbənt	'evening'	/a/	apfl̩	'apple'
/uː/	uːtə	feminine name	/ʊ/	ʊlrɪç	masculine name
/oː/	oːnə	'without'	/ɔ/	ɔft	'often'
/yː/	yːbʊŋ	'excercise'	/ʏ/	ʏpsilɔn	'Upsilon'
/øː/	øːl	'oil'	/œ/	œstlɪç	'easterly'

Table 1: German monophthong pairs

and Raphael, 1994, p. 112) that tense vowels are "characterized by tongue movements that deviate more from the so-called 'neutral position' for schwa than do [the lax vowels]."

If the quality difference is the key factor, then what is the roll played by the quantity difference? ('Quantity' meaning here a difference in physical vowel duration rather than some phonological percept of length). This experiment investigates the differences between the members of the seven pairs of German monophthongs to determine to what extent tenseness and length are indicative of the phonemic contrasts involved.

2 Subject

The subject of this experiment is a German graduate student at Indiana University. He is in his twenties and is a native speaker from the German Southwest. He is multi-lingual, but German is still his primary language and he intends to return to Germany to find work after his education.

3 Method

The subject was invited into a recording room and given word list in Table 2 which contains the 14 vowels in stop-vowel-stop context. The recorder gave the subject a head-mounted microphone and adjusted it so that the microphone picked up as loud a signal as possible

bieten	bitten
beten	betten
köter	töpfe
spuken	spucken
staat	stadt
toten	pocken
tüten	tücken

Table 2: Word list

while at the same time keeping it out of the "aspiration line-of-fire." The recorder then asked the subject to read the word list, first by reading each pair three times and then by reading straight through the list, resulting in four tokens for each vowel. The reading was recorded on a digital audio cassette and the recordings were then digitized using the Soundscope program on an Apple G3 system. Soundscope provides a tool for formant analysis which was applied to the digitized tokens for analysis using the default options from the "L541-tool" file provided by the organizers of Indiana University's Linguistics L541 class. The focus for the measurements was one third and two thirds through the vowel. The back rounded vowels, however, gave the formant picker a lot of difficulty in determining the first formant (F_1), and for those difficult vowels the measurements were read in any two locations where the picker had managed to find F_1, with preference given to having measurements from close to one and two thirds through the vowel. Length was measured as the distance in seconds between the release of the pre-vocalic stop and the closure for the following stop. For reference purposes the subject was later asked to produce four tokens containing schwa (specifically [bɪtət]) which were recorded, digitized and measured like the other tokens.

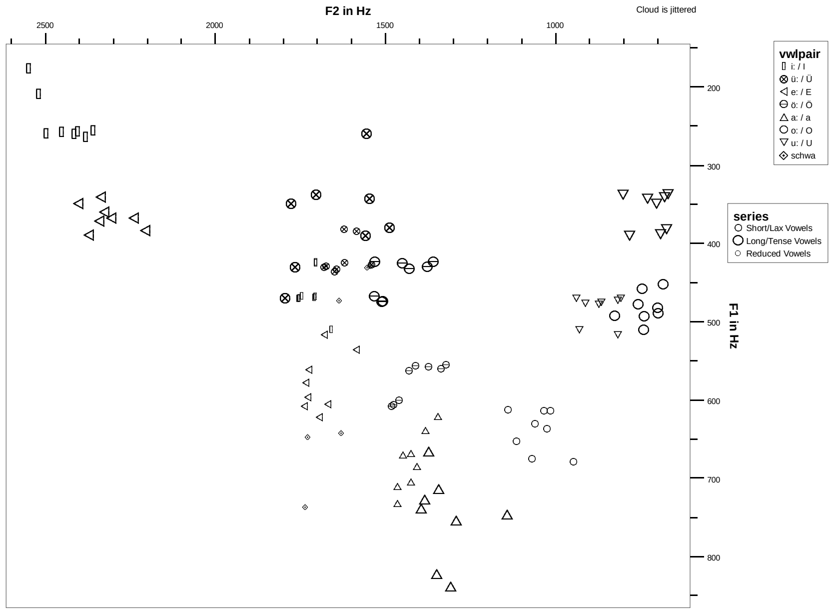

Figure 1: Vowel chart for all tokens

4 Quality

4.1 Results

The results of the vowel formant measurements are presented in Figure 1. The horizontal and vertical axes (both shown in cycles per second) have been reversed to imitate familiar articulatory vowel charts. All eight measurements (two for each token) are shown for each vowel, as well as eight measures for schwa. Members of each vowel pair share the same symbol with the longer, tenser member marked by the larger symbol. A small jitter has been applied to the data set because the formant picker had a tendency to pick the same number repeatedly which laid the markers for some tokens directly on top of other markers.

It may seem surprising that the tokens for [ɪ] and [ʊ] (labeled 'I' and 'U' on the legend) have a higher F_1 than that of [eː] and [oː], but that is normal for German speakers. Comparing Figure 1 to Figure 2, the surprise is how low the measures for [yː] and [øː] ('ü:' and 'ö:' in the legend) are.

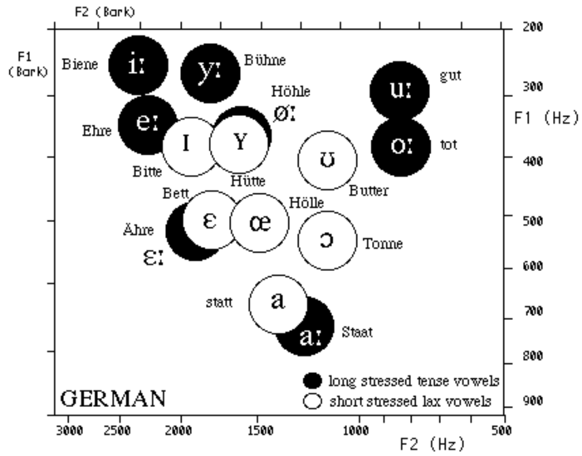

Figure 2: Typical German vowel patterns from Iivonen (1987)

4.2 Discussion

To analyze these quality data, a method is need to transform the formant measures to a measure of tenseness. As mentioned above in the in the introduction, tenseness is interpreted as an extended movement by the tongue away from the "neutral position" of schwa. This is, however, an articulatory description whereas the formant measures represent auditory data. Assuming that schwa's neutral position corresponds to a "uniformly tubular" vocal tract (that is, assuming that the vocal tract has an almost constant radius during the production of a schwa), physics mandates that the first two resonant frequencies of a schwa should have a ratio of 3::1. This seems to be a reasonable assumption because the first two formants of a schwa for an average male speaker are at 500 and 1500 Hz (Kenneth DeJong, Spring 2002 lecture notes).

The average measures for the subject's schwa were (527 Hz, 1625 Hz); the nearest point on the line $F_2=3*F_1$ (i.e., the line of possible uniform tubes) is (540 Hz, 1620 Hz). Perturbation theory says that in order to move away from that point in auditory space, the uniform tube must be constricted at certain places related to the formant frequencies, with greater degrees of constriction leading to greater differences in the resonant frequencies. The distance from a vowels formant measures to (540 Hz, 1620Hz), then, can be interpreted as a measure (called

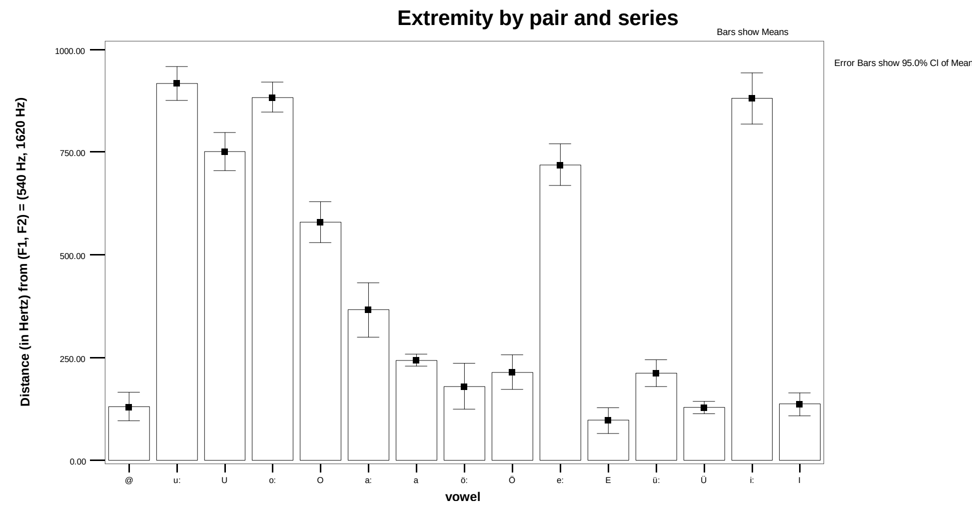

Figure 3: Vowel extremities

here "extremity") of the articulatory effort that went into the production of that vowel. A graph of the calculated extremities for the subjects vowels is presented in Figure 3.

The extremity vales in Figure 3 represent mostly what was expected, although there are some unexpected results. The front unrounded vowels have impressive differences in extremity. The back rounded vowels are also significantly different. The remaining vowels, especially [øː] and [œ] (shown as 'Ö' in the legend) have little to no significant difference in extremity. In Figure 1, however, [øː] and [œ] are clearly in separate places. This raises the question: what exactly are these vowels extreme from? Figure 4 attempts to answer this question by showing lines connecting the center of each vowel cluster to (540 Hz, 1620 Hz).

When this experiment was designed the designers had in mind the notion that tenseness was going to account for all of the difference in quality. That is, they expected that each pair of monophthongs could be specified as a direction from schwa and two distances, a lax and a tense distance. Figure 4 makes it clear that much more is going on. The lines from schwa to [øː] and [œ], for example, make almost a 90°angle, as do the lines from schwa to [eː] and [ɛ]. The line from schwa to [oː] passes right through [ʊ], so why is it that [ʊ] is perceived as being related to [uː] and not [oː]? Perhaps the wrong point was picked for the center of the vowel space. The graphic shown in Figure 5.is the result of recentering the vowel space

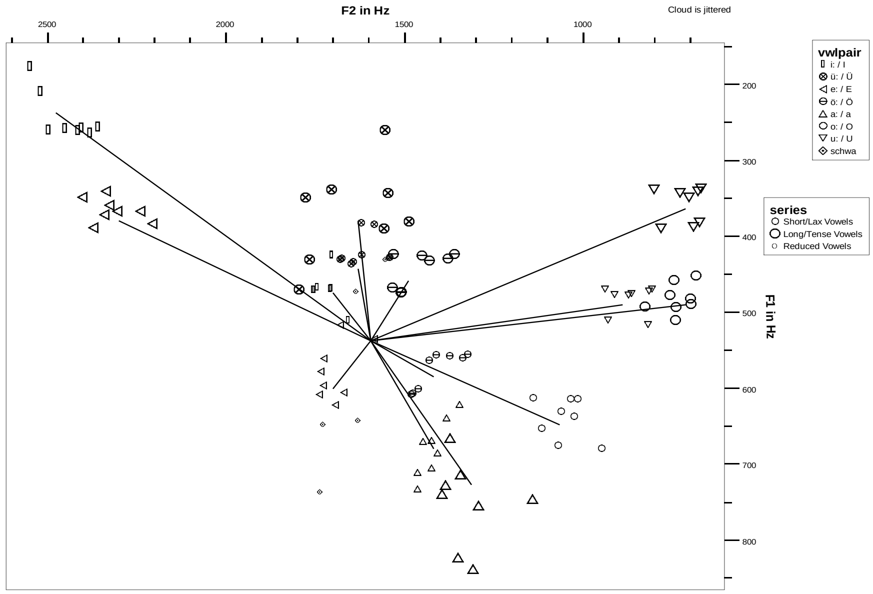

Figure 4: Lines from uniform tube

at (700 Hz, 1300 Hz). In this figure, the lines make nice paths through the vowel pairs, but (700Hz. 1300Hz) is quite a distance away from the nearest possible uniform tube at (460 Hz, 1380 Hz). Moreover, if extremities are calculated for the subject as distance from (700 Hz, 1300 Hz) then the subject's schwa has extremity equal or greater to all of his other vowels except [i:], [e:], [o:], and [u:]! If it is desirable to maintain a definition of tenseness (purely) in terms of distance from a neutral position, then it comes at the cost of losing schwa as that neutral position and losing the uniform tube as a property of that neutral position.

5 Length

5.1 Results

The recorded lengths are presented in Figure 6. The length difference between these vowels is extraordinarily crisp. Within every pair of vowels there is a significant length difference.

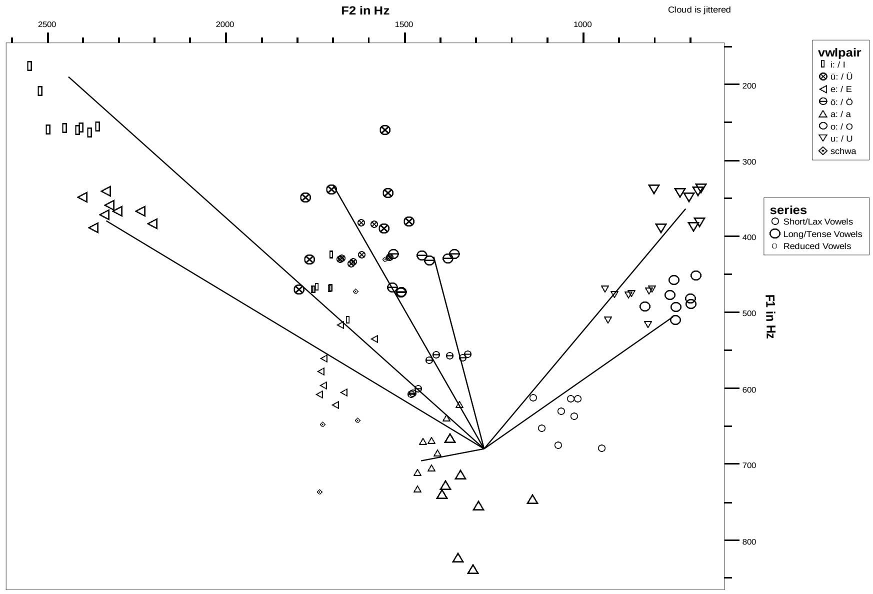

Figure 5: Lines from alternate center

Particularly striking is the length difference between [oː] and [ɔ]; the longer of the two is on average more than $3\frac{1}{2}$ times longer than the shorter!

5.2 Discussion

Comparing Figure 3 and Figure 6, it seems that the more relevant difference between the members of German monophthong pairs is the quantity difference. On the one hand, length is certainly a more reliable indicator of which phoneme is which, but on the other hand many Germans have a phonemic [ɛː], which would necessitate a perceived difference in quality (or perhaps an intermediate duration between /ɛ/ and /eː/). Moreover, confusion between [ɪː] and [iː] is almost unimaginable due to the large difference in quality.

In the end, it seems, paired German monophthongs must be differentiated both by quality and quantity. It is not surprising, then, that the two vowel pairs which exhibit the greatest differences in quality—/iː/,/ɪ/ and /eː/,/ɛ/—are the same two pairs that exhibit the least

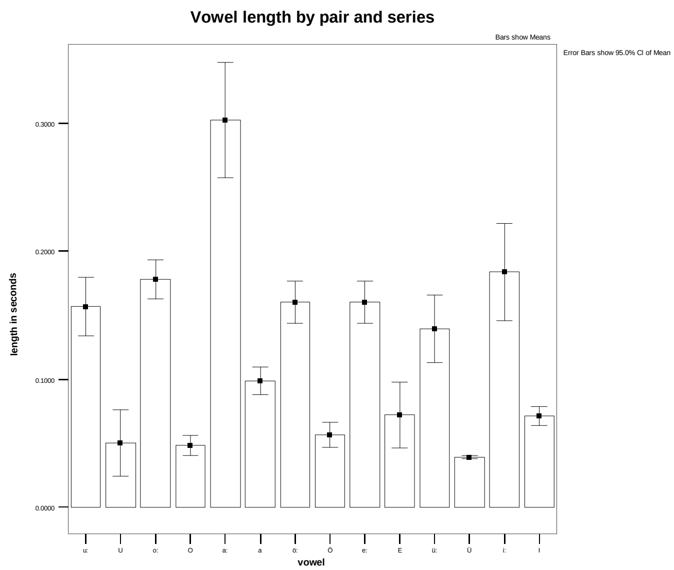

Figure 6: Vowel durations

difference in quantity. Table 3 shows the vowels ordered on the one side by ascending ratios in length (i.e. duration of long vowel :: duration of short vowel) and on the other side by descending extremity ratios. It is not perfect, but it does suggest that the two differences may compensate for each other. The error bars on some of these measurements are quite large, and that error is compounded when the ratio of two errored averages is taken. It would be interesting to see a table similar to Table 3 done with a larger dataset.

6 Conclusions

The results of this experiment challenge the notion that German monophthong pairs are best classified as tense/lax pairs. For many of these pairs, the difference in quantity seems to be a better predictor of series (i.e., short/lax or tense/long) than does tenseness. This experiment also calls into question the notion that tenseness is best described as an exag-

Vowel pair	Length ratio	Vowel Pair	Extremity ratio
/eː/ /ɛ/	2.22	/eː/ /ɛ/	7.44
/iː/ /ɪ/	2.58	/iː/ /ɪ/	6.48
/øː/ /œ/	2.84	/yː/ /ʏ/	1.66
/aː/ /a/	3.06	/oː/ /ɔ/	1.52
/uː/ /ʊ/	3.14	/aː/ /a/	1.50
/yː/ /ʏ/	3.57	/uː/ /ʊ/	1.22
/oː/ /ɔ/	3.69	/øː/ /œ/	0.83

Table 3: Length and Extremity ratios

gerated movement of the tongue away from a central point. If these pairings cannot be rescued by a redefinition of tenseness, one may be forced to concluded that the pairing of these monophthongs may be more phonological than phonetic.

References

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