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.
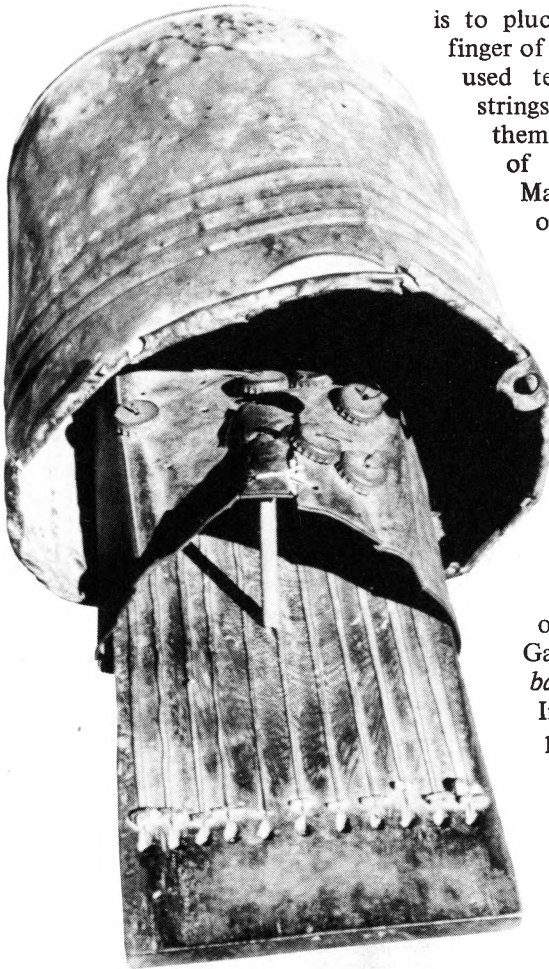
Photo 1: the *bangwe* of Luwizi Nyapyache

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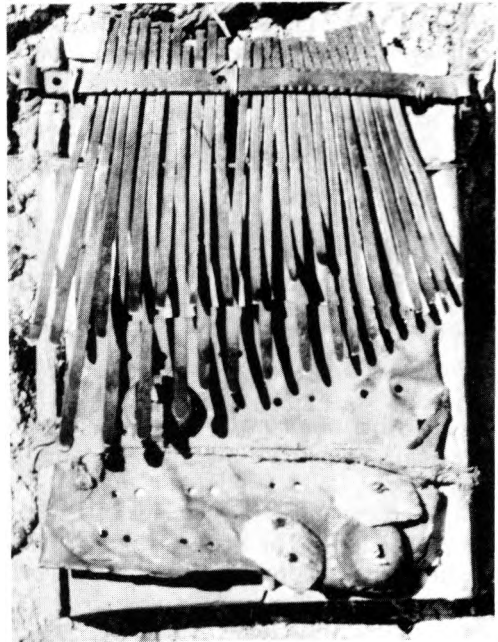
In Appendix 5, the tuning of three sets of *Ntanda* drums (used for the *likhuba* dance, the *madzoka* dance and the *lundu* dance) is given in order to get an idea about the pitch of these drums, compared with other instruments.

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* lamello-phone 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", depend-ing 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:

String no.	1	2	3	4	5	6	7	8	9
Seconds									
Thirds									
Fourths									
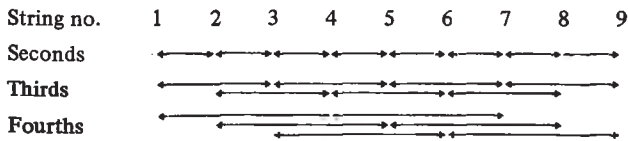
For each instrument I have calculated the mean of the seconds, the mean of the thirds, etc. (notation: $\bar{x}$) and also the standard deviation of each of these intervals (notation: s). The standard deviation is a measure of dispersion about the mean. If the measurements are close together, the value 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.

$\overline{x} = 171$
$s = 33$
$n = 252$
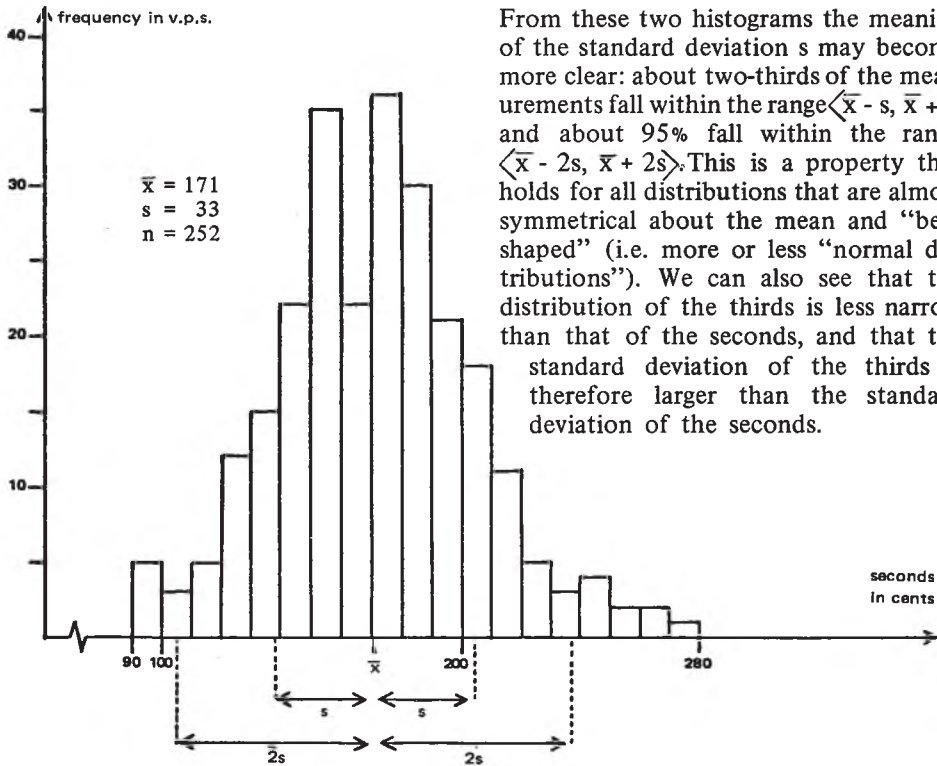
From these two histograms the meaning of the standard deviation s may become more clear: about two-thirds of the measurements fall within the range $\langle \overline{x} - s, \overline{x} + s \rangle$ and about 95% fall within the range $\langle \overline{x} - 2s, \overline{x} + 2s \rangle$. This is 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.

$\overline{x} = 343$
$s = 42$
$n = 235$
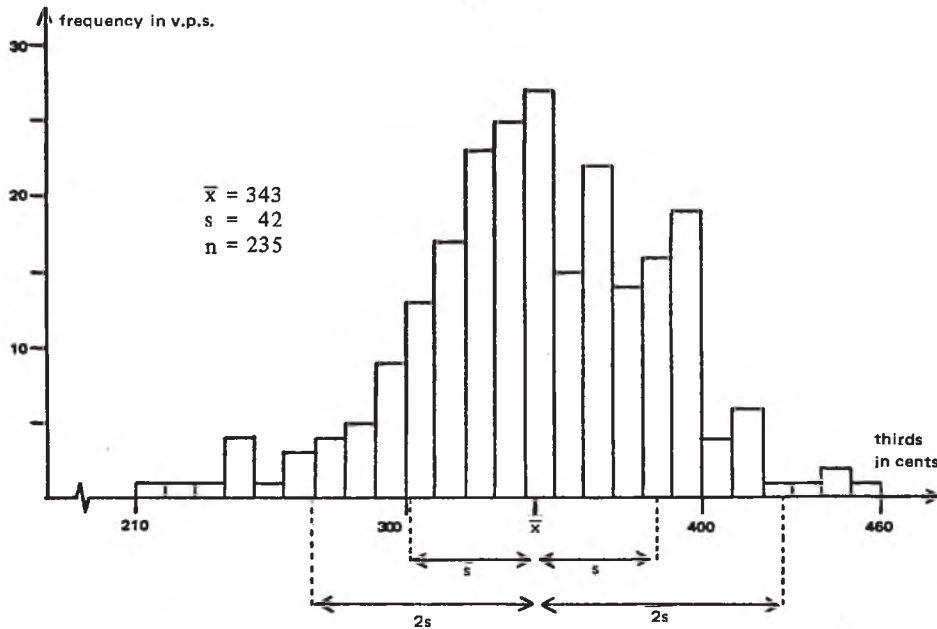
In Table 3 you find the mean and the standard deviation for each of the intervals, up to the octave, on the *bangwes* and *valimbas*.

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

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

Top continuation columns (vps | cents):

vps	cents		vps	cents		vps	cents		vps	cents		vps	cents		vps	cents
245	225		240	139		232	170		252	182		248	107		248	159
223	163		212	214		212	156		228	173		218	224		224	177
202	171		197	127		196	136		204	193		192	220		198	214
181	190		178	176		178	167		186	160		176	150		178	184
164	171		155	239		158	207		168	176		162	144		★	?
151	143		138	202		146	136		152	173		148	156		142	?
140	131		126	157		130	201		136	193		132	199		130	153
127	169		99	418		116	197		104	464		114	254		( )	353
110	249		94	90		106	156		( )	543		75	725		106	303
80	551		69	535		112?	-95		76			( )			89	
98	-351		( )									( )				
r	486		( )													
74																
93?	-396															

13. Nyenyezi		14. Chakanji		15. Nyakamela		16. Gundani		17. Chambuluka	
vps	cents	vps	cents	vps	cents	vps	cents	vps	cents
( )		( )				592		592	
640	111	648	133	616	165	544	147	560	97
600	170	600	107	560	155	466	267	520	128
544	159	564	168	512	170	432	132	448	258
496	208	512	192	464	124	386	195	424	95
440	148	458	151	432	240	348	179	392	136
404	180	420	191	376	154	320	146	336	267
364	202	376	154	344	148	284	206	308	151
324	180	344	164	316	184	252	207	284	140
292	175	313	144	284	153	232	143	256	180
264	165	288	204	260	168	210	173	228	200
240	214	256	141	236	202	189	182	210	143
212	154	236	185	210	173	173	153	182	247
194	130	212	154	190	255	156	179	168	139
180	161	194	188	164	456	136	238	152	173
164	177	174	189	( )		120	217	132	245
148	199	156	163	126	84	110	151	120	165
132	284	142	180	120	1200	101	148	108	182
112	196	128	141	60		94	124	124	-239
( )		118	219			88	114	92	517
100		( )	589			r	372	r	117
		104				71		86	
		( )						( )	
		74						( )	

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.	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.	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.	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.	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.	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	

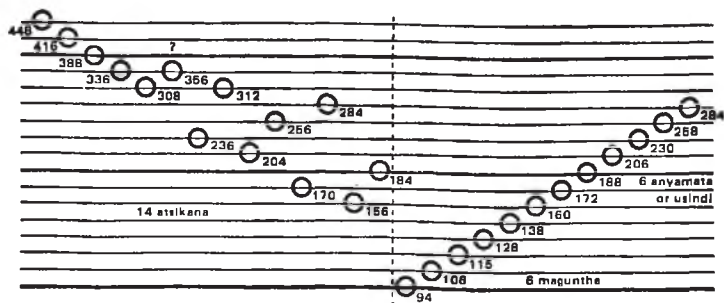## Appendix 4: arrangement of the reeds of the 5 *malimba* lamellophones

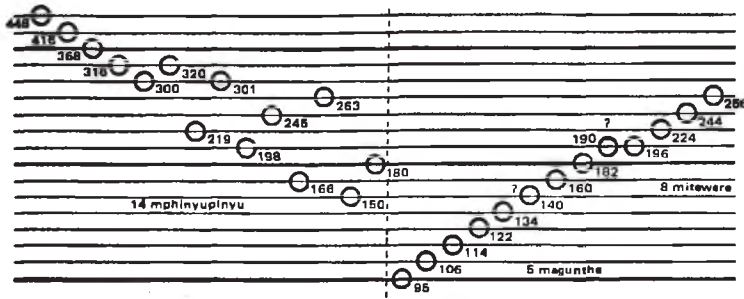### 1. Dzingo Chilingamphale: *nyonga-nyonga* 36 reeds
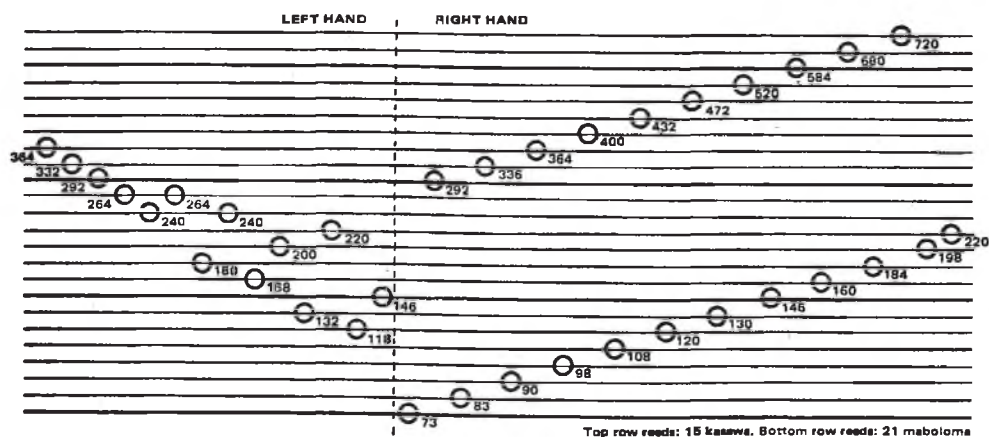
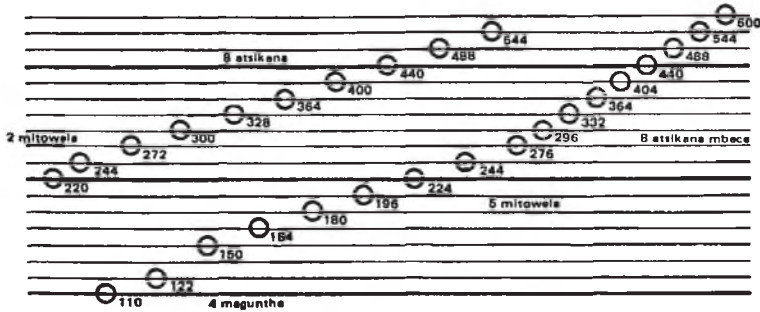### 2. Mbiti Msona: *nyonga-nyonga* 26 reeds
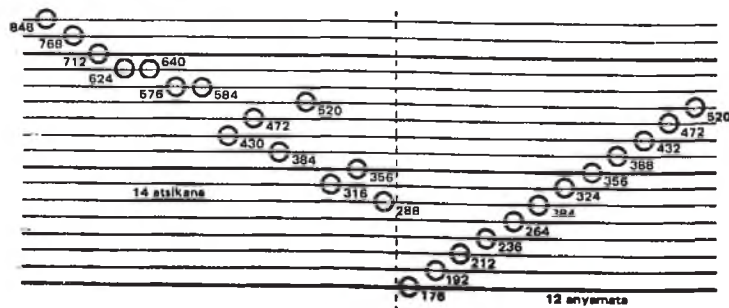
3. Joe Chiputaputa: *nyonga-nyonga* 26 reeds

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			2. Kanaventi			3. Machado		
drum	vps	cents	drum	vps	cents	drum	vps	cents
gogogo	424		gogogo	488		gogogo	372	
		382			379			57
usindi	340		usindi	392		usindi	360	
		312			267			386
usindi	284		usindi	336		usindi	288	
		350			291			316
usindi	232		usindi	284		usindi	240	
		172			411			316
usindi	210		usindi	224		usindi	200	
		407			350			221
usindi	166		nsonjo	183		usindi	176	
		246			321			498
nsonjo	144		nsonjo	152		nsonjo	132	
		530			438			1424?
ntewe	106		ntewe	118		ntewe	58?	
		?			122			?
gunthe	?		gunthe	110?		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 ku 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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