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AN EXPERIMENTAL INVESTIGATION OF SOSOKHUI TONE PERTURBATION

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ABSTRACT

Fundamental frequency correlates of the Sosokhui tones 'high' and 'low' were studied in isolatedly spoken words uttered by native Sosokhui speakers in order to find out if there is any interaction between the well known microperturbations in the tone bearing vowels caused by preceding oral stops and the tone itself. According to Hombert's proposal of 1976[a], there should be an active tendency in tone languages to level out perturbations of the vowel height before they are perceivable in order to keep up the distinctiveness in the tone bearing vowels. As there are not many tonal minimal pairs in Sosokhui it is of interest if there is any need at all to compensate microperturbations and if this effect is of the same dimension as in Hombert's investigations. Indeed even the hypothesis exists that this language is actually losing its small domain of tonality due to its role as a bigger interlanguage. (Friedländer, 1974 and Labouret, 1934).

To carry out the experiments field work was necessary in the Republic of Guinea, West Africa. There the extreme circumstances caused some trouble with the recordings. Regrettably only recordings of two speakers in acceptable quality are left over for evaluation. This and also the fact that only natural material, which is per se not balanced at all, has been used, makes it impossible to talk of more than tendencies. In any case the results seem to strongly support Hombert's theses.

1. INTRODUCTION

Voiceless and voiceless aspirated stops cause a raise in the fundamental frequency (f0) of the following vowel, while voiced stops generally lower their f0. House and Fairbanks (1953) found a difference of approximately 6 Hz between the two sets of stops. Lehiste and Peterson showed a difference of about 10-13 Hz, while Mohr's 1968 investigation tells us of a 5 Hz difference. All of these results are averaged either over the whole course of the vowel or only their peak values. Neither of these investigations has considered the direction of the slope which would have been useful for an articulatory explanation nor have they been conducted with tone languages. For these reasons Hombert carried out some experimental work in which he first (1976[b]) showed that after voiceless aspirated stops f0 is high and falling continuously. After voiced stops the vowel begins at low f0, rising continuously. After 100 ms this difference is still significant. In this experiment the difference was 17 Hz at onset and still 4 Hz after 100 ms. Including the sonorants /w/ and /m/ the investigation also shows that most likely voicing is the main feature by which the slope is triggered. This effect has been observed in all of the five subjects which gives reason to believe in universal mechanism articulatory in nature. In the second part of this investigation Hombert shows that these perturbations are only perceivable after 60 ms probably because of forward masking. This still leaves minimally 40 ms for the perception of the slope because there is still a significant difference after 100 ms. In conclusion, he was able to suspect these perturbations as being responsible for bringing up tonal systems in the long run. (Tonogenesis). In another investigation with Yoruba, a West African tone language (Hombert 1976[a]), he therefore showed the influence on vowels with different tones. Here the following holds: voiced, lowering stops and voiceless, raising stops have more influence on vowels with the opposite tone as compared with their influence on a medial tone. Voiceless stops are of stronger influence on high tones than voiced stops on low tones. Perturbations are generally shorter in this tone language than in non-tonal languages. This last result led to the hypothesis, that there has to be a mechanism to rule out the unintended effect of perturbation to keep up the phonological function of tone. Gandour has found out that perturbations of the Thai tones were only as short as 30-50 ms, which means over an interval much shorter than perceivable (Gandour, 1974). Hombert's et al. and Ling's et al. later work showed that also in other tone languages this interval is not longer than 30-60 ms (Hombert, Ohala, Ewan, 1979 and Ling, Ramming, Schiefer, Tillmann, 1987).

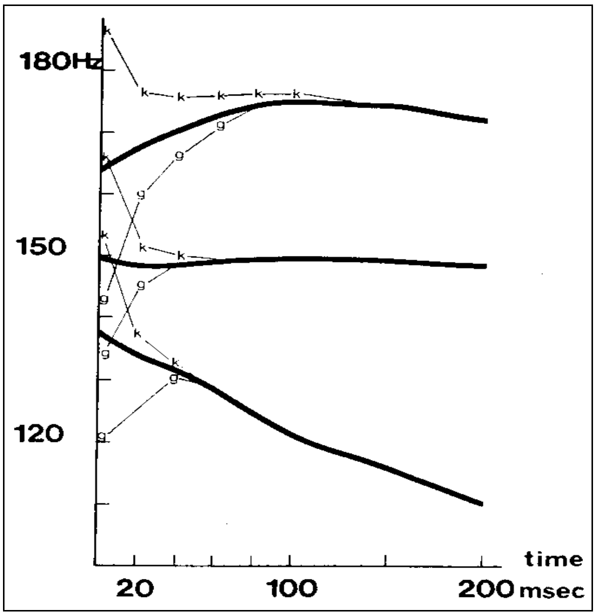

Fig. 1: from Hombert 1976 [a] ('Consonant Types, Vowel Height and Tone in Yoruba'), showing the influence of voiced ('g') vs. voiceless stops ('k') upon the three Yoruba tones.

Three articulatory models
To account for the microperturbations mainly three articulatory models of explanation have been developed.

The first one argues that there must be different aerodynamic processes going on in voiced vs. voiceless plosives leading to different f0 slopes of the following vowels. In voiced stops the transglottal airflow rate drops during occlusion by pressure compensation between subglottal and oral cavities causing a f0 drop which is automatically maximal at closure release. This makes f0 raise in the following vowel up to the normal f0. In voiceless stops the transglottal airflow rate is minimal during closure (because there is no glottal obstacle) but high after explosion and while beginning phonation, causing a high f0 at vowel onset (and falling slope through normalisation). (Ladefoged, 1967; Mohr, 1971). Mainly the short duration of any such aerodynamic process of about 10-20 ms gave reason to doubt this theory because perturbations last much longer, up to 100 ms. (Hombert, Ohala, Ewan, 1979).

Secondly there were a theory which tried to consider the horizontal vocal fold tension responsible for differences in fundamental frequency. After voiceless stops the cricothyroid muscle is relaxed, maintained Halle and Stevens in 1971, and thus the vocal folds as well, consequently lowering f0. But as soon as it was found out that this mechanism of relaxation during closure and activation after explosion holds for both voiceless and voiced stops, this theory became problematic.

Thirdly there emerged an idea about differences in the vertical vocal fold tension responsible for the perturbations. As the larynx height for the voiced stop is low, the vertical tension of the vocal folds should be so, leading to a lower f0 after voiced stops. (Hombert, Ohala, Ewan, 1979). But as there is a similar lowering effect of voiced vs. voiceless sonorants this theory (and the others, too) seems not to be able to explain the effect of voicing on the fundamental frequency.

None of these theories seemed to be able to completely explain the mechanisms leading to the observed effects of perturbation. This lead Kingston to offer an escape by hypothesising there are no perturbations at all responsible for the observed effect but speakers unconsciously make a difference to enhance the distance between the categories. (Kingston, 1985). What we also have to keep in mind is that there might be a mutual influence between vowel intrinsic pitch and perturbation effects by articulation. As Hombert found out in 1976[c] the differences in intrinsic pitch become levelled out by perception. But on the side of production both could be linked in a way that tongue position for different vowels may interfere with the stop production and hence the f0 slope. Firstly Ladefoged (1964) supposed a higher tongue position in high vowels being responsible for a higher vertical tension of the vocal folds by linkage through the extrinsic muscles. In the meantime this idea has proved to be wrong. Ohala and Eukel (1976) however could show there is a possibility that tongue pull is directly transmitted to the larynx by the tissues.

2. THE LANGUAGE

2.1 Affiliation

Sosokhui belongs to the Mande-family which is considered to be part of the north-western branch of the Niger-Congo languages. There are numerous similarities to the other north-western Mande languages such as labiovelar /gb/ as in Kpelle and Loma, which doesn't exist in Bambara and Dyula for example. However, with these languages it has the initial sound (or 'anlaut-') permutation in common. Additional common features are to be found in the verbal system and word formation. (See Jungraithmaier and Möhling, 1983). It is most closely related to Yalunka which is sometimes called a dialect of Sosokhui but mutual comprehension is difficult. Being a tone language, it has two tone levels for lexical and grammatical purposes.

2.2 History

During the migration of the peoples which was caused by the breakdown of the historic empire of Ghana the Soso were forced to leave the mountains of the Fouta-Dialon region. They began to settle in the coastal regions of lower Guinea in the 13th century, forming a part of the emerging empire of Mali. It is difficult to reconstruct their descent because at that times a fusion took place with the other peoples. It is known for sure that the Soso people were part of the Malian empire until it stopped to exist in the 17th century. As inhabitants of the coastal region they came into contact with Europeans very early (the first source which reports on this region is a Portuguese chronicle of 1453). Christian missions began in 1799, too late for the already islamised Soso. This religion brought its writing and so Sosokhui probably was written in the Arabic orthography initially (which is still in use, but mainly for religious purposes).

2.3 Geographic Situation

Sosokhui is mainly spoken in the Republic of Guinea but also in the neighbouring countries Sierra Leone and Guinea-Bissau. Guinea is situated at 10 degree latitude and 10 degree longitude. Beginning in the north-west the following states group clockwise around Guinea: Guinea-Bissau, Senegal, Mali, Ivory Coast, Liberia and Sierra-Leone. After Maninka and Fulani Sosokhui is one of the three major interlanguages of Guinea. This means that many more people than only the approximately 850000 Soso tribe people use this language as a further language.

3. PHONOLOGY

To demonstrate this language's general sound features a brief outline of Friedländer's 1974 description should be sufficient. Thus the official orthographic symbols can be introduced.

3.1 Consonants

p	voiceless bilabial stop
t	voiceless alveolar stop
k	voiceless velar stop
b	voiced bilabial stop
d	voiced alveolar stop
g	voiced velar stop
gb	voiced labiovelar stop
m	voiced bilabial nasal
n	voiced alveolar nasal (preceding g, gb, k, and w it is changed to a velar nasal; preceding b, p, m it is changed to a bilabial nasal, which is also reflected in writing 'm')
ny	voiced palatal nasal
f	voiceless labiodental fricative
s	voiceless alveolar fricative
kh	voiceless velar fricative
h	voiceless glottal fricative (in Arabic loan words; sometimes for kh)
l	voiced lateral
r	voiced alveolar trill (when a nasal precedes it, it changes to an n, also in orthography)
w	voiced bilabial approximant
y	voiced palatal approximant

The only scholar who is talking of a voiceless labiovelar 'kp' is Ladefoged (1964). His instance is 'kpaku' (to hang). This might result from the small contrast of aspiration between the categories voiced and voiceless. All other authors write 'gbaku' and do not have the voiceless instance of this sound in their phonological description. (Houis, 1963: 'gbákù- accrocher'; Friedländer, 1974: 'gbaku- (an- auf-) hängen, hängenbleiben, sich anklammern, umklammern'; Willits, 1995: 'gbaku \ / FR: suspendre, accrocher EN: hang to IT: appendere'). It is obviously the same word. Regrettably this labiovelar sound couldn't be investigated due to its rareness. See also 4.2.

3.2 Vowels

a	open, front
e	close-mid, front
è	open-mid, front
i	close, front
o	close-mid, back
ö	open-mid, back
u	close, back

Diphthongs do not exist. Whenever two vowels meet, they are spoken isolatedly.
While Houis (1963) and Friedländer (1974) describe a corresponding series of long vowels, Touré (1994) tries to show that long vowels result from two or more short vowels, phonologically:

a nakhè a i kha fa
(he/say/you/that/come=he wants you to come)
becomes: a nakhè i: kha fa
and finally: a nakhè: kha fa

Three short vowels become one long one. This matters for the tone, too: when two or more tones meet in this way, the result is a contour. In the example above cited the tones 'low-high-high' blend to a raising tone on the resulting long vowel. Touré also questions the existence of nasal vowels as distinctive phonemes. He points out that a nasal always follows a nasalized vowel, which shows that they are only a result of the context as in:

bare: bara khin	(the dog who bite)
a bara bankhi ti	(he has built a house)

Houis indicates the frequency of the Sosokhui sounds in a corpus of 1950 words. In this language the vowels /i, a, u/, having the biggest articulatory distance from one another, are the most frequent, which is an advantage in this investigation.

3.3 Assimilations and Contractions

Vowels can be subject to assimilation and contraction. The most common assimilation arises by nominalization of verbs by i, following these rules:

a+i>è as in	siga (to leave) >	sigè (the departure)
e+i>e	bere (to play) >	bere (the game)
i+i>i	wali (to work) >	wali (the work)
o+i>oe,e	tongo (to take) >	tongoe (the taking)

u+i>ui,i	khèbu (to greet)>	khèbui (the greeting)
è+i>	waanyè (to hunt) >	waanyè (the hunt)
ö+i>,ö(öè)	sötö (to get) >	sötöè(è) (the receipt)
an+i>anyi	malan (to gather) >	malanyi (the gathering)

Examples for Contractions

m mu a kolon	>	m' a kolon	(I don't know)
kha i wa	>	kh' i wa	(if you want)

3.4 Vowel Harmony

The open and the close vowels only can be combined with one another in one word. 'U' must not combine with 'ö'. 'I' and 'a' may combine with all vowels.

3.5 Syllable Structure

There are only open syllables CV, CCV, V and a group of CVN syllables. Most common is the word type CVCV. Longer words are mostly onomatopoeia. (after Friedländer 1974)

3.5 Tonal Contours?

'...en structure chaque voyelle est associée à un ton ponctuel et un seul.
and:
Ainsi le SOSO, qui est fondamentalement une language à deux tons sans complication particulière, présente sporadiquement des phonèmes dont la systématisation pourrait conduire à un système à deux tons plus down-step.'

(Touré 1994)

Houis talked of contours over long vowels mentioning Trubetzkoy's moras. On the other hand, Touré asserts, there are only two tones which evoke the impression of contours when they are connected with the same (double) short vowel or a nasal following a vowel. They also can be tone-bearing in his theory. This only gradual difference in the phonological judgement does not generally question the existence of two tones.

4. LIMITATION OF THE MATERIAL

The accessible base of natural speech material has been too small to cover all vowels in combination with the two sets of stops and the two tones. The cardinal vowels /i,a,u/, being the most frequent in this corpus, will therefore be the base of this investigation.
We use only initial syllables of isolated words because there the effect of perturbation can be expected to be the greatest. (See Schiefer, 1987)

Nevertheless the material is not balanced. For the comparison between the voiced and voiceless bilabial stop we can use low tone /u/, high tone /a/, and high tone /i/.
For the alveolar stops there is only low tone /u/, /a/ and /i/ and high tone /e/.
After velar stops there is high and low tone /a/ and high tone /i/.
This is quite disparate. At least there are both tones in every stop category.

4.1 Preselection of the Minimal Pairs

According to Houis (1956) this language is very much tonal in the sense that every word carries a lexical tone structure:

'Or ces idiomes (Sosokhui and Bobo) *sont éminemment toniques. Tous les mots, quel que soit le nombre des syllabes, ont une tonalité étymologique; notre étude le prouvera amplement par la suite.'*

But since others suspect the tone is not very widespread in this language, we decided to create a basis of homophoneous words which are only differentiated by their tonal structure:

'Das Susu ist jedoch keine Tonsprache in dem Sinne, daß die gesamte Sprache durch eine Tonale Struktur charakterisiert wird, d.h. die sprachliche Kommunikation kann auch ohne Berücksichtigung von Tönen erfolgen. Daher wird im vorliegenden Lehrbuch auf die Angabe von Tönen verzichtet.'
(Friedländer, 1974)

In minimal pairs tone will stay stable and here we find the only possibility to compare the tones in the exact same environments.

4.2 Further Groups

A base consisting only of minimal pairs would be too small to contain all interesting combinations. Other words are taken to fill the gaps.

Different groups are the result of this procedure:

1. Minimal pairs without stop-vowel-tone-combinations which are only good for checking the reliability of tone.
2. Minimal pairs without indications of tone not suitable for the investigation of stop influence.
3. Minimal pairs with tone indication, suitable for the investigation of stop influence.
4. Other words with tone indication, suitable for the investigation of stop influence.
5. Other words without indications of tone, suitable for the investigation of stop influence.

- The first group can be a reference for a comparison to the groups where there might be perturbation.
- The second group will be a reservoir for gaps in the first group after finding out the tones.

- The third one is the ideal group for our purposes. Here we can suppose the tone to be fully developed. Regrettably this one is the smallest.
- The other groups were selected according to tone and context, to produce as many stop-vowel combinations as possible.

The resulting corpus contains 232 words.

4.3 Remark on the Labiovelar /gb/

For the labiovelar there are not enough instances to be found to take it into consideration. It would have been of interest to know if either the labial or the velar articulation is responsible for the kind of perturbation or, if even new effects could be observed. (See Maddieson 1993).

5. PREPARATION OF THE MATERIAL FOR PRESENTATION

To guarantee a natural pronunciation through reading the material the following precautions were made:

- Subjects must understand the orthography.
- The subject must not get information about the tone.
- The meaning of every word must be clearly understandable.
- 'List intonation' is to be suppressed.
- The material must be read three times.
- The order of the samples must be chosen by chance in every turn.
- Partners of minimal pairs must never meet.

The number of potential subjects becomes very restricted because of these conditions. Only until 1984 school lessons were being held in Sosokhui using the specific orthography. The word meaning is translated in French because this is the most widespread language in Guinea. But only 30 percent of the population did go to school. At the time the local languages were in use at school the pupils didn't learn French. And after this they no longer learned their own language's orthography.
It is difficult to find subjects who are literate, who know Sosokhui orthography and also speak French. One is tempted to ask if these people can still be considered as really native and naive speakers.

To account for 'list intonation' the subjects were asked to take cards out of one box, to read it silently and to put it into another. They were asked to utter it afterwords. If a word was not known they were asked to say so instead of trying to read the word.

6. CONDUCTING THE RECORDINGS

6.1 The Subjects

Since there were not enough suitable subjects in Germany, the recordings took place in Conakry, Guinea. All seven speakers were recruited from secondary schools. They were teachers and pupils, and had no reported history of hearing or speech impairment. Their immediate descent is the area between Conakry, Dubreka and Forecariah, where most of the modern investigations of this language were made.

6.2 The Conditions

It seems worth mentioning the difficult conditions because they finally led to the special procedure of evaluation in this investigation.
All recordings were conducted with the same equipment, a high quality analog cassette tape recorder and active microphone, the subject sitting on a normal chair at a normal table with the microphone in a distance of approximately 50 cm, pointing at the speaker's face at an angle of ca. 45 degrees. No noise suppression was used and recording level was adjusted manually.
The recordings of the first two subjects were made in a sound treated radio broadcasting studio. Unfortunately these speakers turned out to be too young to know enough of the words. All following recordings were made in big classrooms which produced strong reverberation but slightly reduced the noise from the outside. Still, on many recordings one can hear children scream, dogs bark, cocks cry and so on.
Another severe problem was the consistently changing voltage (if there was any at all) which unnoticeably destroyed recordings by adding strange sounds to the recording. The later 'remedy' were voltage stabilisers which caused another initially unnoticed kind of distortion, peculiar sounds caused by their automatic switching.
Only two out of seven recordings remained good enough for evaluation.

7. EVALUATION

After digitising the material auditory and acoustic properties were checked by ear and eye. Sonagram and oscillogram with audio signal showed none of the speakers made use of mechanisms other than mainly f0 to encode tones. Secondary effects are mainly either laryngealization (Kt) or devoicing (Mb) in low tone ultimas.

Sonagraphy
The recordings were still bad enough to confuse the Kay-Elemetrics Sonagraph 5500 which failed in calculating LPCs for f0 extraction.

Signalyze
Some more possibilities of f0 extraction offered by Signalyze couldn't solve this problem.

8. THE ALGORITHM OF SCHÄFER-VINCENT

After the failure with these common methods we decided to try a f0 extraction with a program developed at IPSK (*calc_f0*) which exploits a procedure invented by Schäfer-Vincent (1983) because we consider this method more resistant against noisy recordings than the above mentioned. As in manual period segmentation the base of calculation is the pitch period alone:

'The output of the pitch- extractor provides (...) a period duration for each point within the voiced segment.'
(Schäfer-Vincent, 1983. Our underlining)

This makes the method more independent of the quality of a recording in which the spectral information is disturbed by noise and filtering. If a length difference bigger than 10 % occurs between two periods the program doesn't calculate on these values if the mistake remains smaller than 10 % in the environment. If not the maximal difference must be smaller than 16 % to be safe from irregularities. However, the interesting tendencies should be preserved this way. The advantage seems to be that this method actively avoids miscalculations.
To be sure this method was working we made a detour into the field of the traditional period segmentation by hand and built up a base of material for comparison between the two methods. Because if the microperturbation effects show the same way in both cases we wanted to choose the automatic method to take bigger amounts of data into consideration.

9. SEGMENTATION BY HAND

To carry out a comparison the digitised material was downsampled to 16 kHz and cut into data files containing the relevant vowels. Using the *uss*-program of the IPSK Munich it was possible to mark the corresponding parts of the time signal on screen and to listen to the segmented chunks.

The Vowels
In vowels following a voiceless stop the segmentation begins with the first, complete vowel period at zero crossing and ends 50 ms after. Every period is marked at their zero crossing.
Another target period is marked after (every) 100 ms and one at vowel end.

The Vowel Environment
Length of the voicebar from the first period to the burst.
Length of burst, if existing.

10. SEGMENTATION REMARKS

We took care to get as many periods after onset as possible because perturbation effects fade with each period. But getting incomplete periods at the very onset will be more harmful to proper f0 calculation than leaving out the first period.

Length
The length of period segmentation of 50 ms should be sufficient to show the perturbation effects in a tone language, assuming that perturbation elimination time is not affected by individual f0.
Segmentation of a fixed number of periods leads to different lengths. For direct comparison one would have to normalise the results first. Most of the scholars cited above have measured the perturbation length. The only 'sacrifice': resolutions depend on the fundamental frequency.
Target periods are set to follow the f0 slope over the whole vowel, where needed.

VOT
VOT parameters were used to control the phonological statements concerning the phonetic realities of the stops in question.
Actually the voiced stops in our subjects have their voice onset before the burst which is not or only slightly aspirated. The voiceless stops have no voicing lead and are only slightly aspirated.
We always have segmented both tone bearing vowels in a word to calculate their f0 to find out if the tonal pattern of the utterance corresponds with the canonical form.

'Mistakes'
Some words haven't always been uttered in the canonical tonal shape which was the case when the tonal structure became inverted as in the case of 'high'-'low' switched to 'low'-'high'. Since these mistakes didn't appear systematically in all samples of the three turns but only in some, we supposed an uncertainty in the subject and didn't use these realisations.

We only made judgements of these kind after analysing the acoustic properties of the material to avoid mistakes of mere listening.
This careful procedure also showed that the automatic pitch extraction sufficiently indicates the interesting tendencies. The complicated method should make sure that there is really tone in this language with the main feature f0 because this work is the first to consider the Sosokhui tone phonetically. As mentioned above there has been doubt about the tone in this language. We also suspected a certain danger of artefacts in just applying an automatic pitch extraction on a material whose function was not completely clear. If, for example, tone would have been realised by additional breathiness or laryngealization these parameters could have been neglected and f0 calculation disturbed, too.

11. RESULTS

11.1 The Stops and Place, Manner, Intrinsic Pitch

Subject Mb

After voiceless stops f0 is raised in general. The labial stop has the least influence upon f0 slope, while alveolar and velar cause nearly the same, with the velar in small advance. The velar causes the biggest difference between the contours.

The voiced context makes the high vowels rise and the low vowels fall after all places of articulation. The frequency range is lower than in the voiceless context.

Intrinsic pitch is also an important overall factor. The high vowels mostly group in a narrow space after 25 ms while the low one lies about 10 to 15 Hz lower.

Tone is apparent in all cases: almost every time there is a distinct difference between high and low tone made. The only exception is to be found after /t/ but only for seven seconds after onset in an area probably influenced by perturbation.

Tone really seems to have an influence on perturbation duration because only after 20 ms the compensation is always made.

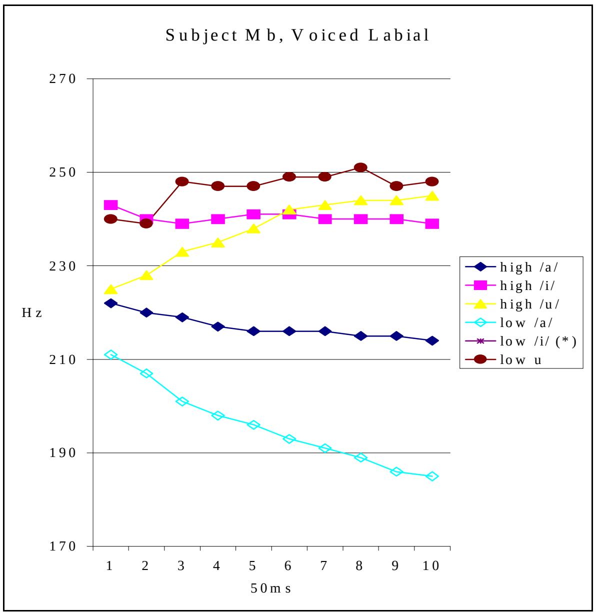

Fig. 2: Subject Mb's f0 contours after voiced labial stops.

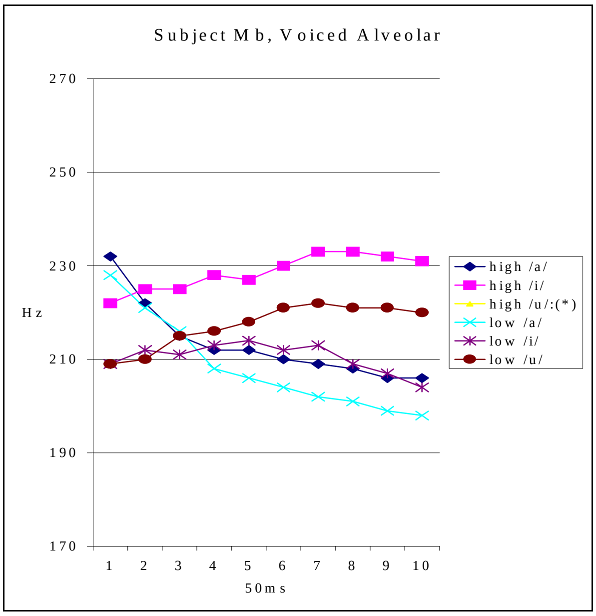

Fig. 3: Subject Mb's f0 contours after voiced alveolar stops. No values for high /u/.

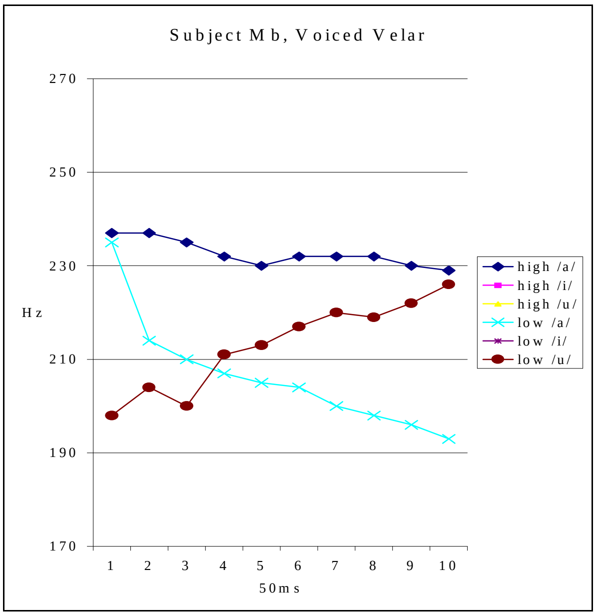

Fig. 4: Subject Mb's f0 contours after voiced velar stops. No values for high /i/, high /u/, low /i/.

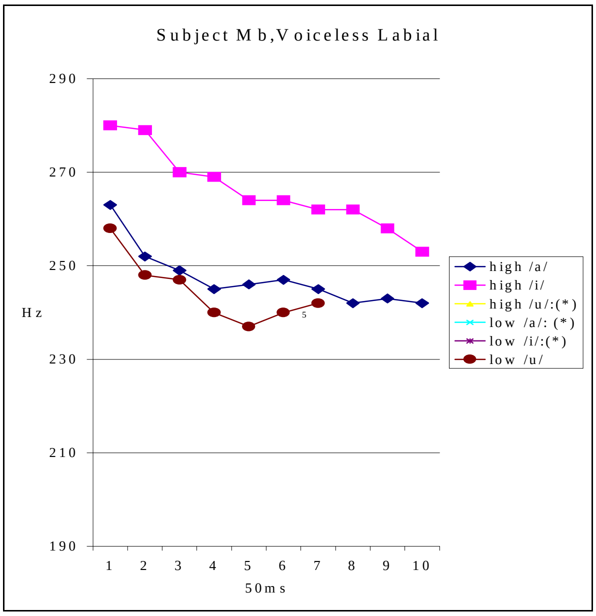

Fig. 5: Subject Mb's f0 contours after voiceless labial stops. No values for high /u/, low /a/, low /i/.

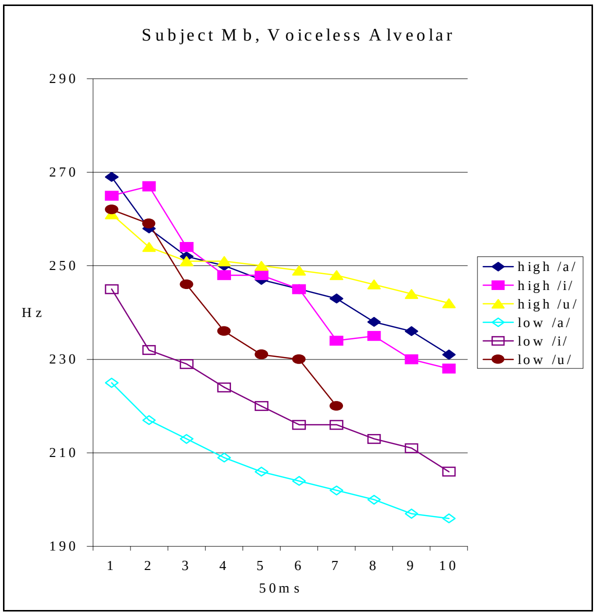

Fig. 6: Subject Mb's f0 contours after voiceless alveolar stops.

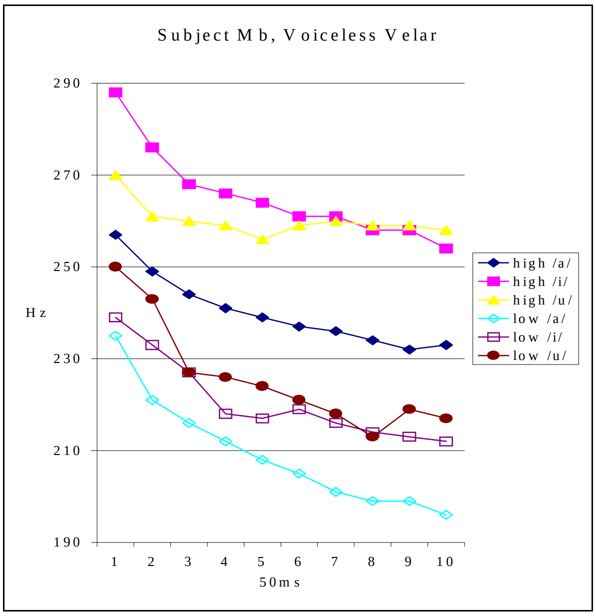

Fig. 7: Subject Mb's f0 contours after voiceless velar stops.

Subject Kt

Voicing of the stops lowers the vowels as we would expect: voiceless stops generally raise the vowel f0.

But in this subject the f0 slope is only slightly changed. After the voiceless labial stop no global tendency may be found. Here the f0 slope depends on the tone: high tone makes it raise, low tone makes it fall. In the labial context the slope is greatest in general.

The alveolar context causes a nearly neutral course in a narrow bandwidth with a small downward tendency of all high tone vowels in the voiceless mode.

Velar place of articulation seems to have a similar but even stronger effect on high vowels in voiceless mode. Additionally here the contours get the biggest distance from each other. Maybe the same holds for the voiceless case but since there are not enough samples this remains tentative.

Intrinsic pitch shows in the clear difference between the high and low vowels. A different behaviour of the contours cannot be observed except for the resistance of the low vowel against the raising influence of voiceless velar context (only the first period) and the falling of low /u/ in the voiceless labial context.

The tones are clearly distinct. After 20 to 40 ms the greatest differences are already reached.

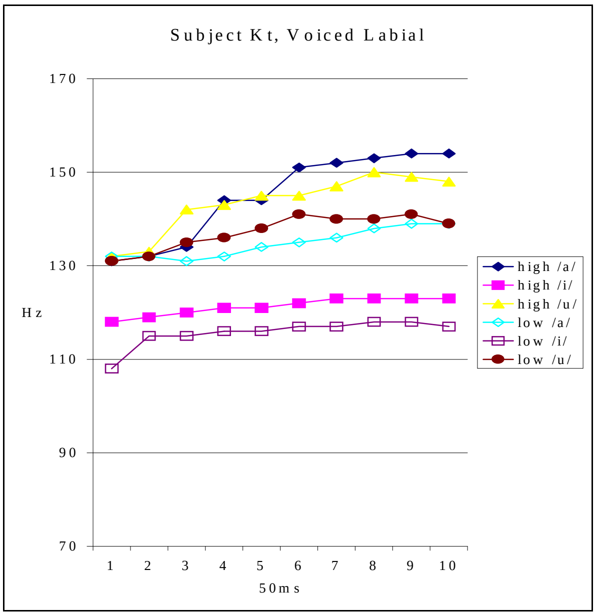

Fig. 8: Subject Kt's f0 contours after voiced labial stops.

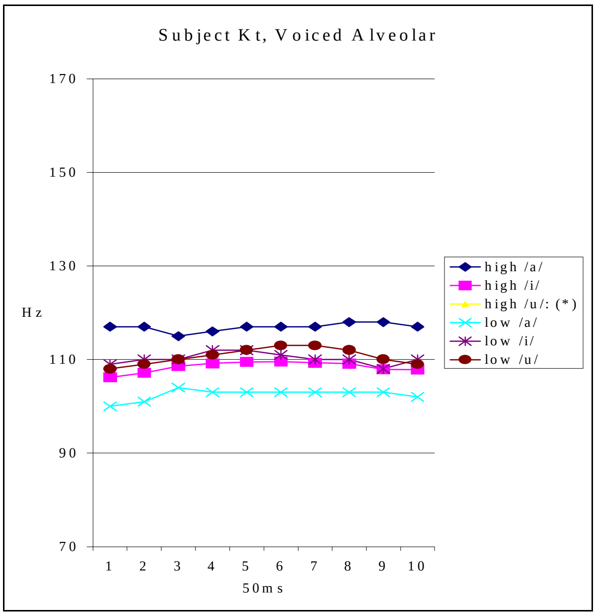

Fig. 9: Subject Kt's f0 contours after voiced alveolar stops. Missing values for high /u/.

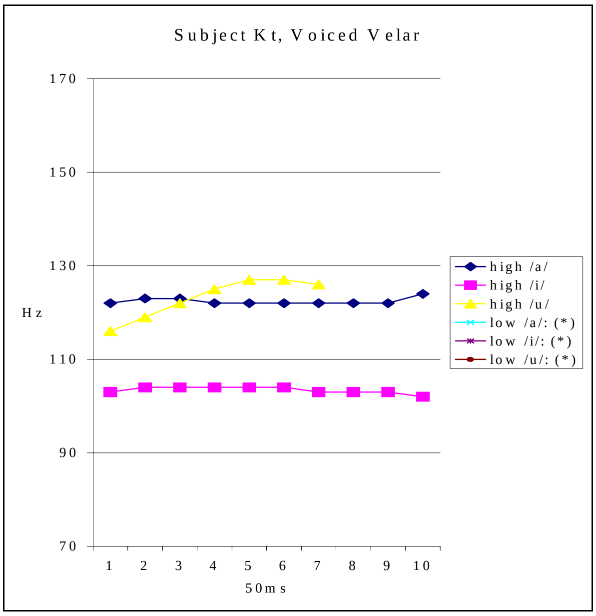

Fig. 10: Subject Kt's f0 contours after voiced velar stops. Missing values for low /a/, /i/, /u/.

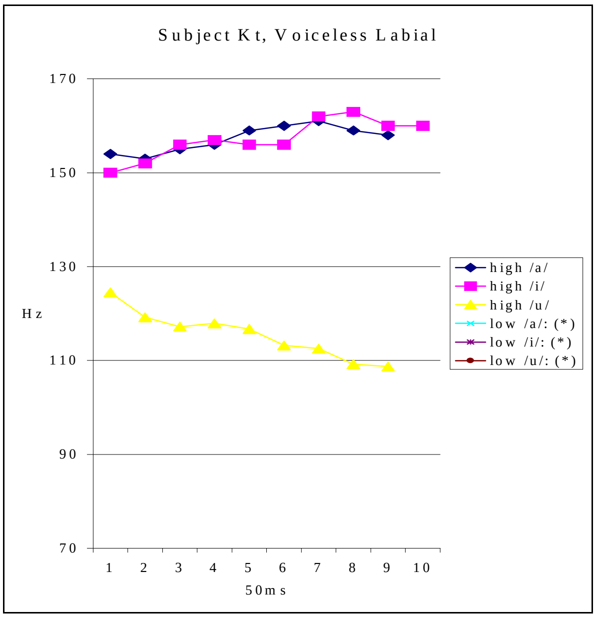

Fig. 11: Subject Kt's f0 contours after voiceless labial stops. Missing values for low /a/, /i/, /u/.

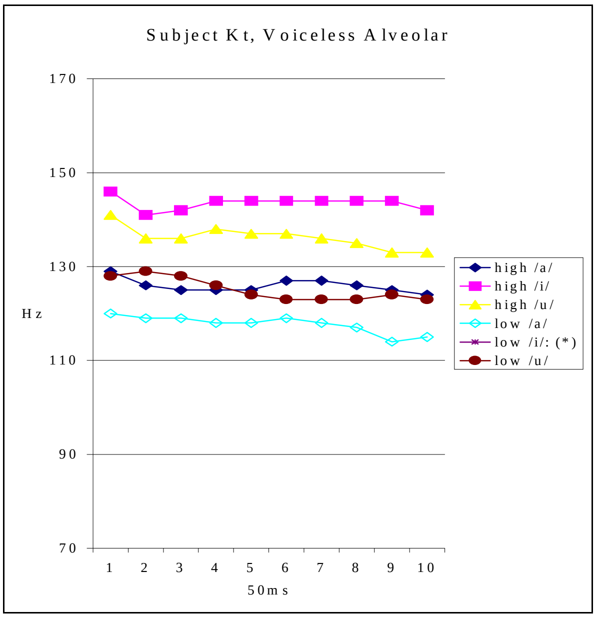

Fig. 12: Subject Kt's f0 contours after voiceless alveolar stops. Missing values for low /i/.

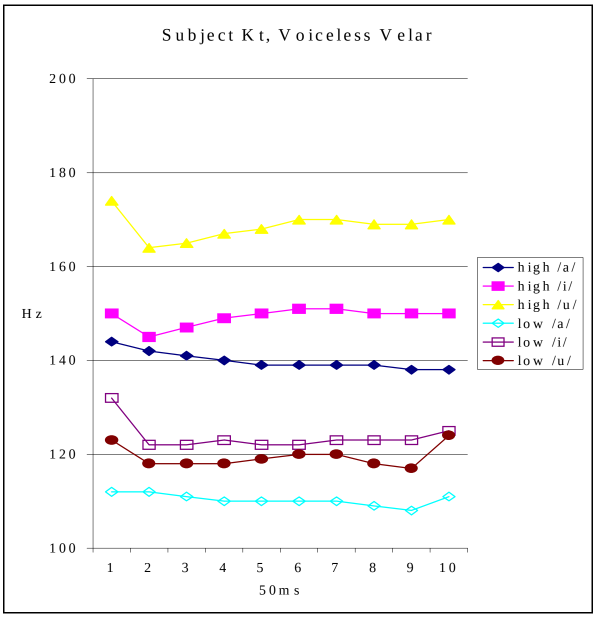

Fig. 13: Subject Kt's f0 contours after voiceless alveolar stops.

Summary: Both Speakers

The most striking difference between the subjects is their behaviour concerning the direction of the f0 slope. While mb's contours are generally falling, subject kt produces neutral or rising slopes. But they have many things in common which we can consider as caused by general mechanisms:

- In both subjects the voiceless context raises f0 of the following vowel.
- After less than 35 ms the tones are maximally distinct although there is a lot of perturbation to be seen before. After this time there is no more substantial change to be found.
- The low vowels are less subject of perturbation than the high. But the contexts are speaker-dependent: while it is the voiced context in mb it is the velar stop in kt.
- Intrinsic pitch and tone interact mostly in the way that the different vowels have a greater difference when bearing high tone than with low tone.
- In a more special way tone is even here a relative phenomenon. The speakers realise it according to their different behaviour in vowel contour slope. Mb's contours are falling with high tone and steeply falling with low tone. Kt produces a rising contours for high tone only in the cases when high and low vowels begin at nearly the same level. But generally he makes a difference since the beginning, with high level for high tone and lower level for low tone both running distinctly with no tendency in the slope.

11.2 Place and Manner in all Vowels

Taking all vowels together means to exclude the influence of intrinsic pitch. To show their different consequences we divided into the two manners.

Subject Mb

Here the manner is the main cue for the global slope of the contours and their distance from each other. In the voiced context we can observe only slightly falling contours and even a rising one in the case of the low velar, whereas after voiceless stops the f0 is falling clearly and the contours have a bigger distance, too.

The places of articulation seem not to cause any tendencies in the contexts.

The tone is the strongest factor to differentiate the contours after all stops. The high and the low version of one contour as well as all members of one group (high resp. low) are distinct from each other.

The weak perturbation is after 20-25 ms only to be seen in the higher f0 of the high tone vowels but not any more in the steeper slope.

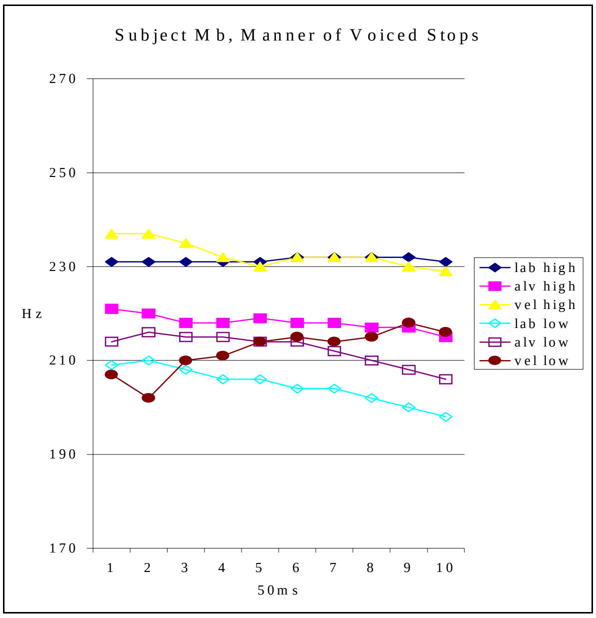

Fig. 14: Subject Mb's f0 contours and manner of voiced stops.

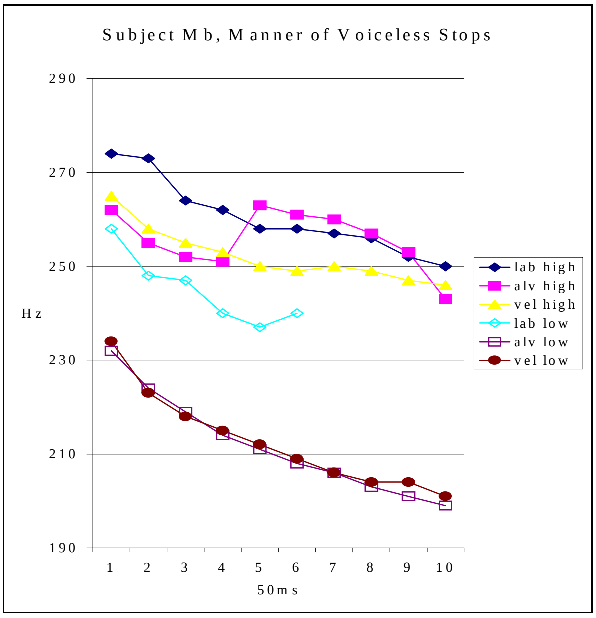

Fig. 15: Subject Mb's f0 contours and manner of voiceless stops.

Subject Kt

Manner makes f0 rise after voiced labial and voiced alveolar stop. The others remain unchanged in their direction. After voiceless stops the f0 contours slightly tend to fall in the first five ms, except for the alveolar stop.

High tone vowels keep their level or rise slightly while the low toned ones either fall slightly or have no slope at all. The vowels are always higher after voiceless stops and have a bigger distance from each other than after voiced ones.

Labial articulation seems to be the reason for the rising of the vowel until 40 ms in both manners.

Tone is the strongest feature to decide how much influence manner and place can take. The tone is always making a clear difference after one place of articulation as well as in the different vowels.

From the 20th ms on the perturbations are already over.

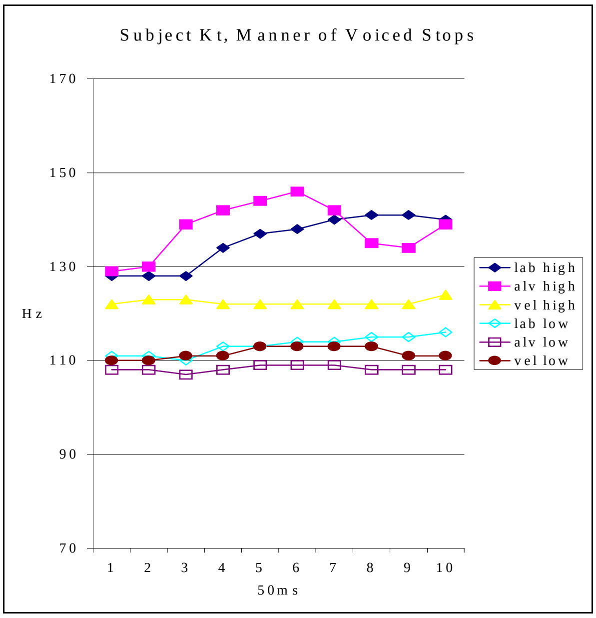

Fig. 16: Subject Kt's f0 contours and manner of voiced stops.

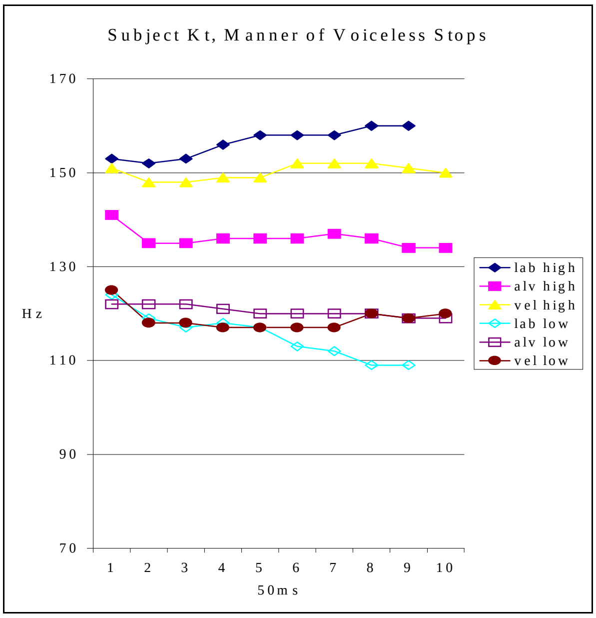

Fig. 17: Subject Kt's f0 contours and manner of voiceless stops.

Summary: Both Speakers

- In both subjects the influence of manner is observable in all vowels. It always makes vowels higher after voiceless stops. After most of the voiceless stop articulations the vowel is raised in the first five ms in comparison to the voiced ones. One side-effect is always a broader spectrum of the vowel contours in the voiceless context.

- Place of articulation makes vowels seldom behave uniformly enough to speak of effects.
- Tone is in all cases the factor which makes a vowel distinct from its partner from onset until end of measurement.
- The individual difference between the subjects consists only in the directions of their vowel slopes: while mb operates with more (for the low tone) or less (for the high tone) falling contours, Kt uses rising patterns for the high and f0 level course for the low tone.

11.3 Vowel Intrinsic Pitch

Subject Mb

Most strikingly, the contours of all vowels are very similar, though they have bases of different seizes, in which the different cases of contexts are not balanced. Even standard deviation is not much bigger than in the other groups.
Tone makes always a clear difference between the high and the low version of one vowel and even a distance between the lowest high and the highest low vowel.

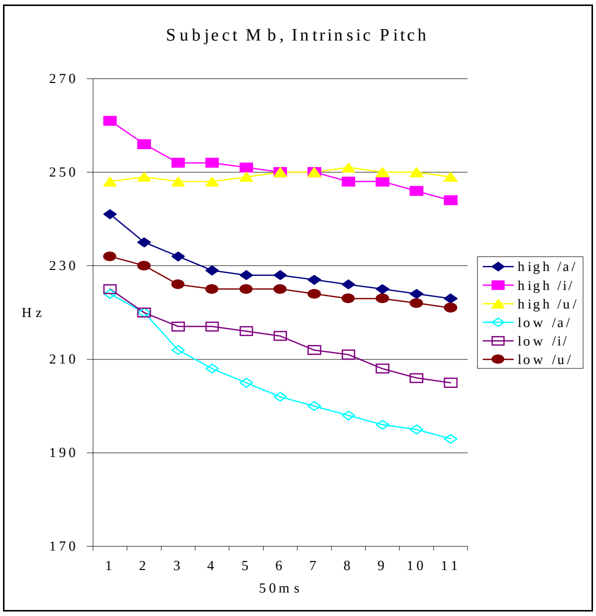

Fig. 18: Subject Mb's f0 contours and intrinsic pitch.

Subject Kt

Intrinsic pitch makes vowels group into the high ones and the low one with high as well as with low tone. Perturbation through intrinsic pitch is least in the low vowel with low tone.
Tone is again making a clear difference. Even high vowels with low tone are still higher than low vowels with high tone.

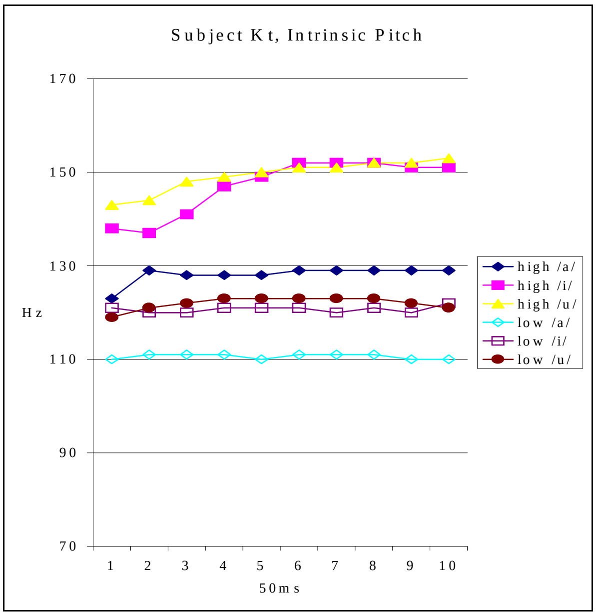

Fig. 19: Subject Kt's f0 contours and intrinsic pitch.

Summary: both Subjects

- In both subjects there is perturbation through intrinsic pitch. High vowels group higher than the low one.
- Both subjects have a change in the slopes after 20 respectively 25 ms.
- The tendency of more or less falling contours for tone indication in speaker mb as well as the behaviour of speaker kt to indicate tone by different levels, some of the high ones rising, is still there.

11.4 Main Tendencies

Considering all manner, place and intrinsic pitch we find the following for both subjects in common:

- Voiceless context makes f0 rise.
- Place of articulation has different influences on the vowels.
- The low vowel is more resistant against perturbation than the high ones.
- High tone spreads the f0 space of the contours.
- Tone is generally realised differently by both subjects.
- After 35 ms there are no more changes of f0 slope to be found.

Considering manner and place we find:

- Voiceless stops make f0 contours rise.
- They cause a steep fall in the first five ms.
- They spread the f0 space.
- Place of articulation has no uniform influences on the vowels.
- Tone makes a f0 difference not only in the high-low pairs of one vowel

Displaying only intrinsic pitch against tone we can see:

- Vowel intrinsic pitch is effective everywhere.
- Tone is realised differently by the speakers.
- After 20-25 ms there is no more essential change in the f0 slope.

The overall trends seem to be perturbations caused by manner and intrinsic pitch. These are of different quality, of course. Perturbations caused by manner are short, their duration seldom exceeds 25 ms. Perturbations caused by intrinsic pitch last for the whole vowel duration. Tone however makes vowels run on its different levels, distinctively. This means any intrinsic low vowel with high tone is still higher than any intrinsic high vowel with low tone.

11.5 Differences in the Subjects

Idiolectal strategies of tone realisation.
In addition to the plain f0 difference for tone encoding both subjects use further means. These individual strategies always consist in the change of the f0 slope in one of the tones to make it even more different from the other. This doesn't seem to be systematic in that there is no preferred tone to add more features to. There is no marked case of both tones because in subject kt the high tones rise while the low tones stay level and in mb the low tones fall more steeply than the high ones.
These additional patterns do not change the observation of tone in principle. It is separable from the consequences of perturbation.

12. DISCUSSION

Stop and Intrinsic Pitch Perturbation
The short duration of perturbation caused by the manner of less than 25 ms corresponds to Hombert's and his followers' thesis of an active suppression of the perturbation to keep up distinctiveness of tone.

Perturbations caused by stop articulation are always biggest after explosion and then fade continously. This always makes the contours rise or fall at least for some time.
Since changes in f0 are more prominent for tone perception than absolute f0 values, it is likely to find these changes compensated while the continuous vowel perturbation by intrinsic pitch can remain without danger for distinctiveness.
The lasting of the perturbations triggered by intrinsic pitch can be additionally explained by the fact that they become normalised in the listener and therefore need no correction in this respect.
In our investigation, however, tone always kept up an absolute f0 difference even though there is a strong influence of intrinsic pitch.

Idiolectals in Tone Realization
In our subjects we can find clearly different behaviour in tone production in a domain which in fact does not seem to be important for Sosokhui tone perception, different from many other tone languages. Maybe one can conclude that in this language the tones are discriminated by an absolute f0 difference plus a general slope distinction for both tones. But there seems to be no importance in the general direction: while subject kt produces rising contours for high tone vowels and level or slightly falling for low ones, speaker mb makes downward contours for high and stronger falling ones for low tone vowels.

Our Results vs. Other Predictions
The results are in clear opposition to Friedländer's and Labourét's theses.
Friedländer claimed in 1974 that tone was of no importance in Sosokhui. If in our small investigation, considering even only words spoken in isolation, most of them being no partner in a minimal pair, the result is so clearcut, one can rather conclude that the language needs tone as a vital means not only in the lexicon but also in syntactic structures. (As described in all publications focusing on Sosokhui syntax).

The same holds for Labourét's (1934) more sociolinguistic idea of a tone loss in the languages of the Mande-family through becoming major interlanguages used by too many nonnative speakers who 'destroy' tonality gradually. At least we can ascertain this theory is not applicable for the Sosokhui, as already proposed by Houis (1956).

13. OUTLOOK

This investigation in Sosokhui tone is of rather preliminary character. Anyway the plausibility of results indicates that our method is able to display the general tendencies even though the chosen way of automatic f0 extraction will slightly misrepresent reality.
It seems possible to do similar more detailed investigations with it, for example if tone in minimal pair partners will behave differently from tone in words which cannot be confused or how tone and accent interact. Another interesting point might be how tone reacts on labiovelar stops.

ACKNOWLEDGEMENTS

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APPENDIX

Word List

With indication of tone, meaning in French and group. If there were deviations in the lexica it is also marked.
1 = Partner in a minimal pair.
2 = Only for plosive influence investigations.
3 = Member of both 1 and 2.
5 = Exceptional: doubtful tone and/or meaning.

BÁ 3 enlever	BÀ 5 maitre, patron
BÂ lt. Dictio.baa 3 mer	BÀABÁ lt. Dictio. baba 2 père
BABAGNI 5 clouer	BÁGÁ 2 le Baga
BÁKHÁ 2 le riz avec du lait	BÀKHÁLÒE 2 animal
BÁKÍ 2 embarquer	BÀRÉ 5 chien
BÀRÊ lt. Dictio. baare / \ 5 taro	BÀRÍ 3 enfanter
BÀRÍ 3 un genie	BÁTÉ lt. Dictio. baate / \ 3 femme préféré d'un polygame
BÀTÉ lt. Dictio. baate 3 cerceau pour grimper aux palmiers	BÉTÌ 5 appat
BÉTÌ lt. Dictio. beeti 1 cantique	BÌGNÉ 2 respect
BÍILÌ 5 magazin.	BÍLÍ 3 arbre
BÌLÍ 3 origine	BÍLÌ lt.Dictio. biili 5 magazin
BÌRÌ 3 la direction	BÍRÍ lt. Dictio. 3 enterrer
BÍTÀNYÌ 2 beaux parents	BÖ \ / 1 rompre
BÖ \ 1 vacciner	BÒBÓÈ 1 esp. poisson
BÓBÓE 1 un muet	BÖLE \ / 1 esp. antilope
BÓLÈ 1 brindille	BÒLÉ 1 esp. antilope
BÖLE 5 epieux	BÖMBÖE / \ 1 esp. arbuste-petite plante
BÖMBÖE \ / 1 bastonnade	BÖMBÖE \ / 1 matrice
BÚ 2 durer	BÚ(GNI) ? 5 tire
BUDU	BÚKHÚBÚKHÚ 2 boullir a gros bouillons
BÚKÌ 2 livre	BÙNYÍ 1 le dessous
BÚNYÍ 1 piquer	BÙRÙKÚ 2 trouver
BÚUBÚ 2 trainent	BÚUTÍ 2 cor
DÀBÁ 2 esp. epinard	DAKHA 2 village de culture
DÀKHÚ 2 etre fou	DE \ / 1 lepre
DEMUI 5 perle noire	DÈMUÍ lt. Dictio. deemui 1 chimpanze
DENAKHAI 5 la ou	DÎ 3 comment?
DÍ 3 enfant	DÍBÀRÌ 2 nourisse
DIBIYÖNI 2 dame-jeanne	DÌGÁN 3 chacque fois
DÌGÌLÍNYÍ 2 etre rond	DÍGÌNÈ lt. Dictio. / / \ 2 fille
DÍK 2 tres	DÍKÌ \ / lt. Houis 2 s'arreter
DÖKUI \ / \ lt. Dictio. döök(u)i 1 canard	DÖKUI \ / 1 esp. de lutin
DÙGÍ 2 pagne	DÙTÚN lt. Dictio. étreindre 2 prendre avec force

FÁN 5 bon	FÍ 1 plaie
FÍ 5 donner	FÖKHE / \ 1 foyer
FÖKHE \ / 1 sel	FÖKHE 5 bien-fonds, hameau, propriete
FÚ 1 dix	FU FA FU 5 rien
FÙGÉ 1 fleur	FÚGÉ 1 haut
FÚTÍ 5 mariage	FÚTÍ lt. Dictio. fuuti / \ 1 eponge vegetale
FÙUTÍ lt. Houis futi 1 arracher	GÀLÍ 3 annuler
GÁLÍ 3 troupe	GÍ 2 courir
GUBU 2 prendre avec force	Í FÈ 1 se moucher
KÁ 3 ou?	KA 3?
KÀBÉ 3 fendillure de la peau	KÁBÉ lt. Dictio. kaaba \ / 3 s'etonner ou mais
KÀFÚ / / lt. Houis 2 aide	KÁKÁ 2 variole
KÀKÚN 2 bailler	KALE \ / \ ? 3 perroquet
KÀLÉ 3 esp. herbe	KÁLÉ lt. Dictio. \ / 3 poudre de graphite
KÁNKÁN begayer	KANKAN 5 chacque fois
KÀSÂ 2 le margouillat	KÁTÁ 2 tenter
KÉRÍ 1 chasser	KÉRÌ 1 houe
KÉRÍ 1 persecuter	KHÁLÉ 1 verser
KHALE 5 coquille	KHÀLÉ lt. Dictio. khele / \ !1 oeufs
KHÁNYÉ 1 gronder	KHÁNYÈ 1 misere materielle
KHÉRÌ 1 bonheur	KHÉRÎ 1 esp. glossine
KHÈRÍ 1 louer	KHÌ 1 dormir
KHÍ 1 journee	KHÌRÍ 5 attacher
KHÌRÍ 5 odeur	KHÖLI / / 1 manger
KHÖLI / / 1 plaisier	KHÖLI / \ 1 desir (lt. Dictio. / /)
KHÖLI / \ lt. Dictio. / /, consommer	KHÖLI \ / 1 urine
KHÖNTÖNYI / / / 1 repos	KHÖNTÖNYI \ / \ 1 coude
KHÖRI / \ 1 os	KHÙNKHÚRÍ 1 foulard
KHÙNKHÚRÌ 1 le petit	KÍ 3 maniere
KÎ lt. Dictio. / 3 donner	KÌIKÍ 2 hennir
KÌKÉ 3 miroir	KÌKÉ 5 la lune
KÍPUÍ 3 crabe de vase	KÍPUÍ 3 debandade
KÌRÁ 2 chemin	KÌRÍ 3 fruit de baobab
KÍRÌ 3 peau	KÍSÍ 2 se sauver (/ \ = salut)
KÍTÌLÌ 2 bouilloire	KÓNKÓE 1 chambre ou piece de veranda
KÒNKÓE 1 esp. palme	KÓNKÓE 1 esp. poisson
KÖNYI / \ 1 hamecon	KÖNYI \ / 1 cou
KÓNYÍ 1 captif	KÒNYÍ 1 action de jouer
KÖÖLA / / 1 noix de cola	KÖÖLA \ / (\) 1 gauche
KÒTÍ 1 amulette	KÓTÌ 1 veste lt. Dictio. kooti

KÛ 2 esp. igname (maninka)	KÚGÚRÍ 2 punaise
KÚÌ lt. Dictio. / 5 l'interieur	KÙPÊ 2 esp. poisson
KÙRÉ 2 bicyclette	KÚRÌ 2 cuisine
KÚTÍNÍ 2 la quille de bateau	KÙYÉ 2 dans l'air
LÀGÍ 1 moineau	LÁGÌ 1 pelure, coquille
LÚLÍ 5 bonbonne	LULI 5 sac a dos
MÀKHÀ 5 laver? to beat? =?	MÀKÚYÈ 5 éloigné
MÁLÌ 1 aide, secours	MÀLÎ 1 hippopotame
N FÁN 5 aussi	NYÖNYI \ / 5 esp. arbre
NÝÖNYÌ 1 lt. Houis \ / 1 fin, deces	PÁT(I) 2 net
PÍISÌ 2 piece	PÍSÍPÍSÍ 2 renforcement
PÙTÙPÚTÚ 2 avoir des spasmes	SÁRÁ 1 flute ou trompette
SÀRÁ 1 vendre	SE V 1 chose
SÉ 1 etre mur	SÈGÉ 1 couper
SÉGÈ 1 milan, faucon	SÈMBÉ 1 aiguille
SÉMBÉ 1 la force	SI V 1 vie
SÍ 1 chevre	SÍ 1 planter
SÍISÍ 1 s'enivrer	SÍISÍ 1 thorax
SÒ 1 entrer	SO AYI 5 remettre
SÒÉ 1 cheval	SÓE lt. Dictio. \ 1 action d'entrer
SÖKHÖ / \ 1 oncle	SÖKHÖ \ / 1 percer
SURI V \ lt. Dictio. / \ 1 furoncle	SÙRÍ 1 île
TÁ 2 village (tàá?)	TÀBÊ lt. Dictio. \ / 2 cuisse
TÀFÉ 2 esp. plante	TÀGÍ 2 centre, milieu
TÀKÁNYÌ 2 le chef de la village	TÁKHÚNYÌ 2 etre separee
TÀLÍ 1 scorpion	TÀLÍ lt. Dictio. taali 1 proverbe
TARI V \ 2 vin de palme	TÀTÉ 2 palissade
TÉ 1 feu	TÉ lt. Houis \ / 1 nid
TI V lt. Dictio. / 3 construire	TI 3 the
TÌGÍ / / lt Houis front	TÔ lt. Dictio. / 3 aujour d'hui
TÓ lt. Dictio. \ 3 voir	TÓNGÓE 1 action de prendre
TÒNGÓÈ lt. Dictio. / \ 1 nain	TU V lt. Dictio. / 2 crever
TÙBÍ tuubi 2 se repentir	TÚGÍ 2 regime de palme
TÙKHÚNÝÍ 2 butte de manioc	TÚLÍ 2 oreille
TÚMBÉ 1 epine	TÙMBÉ 3 renommee
TÚPÌ 2 etoupe	WASI 1 se glorifier
WASI 5 sueur	WÚRÈ 1 fer
WÙRÉ 1 patate douce	YA V 1 maintenant

YÁ 1 oeil	YÁMBÁ 1 briller
YÀMBÁ 1 chanvre	