THE EQUIDISTANT HEPTATONIC SCALE OF THE ASENA IN MALAWI

by

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The musical scale of the Sena people of Southern Malawi can be characterised as an equidistant heptatonic tone system.

Kubik (1968) reports: "The equi-heptatonic tuning with its standard interval of 171 cents gives an unmistakable sound to the Asena *bangwe.* The same scale is used for the tuning of the large *ulimba* xylophones".

The *bangwe* (a board zither) and the *ulimba*, belong, next to drums and rattles, to the most common instruments of the Asena in the Lower Shire Valley of Malawi. In the years 1970-1971 I measured tunings, mainly of *bangwes* and *valimbas* (this name is more common than *ulimba*; another name for this xylophone is *malimba*) in this region.[1] I will analyse these tone measurements in order to see how well they fit the model of an equidistant heptatonic scale. And if this is indeed the model that the musicians use in tuning their instruments, how large is the variability in their tuning? The deviation from the tuning model that is tolerated by the musicians is an important but sometimes neglected topic. These questions are also of interest to other areas where equidistant heptatonic scales are found. These areas include North East Rhodesia (Andrew Tracey: 1970) and the Southern part of Mozambique (Hugh Tracey: 1948).

Below I will first give some information on the instruments and their players. Next I will analyse their tuning. These results will be compared to other data on tone measurements concerning a scale that is (almost) equidistant: the *slendro* scale used in Javanese gamelans (Wasisto Surjodiningrat et al: 1972).

The bangwes and valimbas and their players

A *bangwe* is a board zither that may vary in size and number of strings. The board is about 1 cm thick and measures from 15 cm by 45 cm to 20 cm by 65 cm. The *bangwe* players prefer *mlombwa* (also called *mbira*) wood for the board.[2] The strings are formed by winding one piece of strong steel wire through the holes at the top end and the holes at the bottom end of the board. The strings are lifted 3 to 4 mm from the board by small pieces of wood, usually bamboo. The tuning of the instrument is accomplished by putting these pieces of bamboo at the ends of the strings in the right positions.

The top end of the board is put into a paraffin tin (*bekete*) for resonance. A large calabash (*dende*) can also be used for this purpose. Some bottle tops are fixed on top of the paraffin tin in order to make a buzzing sound to accompany the playing.

The *bangwe* is always played by men on their own, to accompany their own singing. The *bangwe* playing (*kuimba bangwe*) is done at home for one's own pleasure, at beer parties where people may dance to its music, and sometimes at funerals. The *bangwe* players that I recorded in 1970-1971 were all between about 25 and 40 years of age, except for Jester Razikeni Makoko, who was by that time 65 years old.

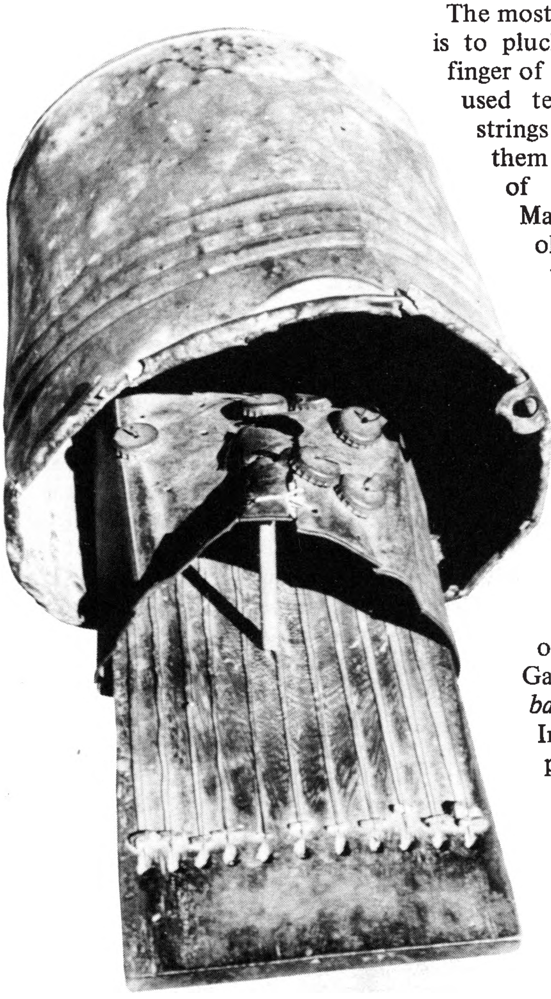


Photo 1: the *bangwe* of Luwizi Nyapyache

The most common way of playing the *bangwe* is to pluck the strings with thumb and forefinger of each hand. The other, less frequently used technique, is to mute some of the strings by putting the left hand fingers on them and strumming with the forefinger of the right hand. Jester Razikeni Makoko called this last technique the old style of playing. This strumming technique was only sometimes applied by Jester himself and Botomani Sande. Jester, who was the eldest of the *bangwe* players I recorded, recalled that he saw in his youth *bangwes* with strings made from the intestines of cattle.

Appendix 1 presents the tuning of the *bangwes* in vibrations per second. The intervals between the notes are given in cents. Luwizi A and Luwizi B are tunings of the *bangwe* of Luwizi Nyapyache on two different days. Gasitoni A and Gasitoni B are tunings of two different *bangwes* belonging to Gasitoni Thole. In one song I recorded, Gasitoni Thole played the two *bangwes* together: one *bangwe* with his left hand and one *bangwe* with his right hand.

The *valimba* is a xylophone consisting of a long frame on which about twenty keys (*limba*, plural *malimba*) are fixed. Calabashes (*madende*) hang just below the keys for resonance. If possible, there is one calabash below each key. This is not always possible for the larger keys, as here the calabashes have to be larger too. In each calabash one or two rectangular holes are cut out, on which the tissue for the eggs of a spider (*mvema*), or, more common nowadays, cigarette paper, is stuck. The juice of a fig tree or *nsima* (maize porridge) can be used as glue. The function of the cigarette paper is to increase the volume of the tone and to produce a buzzing sound. Like the board of the *bangwe*, the wood used for the keys and framework is *mlombwa*.

Usually there are three players for one *valimba*: one plays the higher notes (*magogogo*), one plays the medium range notes (*mapakati*) and one the lower notes (*magunthe*). Each player has two sticks that are covered with rubber at the striking end. Usually a rattle (*nkhocho*) accompanies the *valimba*. Sometimes this "rattle" consists of two slats fixed on the *valimba*, one on top of the other. A drum (*mulakasa* or *gaka*) may also be added. Only boys and young men play the *valimba.* Their ages ranged between 10 and 33 years, while three-quarters of them were under 20 years of age. They play at beer parties, wedding and funeral parties, and quite often in the evenings just for pleasure, accompanying the dancing of women, girls and small boys.

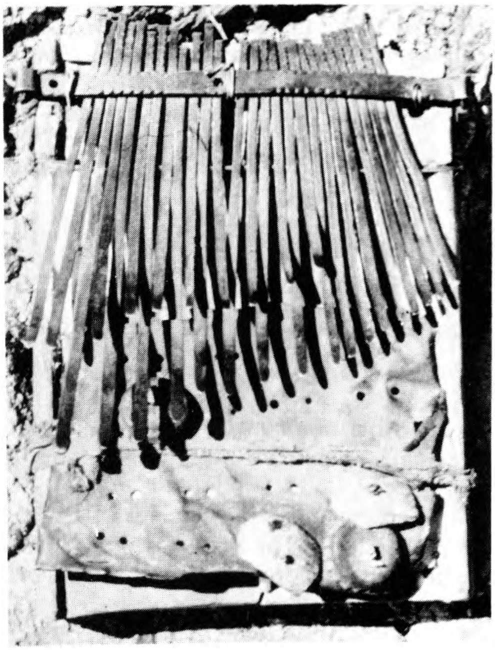
Photo 2: the *valimba* of Makoko village

Apart from the rattle and the drum, the *valimba* is not combined with other instruments. Sometimes a small and a large *valimba* are played together: Mb
played together: Mbang'ombe S and Mbang'ombe L, and Chapo S and Chapo L.

Appendix 2 presents the measured tuning of the *valimbas* in vibrations per second. The intervals between the keys are given in cents.

Appendix 3 presents the measured tuning of some *malimbas*, instruments of the mbira class of lamellophones. These tunings will also be used in my analysis. In Appendix 4 the arrangement of the reeds of these *malimbas* is given, using the system as applied by Andrew Tracey.

Photo 3: *malimba mano a mbuzi* of Semba



In Appendix 5, the tuning of three sets of *Ntanda* drums (used for the *likhuba* dance, the *madzoka* dance and the *lundu* dance) is given in order to get an idea about the pitch of these drums, compared with other instruments.

Photo 4: warming up the membranes of the *Ntanda* drums in order to get the skins tight for playing.

Some concepts concerning the tuning

The Asena distinguish a high tone, *fala ing'ono* (litt.: small tone) from a low tone, *fala ikulu* (litt.: great tone). In the range from high to low, the tones are classified in greater detail according to their relative pitch, but not all the tones (of strings, keys, drums) have a name of their own. Usually the name is given to a group of tones. The classification differs from one instrument to the other. The *Ntanda* drums (which are lined up in a row), the strings of the *bangwe*, and the keys of the *valimba* are all arranged in such a way that the highest tone is produced by the drum, string or key on the right, as seen from the players. Going to the left the pitch decreases.

Below I present some arrangements of the drums, strings and keys as seen from the players: left of page = left of players.

	lowest pitch — — — — — — — — — — — — — — — highest pitch
Ntanda drums:[3]	1 gunthe, 1 ntewe, 1 nsonjo, 5 usindi, 1 gogogo (2 misonjo) (4 usindi)
Bangwe Luwizi:	4 magunthe, 3 misonjo, 4 usindi
Bangwe Botomani:	1 gunthe, 1 ntewe, 2 mphanambe, 4 usindi, 1 gogogo
Bangwe Topiyasi:	4 magunthe, 3 mapakati, 3 magogogo
Valimba xylophones:	magunthe, mapakati, magogogo

Each of the *valimba* players plays his own part: *magunthe, mapakati* or *magogogo.* The same holds true mutatis mutandis for the *Ntanda* drums; here, there are five players.

The arrangement of the reeds of the *malimba* lamellophones is more complicated: see Appendix 4. The *malimba* players call their higher notes *atsikana* (= girls), their medium range notes *mitewere* (*mitowela*), *anyamata* (= boys) or *usindi*, and their lower range notes *magunthe.*

The tuning of the *bangwe* zither usually starts on the higher notes. Triplets of three consecutive notes are played and tuned, from high to low. After these triplets, the players usually check the octaves. One of the *valimba* xylophone players said, that when their instrument was made, it was tuned from the highest note descending. Dzingo Chilingamphale, however, started tuning his *malimba nyonga-nyonga* lamellophone from the lowest note.

The distance between two consecutive notes is, by some players, expressed as 1 *fala*, and as 2 *mafala* when one note is in between the two, etc. Sometimes the octave is called *fala* or *faka.*

Measurement and measurement error

The measurement of the pitch of the tones was done in the field by means of a set of 54 tuning forks.[4] The set has a range from 212 vibrations per second (v.p.s.), ascending by 4 v.p.s. to 424 v.p.s. A tuning fork was struck and put onto the board of the *bangwe* or the frame of the *valimba.* A string of the *bangwe* was plucked, or a key of the *valimba* beaten with its beating stick and the tone of the tuning fork compared with the one of the instrument. The vibrations per second of the nearest tuning fork were chosen to represent the pitch of the tones of the instruments. Sometimes I interpolated between two tuning forks. In this process of comparing I usually asked the opinion of the players too.

The measuring, of course, is not quite exact. I estimate the error of measurement of the order of 2 v.p.s. in the upper range (near 424 v.p.s.) and 1 v.p.s. in the lower range (near 212 v.p.s.).[5] This means that in the lower range the distance between two consecutive tuning forks is so large that my ear can distinguish tones of three different frequencies in between the frequencies of the forks, whereas in the upper range my ear can distinguish only one tone frequency in between two consecutive forks. This measurement error corresponds to about 9 cents. I will assume that it is constant throughout the range that I used for analysis, i.e. 130 v.p.s. up to about 700 v.p.s.

The error in the calculated interval between two notes depends on the error in the two pitch measurements: see the scheme below.

Analysis of the tunings

It seems that *bangwe* players and *valimba* players always start a particular song on the same note. They say, however, that one may start a song on any string or key, as long as the song is playable on the instrument. If this is so, and if the interval between the consecutive notes of the scale would not be the same throughout the octave, this would mean that a song could be played in different "modes", depending on where it starts. The concept of "mode", however, seems not to occur in the Sena music. Therefore the statement that a song may begin on any note gives us a strong indication that the scale Sena musicians use is equidistant.

I shall assume that indeed the tuning model is such as to achieve the same intervals between the seven notes within one octave. If so, how much deviation from this model is there in the actual tuning of the *bangwes* and *valimbas*?

The *bangwes* and *valimbas* are, with a few exceptions, not played together with other instruments other than rattles and drums. This may explain the apparent absence of a "reference note" such as the *hombe* of the Chopi *timbila* xylophones (Hugh Tracey: 1948). Therefore, I will analyse each *bangwe* and *valimba* on its own.

The octave

First of all I want to investigate the octaves. If a *bangwe* has, for example, eleven strings, indicated by the numbers 1 to 11, then there are four octaves on this *bangwe*: 1 - 8, 2 - 9, 3 - 10 and 4 - 11. If we take all the *bangwes* together there are a total of thirty five octaves. The mean octave is 1222 cents, which is slightly more than the "physical octave" of 1200 cents. So the *bangwe* players seem to tune their instruments such as to achieve octaves that are slightly above 1200 cents. The picture becomes even more clear in Table 1.

Player	Mean octave in cents	Number of octaves below 1200 cents	Number of octaves of 1200 cents	Number of octaves above 1200 cents	Total number of octaves
1. Medisoni	1206	2	2	1	5
2. Manyindu	1193	4	2	0	6
3. Luwizi A	1242	1	0	3	4
4. Luwizi B	1237	0	1	3	4
5. Gasitoni A	1211	1	0	4	5
6. Gasitoni B	1245	0	0	6	6
7. Botomani	1222	0	1	1	2
8. Topiyasi	1239	0	0	2	2
9. Jester	1217	0	0	1	1
All *bangwes*	1222	8	6	21	35

Table 1: the octaves of the *bangwes*

60% of the octaves are slightly above 1200 cents and only 23% are slightly below 1200 cents.

For the *valimbas* the same analysis has been carried out. Here I have, however, only taken into account the notes of 130 v.p.s. or more for the analysis. Below 130 v.p.s. the tuning of the *magunthe* notes is clearly not always such as to achieve intervals of about 171 cents, the standard interval: see appendix 2. Table 2 gives the results.

Valimba	Mean octave in cents	Number of octaves below 1200 cents	Number of octaves of 1200 cents	Number of octaves above 1200 cents	Total number of octaves
1. Mbang'ombe A	1229	2	1	6	9
2. Mbang'ombe S	1204	2	1	3	6
3. Mbang'ombe L	1190	4	3	2	9
4. Nkuzaduka	1215	3	1	7	11
5. Chapo S	1232	1	0	6	7
6. Chapo L	1200	4	1	4	9

7. Nchenyela	1214	5	0	5	10
8. Mbeta	1220	1	2	6	9
9. Mbeta (Soche)	1212	3	3	4	10
10. Tipa	1222	1	2	7	10
11. Makoko	1212	3	2	4	9
12. Nthepheya	1211	2	4	2	8
13. Nyenyezi	1224	3	1	6	10
14. Chakanji	1167	7	1	2	10
15. Nyakamela	1198	5	0	2	7
16. Gundani	1253	0	0	8	8
17. Chambuluka	1222	3	1	5	9
All *valimbas*	1213	49	23	79	151

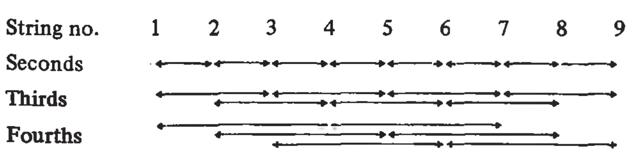
Table 2: the octaves of the *valimbas*

From this table it is clear that apparently also the *valimba* tuners want their octaves tuned slightly above 1200 cents.[6]

Other intervals and their variability

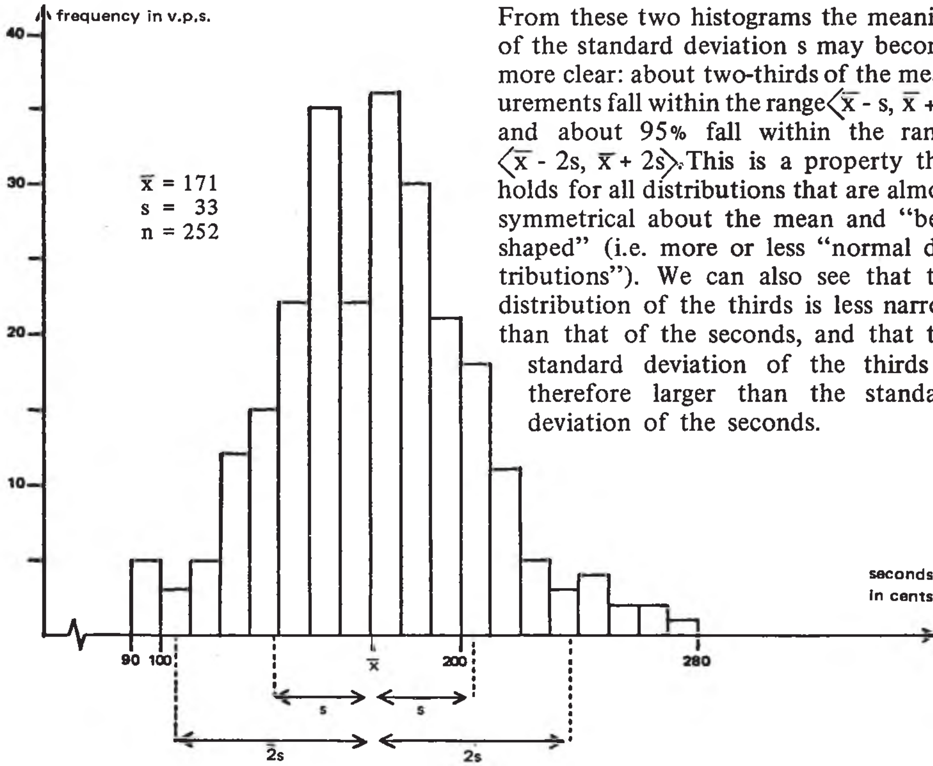
If the scale is meant to be equidistant, this means that the intervals between consecutive strings of the *bangwe* are meant to be the same. The same holds true for the notes on *valimbas* above 130 v.p.s. If all the seconds are tuned so as to be the same, it follows that also all the thirds are meant to have the same interval. (This is certainly not the case in the Western Major scale, where the thirds are sometimes major thirds and sometimes minor thirds.) The same holds good for fourths, fifths, etc.

If a *bangwe* consists of nine strings, then there are eight seconds, seven thirds, six fourths, etc. on this *bangwe*. See the scheme below:

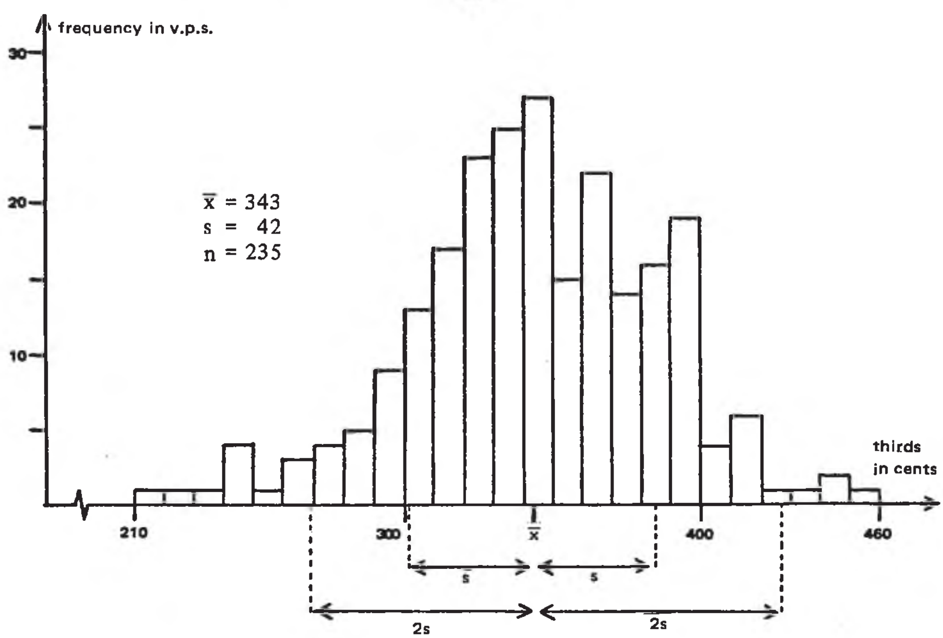


For each instrument I have calculated the mean of the seconds, the mean of the thirds, etc. (notation: $\bar{x}$) and also the standard deviation of each of these intervals (notation: s). The standard deviation is a measure of dispersion about the mean. If the measurements are close together, the value of s is small, and if the measurements are broadly distributed, s is large.[7] Both the mean and the standard deviations are given in cents in our case.

For the *valimbas* together the picture (histogram) of the frequency distribution of the seconds and the picture of the frequency distribution of the thirds are given below as an example. You can derive these frequency distributions from the data given in Appendix 2.



From these two histograms the meaning of the standard deviation s may become more clear: about two-thirds of the measurements fall within the range $\langle \bar{x} - s, \bar{x} + s \rangle$ and about 95% fall within the range $\langle \bar{x} - 2s, \bar{x} + 2s \rangle$. This is a property that holds for all distributions that are almost symmetrical about the mean and "bell-shaped" (i.e. more or less "normal distributions"). We can also see that the distribution of the thirds is less narrow than that of the seconds, and that the standard deviation of the thirds is therefore larger than the standard deviation of the seconds.



In Table 3 you find the mean and the standard deviation for each of the intervals, up to the octave, on the *bangwes* and *valimbas*.

n = 89 means that the calculation is based on 89 intervals. If the value of s is put between brackets, this means that the calculation is based on four or less intervals.

	Seconds		Thirds		Fourths		Fifths		Sixths		Sevenths		Octaves	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Bangwes														
1. Medisoni	174	31	340	37	511	46	686	56	861	57	1035	55	1206	53
2. Manyindu	169	13	338	15	508	19	680	18	851	14	1023	16	1193	7
3. Luwizi A	177	44	356	29	530	52	709	46	888	51	1066	53	1242	(39)
4. Luwizi B	177	22	352	27	529	34	707	21	885	15	1062	10	1237	(32)
5. Gasitoni A	170	43	351	36	525	39	695	43	865	40	1036	42	1211	44
6. Gasitoni B	175	40	346	45	521	54	697	59	884	49	1067	32	1245	26
7. Botomani	173	23	349	26	524	21	693	31	867	(25)	1048	(21)	1222	(31)
8. Topiyasi	175	23	354	31	528	22	699	6	874	(24)	1056	(38)	1239	(14)
9. Jester	174	30	357	30	536	23	712	(40)	896	(32)	1071	(20)	1217	(00)
All bangwes	173	31	348	31	522	37	696	40	873	39	1048	38	1222	36
	(n = 89)		(n = 80)		(n = 71)		(n = 62)		(n = 53)		(n = 44)		(n = 35)	
Valimbas														
1. Mbang'ombe A	174	32	350	35	523	34	698	32	877	36	1056	34	1229	30
2. Mbang'ombe S	167	37	335	36	511	38	684	37	855	46	1032	32	1204	45
3. Mbang'ombe L	168	30	332	36	501	38	670	45	842	45	1019	37	1190	39
4. Nkuzaduka	172	23	345	30	516	34	688	41	861	38	1036	37	1215	33
5. Chapo S	166	38	342	53	521	59	702	51	880	50	1058	56	1232	59
6. Chapo L	170	24	342	31	515	35	683	41	854	49	1029	50	1200	49
7. Nchenyela	168	42	341	58	519	50	690	48	859	56	1036	57	1214	43
8. Mbeta	174	32	349	47	521	48	692	50	870	52	1044	39	1220	27
9. Mbeta (Soche)	168	34	338	40	513	44	685	49	859	52	1035	51	1212	42
10. Tipa	177	24	349	26	524	21	701	24	876	20	1049	22	1222	25
11. Makoko	165	40	332	60	505	67	682	70	862	75	1041	76	1212	70
12. Nthepheya	174	26	354	35	524	36	698	50	872	58	1039	55	1211	51
13. Nyenyezi	171	28	344	35	517	40	691	37	867	44	1047	45	1224	38
14. Chakanji	164	26	331	35	500	36	667	32	834	36	1001	31	1167	39
15. Nyakamela	176	37	347	40	519	47	688	51	862	40	1030	46	1198	48
16. Gundani	182	38	362	37	535	30	714	39	891	35	1068	24	1253	40
17. Chambuluka	173	58	347	64	524	38	698	66	872	71	1053	51	1222	67
All valimbas	171	33	343	42	517	41	690	46	864	49	1039	46	1213	46
	(n = 252)		(n = 235)		(n = 219)		(n = 202)		(n = 185)		(n = 168)		(n = 151)	
Equidistant heptatonic scale with octave of 1200 cents	171		343		514		686		857		1029		1200	

Table 3: the mean $\bar{x}$ and the standard deviation s in cents for the seven intervals

Table 3 shows that the *bangwe* of Manyindu and the *valimba* from Tipa village are rather close to the model of equidistant intervals as the standard deviations are small and almost the same for all intervals. But what about the other instruments? If these instruments are also tuned according to the model of equidistancy, the variability is quite often rather large according to the measurements. The measurement error of 13 cents is usually small compared with the total "error", i.e. the standard deviation as given in table 3.[8] That is to say, to many players a broad range of tuning possibilities is acceptable. The great tolerance in accepting tunings may also be seen from the tuning of the *bangwe* of Luwizi on two different days.

The other possibility is, of course, that most players do not really tune their instruments according to the model of equidistancy. Their model may be a different one and the high values of the standard deviations may be caused by systematic errors (i.e. we are applying the wrong model to the actual situation), rather than random errors (i.e. the tolerance of the musicians with respect to variability of the intervals and the measurement error).

The primes

On the *bangwe* and on the *valimba* there are no notes that are meant to be the same, but on the *malimba* lamellophones there are. In Appendix 4 the notes that are meant to be the same are drawn on the same line. Sometimes there is a small difference in pitch between these tones. I have calculated the mean of these primes and their standard deviation. The *malimba* of Rosi Lenso is not included in these calculations. This *malimba* was not well tuned according to Dzingo Chilingamphale and I think he is right. The results are put in Table 4.

	$\bar{x}$ in cents	s in cents	n (i.e. the total number of primes that occur)
Dzingo Chilingamphale	18	25	12
Mbiti Msona	18	17	9
Joe Chiputaputa	33	29	9
Semba	12	13	10
All *malimbas*	20	23	40

Table 4: the mean and standard deviation of the primes on the *malimba* lamellophones

The mean difference in pitch for all *malimbas*, $\bar{x} = 20$ cents, gives us an idea as to what are tolerable differences between tones that are meant to be the same. For, as the measurement error in the differences in pitches is of the order of thirteen cents (see section on measurement and measurement error), it follows that the just noticeable differences between two tones of the *malimba* lamellophone that are meant to be the same are of the order of fifteen cents ($20^2 \approx 13^2 + 15^2$). This is close to the results that Lehiste (1970) quotes on experiments in laboratories.

In the above calculations for the primes I have not taken into account that the *malimba* reeds may be tuned to the first overtone (i.e. a tone usually approximately two octaves higher than the fundamental) and not to the fundamental (Andrew Tracey: 1970, 1972). My results hold for the fundamentals and not for the first overtones. If this analysis is carried out with first overtones (of the right hand part) instead of fundamentals, I expect the results to be similar, as the "ideal relation" between first overtone and fundamental will most probably be a difference of exactly two octaves. My results on the primes as given above should therefore only be taken as a **rough indication** on the just noticeable difference between two tones that are meant to be the same.

Comparison with the Javanese slendro scale

Gamelans in Java may be tuned to the pentatonic *slendro* scale, which is (almost) equidistant. Wasisto Surjodiningrat, P.J. Sudarjana and Adhi Susanto from Gajah Mada University measured the tunings of a number of gamelans in Central Java (Wasisto (et al.): 1972[2]). One of the instruments of the gamelan orchestra is the *gambang*, a trough xylophone with wooden keys. Only two tone measurements of *slendro gambangs* are given by the authors: the one on page 37 of the *slendro* gamelan Kyahi Madumurti of the Yogyakarta kraton (20 keys ranging from 113 v.p.s. to 1662 v.p.s.), and the other on page 41 of the *slendro* gamelan Kyahi Kanjutmesem of the Pura Mangkunegaran in Surakarta (20 keys, ranging from 109 v.p.s. to 1632 v.p.s.). I have analysed the tone measurements of these two *gambangs* in the same way as the tone measurements of the *bangwes* and *valimbas* in Malawi described above, in order to compare the results. From the instruments of the gamelan orchestra I took the *gambang* because this instrument is closest to the *valimba* of the Asena.

Assuming that the *slendro gambang* is indeed tuned to the model of an equidistant pentatonic scale, I have calculated the mean and standard deviation of the seconds (interval between two consecutive keys), thirds (interval between one key and the second next), fourths, fifths and octaves. The results are given in table 5. The mean and standard deviation are given in cents.

	Seconds		Thirds		Fourths		Fifths		Octaves	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Gambang										
Kyahi Madumurti	245	18	489	18	733	21	977	24	1219	21
Kyahi Kanjutmesem	247	18	490	25	735	29	981	33	1228	38

Table 5: the mean $\bar{x}$ and the standard deviation s in cents for the five intervals on *slendro gambangs*

The values for the standard deviations are of the same order as the values that we found for the Malawian xylophones: compare with table 3. Note that, here also, the octaves are apparently meant to be more than 1200 cents. Each *gambang* has in fact two octaves below 1200 cents, one octave of 1200 cents and twelve octaves above 1200 cents.

There are, however, important differences between the *gambang* and the *valimba* xylophone. The first difference is that the *gambang* is played as part of a gamelan orchestra and the *valimba* on its own. The second difference is that the notes of the *slendro* scale, in contrast to the notes of the Sena scale (as far as I know), each have their own name: *barang, gulu, dada, lima, nem, (barang)*. This enables us to calculate the mean interval between *barang* and *gulu*, the mean interval between *gulu* and *dada*, etc. over a number of instruments, in order to see whether indeed these intervals are the same. It gives us the opportunity to check more accurately whether the *slendro* scale is equidistant. In table 8, p. 51, Wasisto (et al.) presents the tuning of twenty eight "outstanding *slendro* gamelans" from Yogyakarta and Surakarta, based on the pitches of either the *saron demung* or the *gender barung* (two xylophones with respectively six or seven and twelve to fourteen keys of bronze in the gamelan orchestra). I have calculated the mean and the standard deviation of the twenty eight intervals *barang – gulu.* The same has been calculated for the twenty eight intervals *gulu – dada*, etc. The results are given in Table 6.[9]

Name of tone:	Barang		Gulu		Dada		Lima		Nem		Barang
Mean interval in cents:		233		239		246		243		252	
Standard deviation in cents:		9		11		12		9		9	

Table 6: the mean and standard deviation of the intervals between the consecutive tones *barang, gulu, dada, lima* and *nem* on the *slendro* scale

These results show that the *slendro* scale is indeed almost, but not entirely, an equidistant pentatonic scale. The first interval, between *barang* and *gulu,* is apparently meant to be smaller than the last interval, between *nem* and *barang*, as the authors point out. (p. 21). The mean octave *barang – barang* is 1213 cents.

On page 37, Wasisto (et al.) gives the tuning of all the instruments of the *slendro* gamelan Kyahi Madumurti and on page 41 the tuning of all the instruments of the *slendro* gamelan Kyahi Kanjutmesem. Some tones are meant to be the same on the different instruments, so we can again calculate the mean of primes, in order to get an idea about what are tolerable differences between tones that are meant to be the same. The mean of the primes in the octave IV (ca. 280 v.p.s. to 500 v.p.s.) appears to lie between six cents (for the tone *barang* of the gamelan Kyahi Madumurti) and fourteen cents (for the tone *lima* of the gamelan Kyahi Kanjutmesem).

The tolerable differences between tones that are meant to be the same are, therefore, smaller in the Javanese *slendro* gamelan orchestra than on the *malimba* lamellophones of the Asena.

From looking at these results for the *slendro* scale it is possible to give a better evaluation of the findings for the Sena scale. I have analysed the Sena tunings, assuming that the tuning is done according to the model of an equidistant heptatonic scale. From table 3 it can be seen that most Sena players, assuming that they tune according to this model, tolerate much deviation from the model, as the standard deviations are not small.

It has been pointed out that the tuning model may be slightly different from the equidistant heptatonic scale model. I have not been able to show that the Sena scale is **not** entirely equidistant, such as Wasisto (et al.) has shown for the *slendro* scale. This is because of the fact that the Sena people apparently do not give each note a name of its own.

The Chopi musicians of Mozambique, however, do give each note of the *timbila* xylophone a number, starting from the note *hombe* (Hugh Tracey: 1948, p. 120). More detailed analysis of the tuning of their instruments may clarify whether the Chopi musicians really use an equidistant tuning model or whether they slightly deviate from it on purpose.

Appendix 1: the tuning of *bangwes* in vibrations per second (v.p.s.) and the intervals between consecutive strings in cents.

The highest tone is produced by the string on the utmost right of the players. * indicates that a string is not used. Luwizi A and Luwizi B are tunings of the same *bangwe* of Luwizi Nyapyache on two different days. Gasitoni A and Gasitoni B are tunings of two different *bangwes* possessed by Gasitoni Thole.

1. Medisoni		2. Manyindu		3. Luwizi A		4. Luwizi B		5. Gasitoni A		6. Gasitoni B	
vps	cents	vps	cents	vps	cents	vps	cents	vps	cents	vps	cents
640		560		456		472		464		624	
	182		182		176		153		156		163
576		504		412		432		424		568	
	151		173		154		168		190		153
528		456		377		392		380		520	
	136		159		178		167		213		197
488		416		340		356		336		464	
	148		175		128		207		173		124
448		376		316		316		304		432	
	179		154		234		184		168		186
404		344		276		284		276		388	
	180		186		130		180		157		249
364		309		256		256		252		336	
	181		165		231		141		173		151
328		281		224		236		228		308	
	201		181		137		185		159		215
292		253		207		212		208		272	
	175		180		242		172		175		132
264		228		180		192		188		252	
	136		159		161		210		237		158
244		208		164		170		164		230	
	243		166						65		141
212		189						158		212	
			143								227
		174						* (4 strings)		186	

7. Botomani		8. Topiyasi		9. Jester	
vps	cents	vps	cents	vps	cents
324		472		408	
	180		153		160
292		432		372	
	175		168		155
264		392		340	
	194		206		194
236		348		304	
	185		168		168
212		316		276	
	136		160		184
196		288		248	
	186		157		224
176		263		218	
	188		217		132
158		232		202	
	136		173		
146		210			

Appendix 2: the tuning of *valimbas* in vibrations per second and the intervals between consecutive keys in cents.

The key that produces the highest tone is on the right of the players. * indicates a broken or not sounding key, and ( ) a key that is not used. r is a rattle, consisting of two slats, one on top of the other. Only frequencies of 130 v.p.s. or higher have been used in the analysis.

1. Mbang'ombe A		2. Mbang'ombe S		3. Mbang'ombe L		4. Nkuzaduka		5. Chapo S		6. Chapo L	
vps	cents	vps	cents	vps	cents	vps	cents	vps	cents	vps	cents
630		584		576		756		600		600	
	149		201		177		178		120		120
578		520		520		682		560		560	
	170		95		139		204		182		182
524		492		480		606		504		504	
	159		194		150		131		204		204
478		440		440		562		448		448	
	151		148		165		174		179		179
438		404		400		508		404		404	
	196		180		163		157		162		162
391		364		364		464		368		368	
	187		181		202		152		199		199
351		328		324		425		328		328	
	188		201		180		217		177		177
315		292		292		375		296		296	
	185		123		148		180		147		172
283		272		268		338		272		268	
	127		217		192		189		217		163
263		240		240		303		240		244	
	232		182		214		193		214		179
230		216		212		271		212		220	
	158		151		119		153		119		148
210		198		198		248		198		202	
	155		136		145		154		145		124
192		183		182		227		182		188	
	150		897		181		168		98		195
176		109		164		206		172		168	
	243				131		158		871		162
153				152		188		104		153	
	154				218		195				179
140				134		168				138	
	155				120		173				185
128				125		152				124	
	201				221		143				176
114				(110)		140				112	
	78				-62		356				196
109				114		114				100	
	371			( )	635		772			*	344
88				79		73				82	

7. Nchenyela		8. Mbeta		9. Mbeta(Soche)		10. Tipa		11. Makoko		12. Nthepheya	
vps	cents	vps	cents	vps	cents	vps	cents	vps	cents	vps	cents
664		624		616		696		( )			
	147		139		116		212				
610		576		576		616		552		600	
	123		151		124		165		103		170
568		528		536		560		520		544	
	277		165		192		128		110		217
484		480		480		520		488		480	
	173		150		150		227		148		150
438		440		440		456		448		440	
	94		183		183		176		162		183
415		396		396		412		408		396	
	152		184		184		158		160		184
380		356		356		376		372		356	
	192		207		207		174		197		121
340		316		316		340		332		332	
	177		184		136		149		198		175
307		284		292		312		296		300	
	166		153		228		188		199		170
279		260		256		280		264		272	

vps	cents
	225
245	
	163
223	
	171
202	
	190
181	
	171
164	
	143
151	
	131
140	———
	169
127	
	249
110	
	551
80	
	-351
98	
r	486
74	
	-396
93?	

vps	cents
	139
240	
	214
212	
	127
197	
	176
178	
	239
155	
	202
138	———
	157
126	
	418
99	
	90
94	
	535
69	
( )	
( )	

vps	cents
	170
232	
	156
212	
	136
196	
	167
178	
	207
158	
	136
146	
	201
130	———
	197
116	
	156
106	
	-95
112?	

vps	cents
	182
252	
	173
228	
	193
204	
	160
186	
	176
168	
	173
152	
	193
136	———
	464
104	
( )	543
76	

vps	cents
	107
248	
	224
218	
	220
192	
	150
176	
	144
162	
	156
148	
	199
132	———
	254
114	
	725
75	
( )	
( )	

vps	cents
	159
248	
	177
224	
	214
198	
	184
178	
	?
*	
	?
142	
	153
130	———
( )	353
106	
	303
89	

13.
Nyenyezi

vps	cents
( )	
640	
	111
600	
	170
544	
	159
496	
	208
440	
	148
404	
	180
364	
	202
324	
	180
292	
	175
264	
	165
240	
	214
212	
	154
194	
	130
180	
	161
164	
	177
148	
	199
132	———
	284
112	
( )	196
100	

14.
Chakanji

vps	cents
( )	
648	
	133
600	
	107
564	
	168
512	
	192
458	
	151
420	
	191
376	
	154
344	
	164
313	
	144
288	
	204
256	
	141
236	
	185
212	
	154
194	
	188
174	
	189
156	
	163
142	———
	180
128	
	141
118	
( )	219
104	
( )	589
74	

15.
Nyakamela

vps	cents
616	
	165
560	
	155
512	
	170
464	
	124
432	
	240
376	
	154
344	
	148
316	
	184
284	
	153
260	
	168
236	
	202
210	
	173
190	
	255
164	———
( )	456
126	
	84
120	
	1200
60	

16.
Gundani

vps	cents
592	
	147
544	
	267
466	
	132
432	
	195
386	
	179
348	
	146
320	
	206
284	
	207
252	
	143
232	
	173
210	
	182
189	
	153
173	
	179
156	
	238
136	———
	217
120	
	151
110	
	148
101	
	124
94	
	114
88	
	372
r	
71	

17.
Chambuluka

vps	cents
592	
	97
560	
	128
520	
	258
448	
	95
424	
	136
392	
	267
336	
	151
308	
	140
284	
	180
256	
	200
228	
	143
210	
	247
182	
	139
168	
	173
152	
	245
132	———
	165
120	
	182
108	
	-239
124	
	517
92	
r	117
86	
( )	
( )	

Appendix 3: the tuning of *malimba* lamellophones in vibrations per second and the intervals between consecutive notes in cents.

The tuning is given from high to low notes and not according to the arrangement of the reeds. For the arrangement of the reeds see Appendix 4. Notes that are meant to be the same are put between brackets and the mean of each pair is written next to the bracket.
The first four *malimbas* are of the *nyonga-nyonga* type and the last one is of the *mano a mbuzi* type.

Dzingo Chilingamphale

v.p.s.	mean	cents
720		
		98
680		
		264
584		
		201
520		
		168
472		
		153
432		
		133
400		
		163
(364 / 364)	364	
		150
(336 / 332)	334	
		232
(292 / 292)	292	
		175
(264 / 264)	264	
		165
(240 / 240)	240	
		150
(220 / 220)	220	
		174
(200 / 198)	199	
		154
(184 / 180)	182	
		181
(168 / 160)	164	
		201
(146 / 146)	146	
		188
(132 / 130)	131	
		166
(120 / 118)	119	
		169
108		
		168
98		
		148
90		
		140
83		
		222
73		

Mbiti Msona

v.p.s.	mean	cents
848		
		172
768		
		131
712		
		207
(640 / 624)	632	
		148
(584 / 576)	580	
		189
(520 / 520)	520	
		168
(472 / 472)	472	
		157
(432 / 430)	431	
		191
(388 / 384)	386	
		140
(356 / 356)	356	
		185
(324 / 316)	320	
		194
(288 / 284)	286	
		139
264		
		194
236		
		186
212		
		172
192		
		150
176		

Joe Chiputaputa

v.p.s.	mean	cents
448		
		128
416		
		121
388		
		149
(356 / 336)	?	[100]
		139
(312 / 308)	310	
		152
(284 / 284)	284	
		173
(258 / 256)	257	
		170
(236 / 230)	233	
		222
(206 / 204)	205	
		168
(188 / 184)	186	
		146
(172 / 170)	171	
		137
(160 / 156)	158	
		234
138		
		130
128		
		185
115		
		141
106		
		208
94		

Rosi Lenso

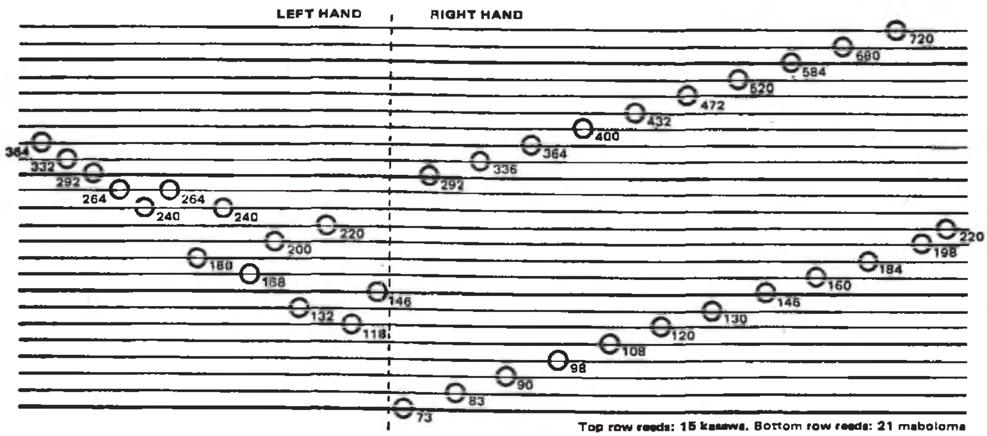
v.p.s.	mean	cents
448		
		128
416		
		212
368		
		253
(320 / 316)	318	
		95
(301 / 300)	301	
		254
(263 / 256)	260	
		103
(245 / 244)	245	
		171
(224 / 219)	222	
		207
(198 / 196)	197	
		63
190 ?		
		84
(182 / 180)	181	
		181
(166 / 160)	163	
		144
(150 / 140)	?	[119]
		76
134		
		162
122		
		117
114		
		126
106		
		190
95		

Semba

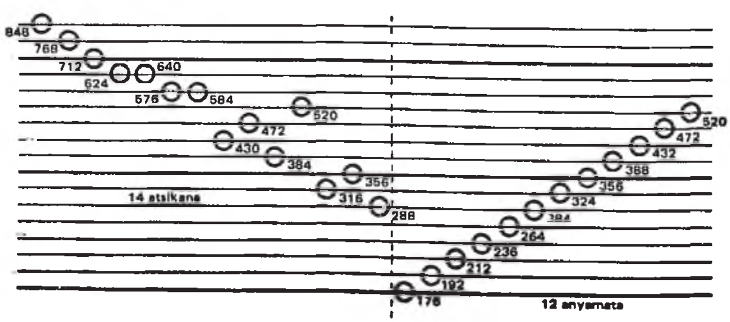
v.p.s.	mean	cents
600		
		170
(544 / 544)	544	
		188
(488 / 488)	488	
		179
(440 / 440)	440	
		157
(404 / 400)	402	
		171
(364 / 364)	364	
		170
(332 / 328)	330	
		177
(300 / 296)	298	
		145
(276 / 272)	274	
		201
(244 / 244)	244	
		163
(224 / 220)	222	
		216
196		
		148
180		
		161
164		
		154
150		
		358
122		
		179
110		

Appendix 4: arrangement of the reeds of the 5 *malimba* lamellophones

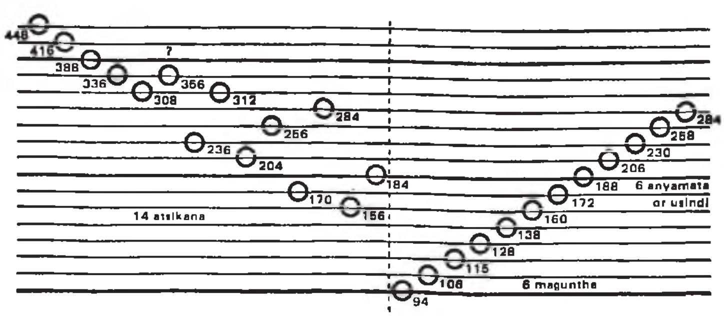
1. Dzingo Chilingamphale: *nyonga-nyonga* 36 reeds



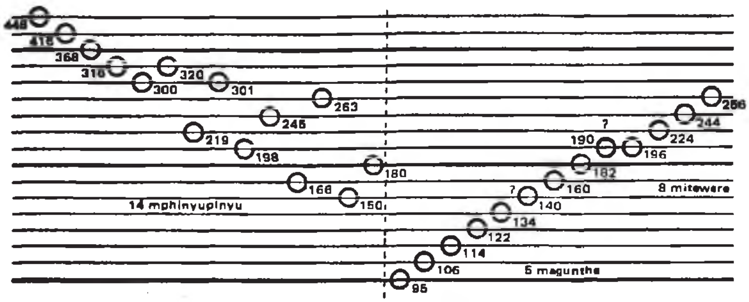
2. Mbiti Msona: *nyonga-nyonga* 26 reeds



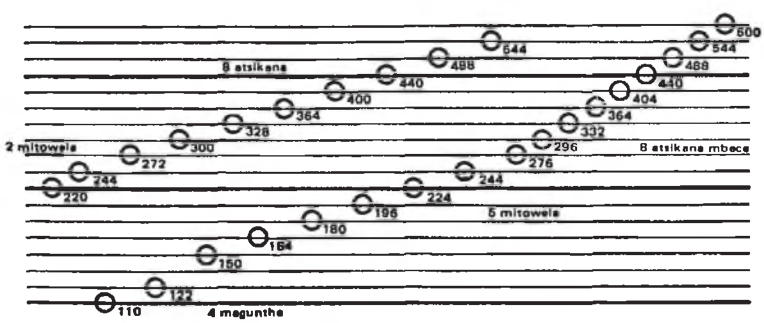
3. Joe Chiputaputa: *nyonga-nyonga* 26 reeds



4. Rosi Lenso: *nyonga-nyonga* 27 reeds



5. Semba: *mano a mbuzi* 27 reeds



Appendix 5: the tuning of *ntanda* drums in vibrations per second and the intervals between consecutive drums in cents.

The tuning

The nine drums are lined up in a row. The *gogogo* drum is on the right, as seen from the players.

1. Mbang'ombe

drum	vps	cents
gogogo	424	
		382
usindi	340	
		312
usindi	284	
		350
usindi	232	
		172
usindi	210	
		407
usindi	166	
		246
nsonjo	144	
		530
ntewe	106	
		?
gunthe	?	

2. Kanaventi

drum	vps	cents
gogogo	488	
		379
usindi	392	
		267
usindi	336	
		291
usindi	284	
		411
usindi	224	
		350
nsonjo	183	
		321
nsonjo	152	
		438
ntewe	118	
		122
gunthe	110?	

3. Machado

drum	vps	cents
gogogo	372	
		57
usindi	360	
		386
usindi	288	
		316
usindi	240	
		316
usindi	200	
		221
usindi	176	
		498
nsonjo	132	
		1424?
ntewe	58?	
		?
gunthe	?	

NOTES

1. I am very much indebted to Mr. Ralph Kabwadza, at that time a student at Chancellor College, University of Malawi, who assisted me in doing this research.
2. *Mbira* is the metasthesis of *limba* (Nurse: 1970). The meaning of *kulimba* (root: *limba*) is "to be firm, hard, strong" (Scott and Hetherwick: 1929^2).
3. Kubik (1968) gives a more detailed nomenclature for the five *usindi* drums: *ntuwizi* (next to *nsonjo*), *nkazi ntuwizi, usindi wa pakati, usindi wa ku lingana ndi wa ku nkomo, usindi wa ku nkomo* (next to *gogogo*). This information was given to him by Mr. Dennis Bauleni from Chipwembwe near Nsanje.
4. I am very grateful to Hugh Tracey and Andrew Tracey who lent me one of their sets of tuning forks in 1970.
5. Apart from my own judgement it seems reasonable to take such a measurement error in view of the results on "just noticeable differences" between frequencies as quoted by Lehiste (1970, p. 62-64).
6. From the tuning of the *valimbas* given in appendix 2 it can be seen that many top tones of the *valimba* are a little flat if we take the interval of 171 cents as a standard. This may be due to the physical constraints on getting the keys tuned high enough, but it may also have been done on purpose. Anyway, it means that relatively speaking many octaves below 1200 cents appear in the part of the *valimba* with the higher tones. If we would restrict ourselves to frequencies between 500 v.p.s. and 130 v.p.s. only (instead of 756 v.p.s. and 130 v.p.s.) the mean octave for all *valimbas* would be 1218 cents in that range. The one hundred and one octaves in this range consist of twenty eight below 1200 cents, sixteen of 1200 cents and fifty seven above 1200 cents.
7. The definition of the (arithmetic) mean and the standard deviation of the n measurements $x_1, x_2, x_3, \ldots x_n$ is as follows:

   Mean: $\bar{x} = \frac{1}{n}\left\{x_1 + x_2 + x_3 + \ldots + x_n\right\}$

   Standard deviation: $s = \sqrt{\frac{1}{n-1} \cdot \left\{(x_1 - \bar{x})^2 + (x_2 - \bar{x})^2 + \ldots + (x_n - \bar{x})^2\right\}}$
8. The standard deviations that are given in table 3 are each supposed to be caused by two errors: (1) the measurement error of the interval, estimated at 13 cents, and (2) the dispersion that the players allow to occur. If a standard deviation in table 3 is a figure of about 25 cents or higher, the measurement error is negligible compared to the dispersion that is caused by the tolerance of the players themselves. In these cases the standard deviations of table 3 may be taken to represent the actual standard deviation of the intervals as caused by the tuning of the players. For instance, if the actual standard deviation is 21 cents, the standard deviation in table 3 would lie between 21 cents and $\sqrt{21^2 + 13^2} = 25$ cents, which is very close to 21 cents.
9. Wasisto (et al.) presents other figures. His calculations are based on first determining the mean frequency of the *barang* tone on the twenty eight *sarons* or *genders*. the mean frequency of the *gulu* tone on the twenty eight *sarons* or *genders*, etc. Next he calculates the mean interval between these mean frequencies:

	Barang		*Gulu*		*Dada*		*Lima*		*Nem*		*Barang*
Mean v.p.s.:	273		312		359		413		474		550
Interval in cents:		231		243		243		238		257	

(In fact the last interval is wrongly given as 253 cents instead of 257 cents.)

Their method seems less appropriate. We should rather look at the intervals *within* one *saron* or *gender* first. The importance lies within the *intervals* rather than in the absolute pitch of the *barang* tone, the *gulu* tone, etc. on the instruments. The question of the absolute pitch of the tones should be distinguished from the question of the intervals occurring in the scale. (In fact, the range of the first *barang* tone on these *sarons* and *genders* as given on page 51 by Wasisto (et al.) is from 306 v.p.s. to 246 v.p.s.).

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