The Ethiopian Lyre *Bagana*. An ethno-acoustical study

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2pMU5. The Ethiopian Lyre Bagana. An ethno-acoustical study

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The Ethiopian lyre bagana is usually finger-plucked and monodic, with a skin soundboard and ten gut strings tuned to low-frequency pitches (ca 50-150 Hz). Its most important sonorous characteristic is its buzzing sounds, produced thanks to leather pieces placed between each string and the wide bridge. This study is based on a corpus of sounds produced by eight different instruments played by a virtuoso master and recorded in situ with and without the leather pieces. The sounds have been analyzed through calculation of several timbre descriptors based on time-domain, sinusoidal harmonic model and short-time Fourier transform representations. These results have been compared with ethnomusicological analyses of the repertoire and the socio-cultural aspects of the bagana, in order to understand how the sound qualities are dealt with by the players. These joint analyses show that the very distinctive buzzing quality of the bagana sounds can be linked with auditory roughness and inharmonicity descriptors (indicating that it is not due to noise but rather to quasi-harmonic components) while the significant timbre variation between sounds is mostly due to differences in string quality, location of the leather pieces on the bridge and musicians' need to produce the longest possible duration.

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1. Introduction

The *bagana*, a large ten-stringed lyre of the Ethiopian Amhara, is comprised of ten thick gut strings, an open wooden sound box covered most of the time with cattle skin (a few instruments use a wooden soundboard), two engraved arms and a sculpted crossbar (see Figure 1, left). Among Amhara chordophones, the *bagana* is the most carefully crafted, as it is solely devoted to the playing of a repertoire with a spiritual meaning, the *zema*. Tradition holds that the *bagana* was given to the biblical King David by God, and brought to Ethiopia together with the Ark of the Covenant by Menelik I, legendary son of the King Solomon and the Queen of Sheba. This gives the *bagana* a unique status. Played by kings, nobles, pious men and women, it neither became widespread nor did it disappear, not even under the Derg regime (1974-1991) which had banned the instrument.

The *bagana* is considered as a very powerful instrument: its presence in a house protects it from the devil and evil spirits. Listening to *bagana* is encouraged by priests and preachers, especially during fasting and penitence periods such as Lent (*Fasika Tsom*). The spiritual importance of the *bagana* is a key feature in the way the instrument is conceptualized, played and listened to. Playing postures adopted by musicians in public performances reflect this significance: players only perform strictly musical movements and do not stage themselves (not even through eye contact with the audience). The player, wearing traditional clothes, withdraws behind his/her instrument. *Bagana* induces intense emotions in players and listeners [Weisser 2012], as its performance mainly aims to convey prayers and praises and to create a special connection between the player and God.

Figure 1. Left: *Bagana*, MIM, Brussels, Inv. Nr 4140. Photo © MIM. Right: detail of the bridge and buzzers *enzirotch*. Photo: Stéphanie Weisser.

Musically, the *bagana* is a solo instrument that can only be accompanied in a rather strict homophonic relationship by singing voice (either the player's or an additional singer). Based on repetition, *yebagana mezmurotch* [*bagana* songs] comprise a short melody (which often lasts no more than one minute) repeated up to more than 20 times, with a new text for each occurrence (except for the refrain if it includes text). Melodic variations, when introduced, are always subtle [Weisser 2005]. *Bagana* strings are plucked with the left-hand fingers' flesh, the index finger playing two strings tuned in unison. The instrument produces therefore five different pitches, being pentatonic as is the rest of the Amhara music. Pitches can be adjusted to the singing voice, ranging from about 50 to 150Hz, depending on the player.

The *bagana* is the only Amhara instrument producing buzzing sounds, which constitutes its sonorous identity marker. The mechanism generating its particular sound quality comprises a wide bridge and leather pieces (*enzirotch*) set between each string and the bridge (see Figure 1, right). This mechanism seems to work in a similar way as the wide curved bridge and cotton thread system of the

Indian *tampura*, the *jawari*. This *jawari* mechanism has been studied since 1921 and several researchers have conducted complex mathematical and physical investigations on the subject (see Vyasarayani et al. [2009, pp. 3673] for a brief review). The wide curved bridge and cotton thread device of the *tampura*, as well as the parabolic wide bridge of the *sitar*, acts similarly. They change the plucked string's vibratory motion into a movement very similar to the Helmholtz vibratory motion [Fletcher and Rossing 1998, pp. 268-9]. The wide bridge is curved, "so that when the string vibrates it smoothly wraps and unwraps from the bridge (...). [T]he cotton thread inserted between the bridge and the string gives this modulation of length a discontinuous character, as the string comes in contact with or leaves the bridge" [*Ibid.*, pp. 268-9].

Valette et al. [1991] showed that the *tampura* bridge acts as a precursive wave generator. When a string is plucked, a transverse high-frequency signal is generated. This high-frequency signal (called "precursor" because it precedes the main signal) is partially trapped in the short portion of the string located between the buzzer and the contact point between the string and the bridge. There it reflects, making this string portion vibrate with a high-frequency transverse motion. This "double bridge" is then responsible for the production of high-frequency components in the *tampura* sound spectra.

Research conducted by Burrige et al. [1982] and later by Vyasarayani et al. [2009, pp. 3674-5] shows that string motion can be divided into distinct phases: two according to Burrige et al., and three according to Vyasarayani et al. According to the latter, "the phase-I motion occurs when there is no contact with the obstacle [classical string behaviour]; partial wrapping on the obstacle is called phase-II motion; a completely wrapped string is considered to be in phase-III motion (...)" The authors also note that "as many as 60 natural frequency components of the string are present in the wrapped string, in particular, during phase-II motion" [Vyasarayani et al. 2009, pp. 3681]. It is hypothesized that the *bagana*'s wide bridge and leather buzzers works in a very similar way as the Indian *jawari*. An experimental curved bridge mounted on the *bagana* produced buzzing sounds just as the regular flat one. According to this hypothesis, important modifications are to be induced by the presence of the buzzers, regarding temporal and spectral properties.

2. Material and methods

In 2003, eight instruments played by the virtuoso player Alemu Aga were recorded. Four instruments belonged to Alemu Aga and the other four to the Yared Music School (National School for Music, located in Addis Ababa). Sounds were recorded with the *enzirotch* and without them, in an office of the Centre Français des Etudes Ethiopiennes (Addis Ababa) with a portable Tascam DA-P1 recording device and a couple of Beyer Dynamic M88 TG microphones. Sounds were analyzed using the Timbre Toolbox [Peeters et al. 2011] for descriptors' calculation and MIR Toolbox [Lartillot and Toivainen 2007] for Roughness and Inharmonicity calculation. Fundamental frequencies were calculated using IRCAM's Audiosculpt software. Mean and Coefficient Variation (CV) have been calculated for all sounds of the eight instruments.

3. Results

Results for sounds produced with buzzers (Table 1) confirm that *bagana* sounds are characterized by their important variability: mean coefficients of variations per instrument are high (the highest being reached by *bagana* 1, the lowest by *bagana* 8). Variation is most important for Total Energy (median and interquartile range), followed by Tristimulus 1 (median), all three above 1. Variation is less important for Increase Slope, followed by Spectral Centroid (median) and Effective Duration. Results produced for sounds without buzzers (see Table 2) show that variation is noticeably less important than in sounds produced with buzzers (mean CV of 0.37 vs 0.56 when buzzers are in place). Although the most- and least-varying descriptors are unchanged: without buzzers, variation is most important in Total Energy (median and interquartile range), followed by Tristimulus 1 (median). The least variation is observed in Increase Slope, Attack Duration and Spectral Centroid (median).

4. Discussion

Variability is an important characteristic of *bagana* sounds. Even if it does not seem to be generated but rather increased by the presence of the buzzers, heterogeneity in *bagana* seems to be correlated positively with instrument condition: variation is more important in instruments considered as good and regularly played and maintained (*bagana* 1 to 4) than in instruments of poor quality, being unplayed and unmaintained for decades (*bagana* 5 to 8). As instruments produce frequencies within a very limited pitch range (57-120 Hz), variability can not be related to potential registers.

It is however worth noticing that, whereas variability in sounds produced by instruments without buzzers shows an 'inevitable' variability, due to the instrument itself (including the strings) and over which the player has no control, the increase of variability due to the presence of the buzzer is, on the contrary, due to the fine adjustment of the leather pieces by the musician. Therefore, it is interesting to notice that the musician's precise placement of the buzzer is done in such a way that the Effective Duration is as homogenous as possible. This confirms the fact that the *bagana* player favours long sounds, for example, over sounds of equal loudness (see Total Energy).

It is also worth noticing that sound color homogeneity is not achieved, nor probably desired. As *bagana* songs are very repetitive, and constructed with as few as five different pitches, variety is brought by heterogeneity in sound quality. *Bagana* and *bagana* strings making are not standardized or widespread activities; moreover, materials such as skin (for the sound table) and gut (for the strings) can vary a lot in quality as well as in condition (with age, maintenance, weather). Nevertheless, as shown here, variability in sound is a specific feature of the instrument, and should be taken into consideration in acoustical as well as ethnomusicological analyses.

5. Acknowledgements

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Table 1. Mean Values and Coefficient of Variation for descriptors calculated on *bagana* 1-8 sounds with buzzers: Attack Duration, Increase Slope (Incr. Slope), Decrease Slope (Decr. Slope), Effective Duration (Eff. Dur.), Total Energy (Tot. Energy), Tristimulus (TriStim.) 1 to 3, Spectral Centroid (SpecCentr.), Spectral Rolloff (RollOff), Roughness and Inharmonicity. For spectral descriptors and Total Energy, median (med.) and interquartile (iqr.) values are included.

	Bagana 1		Bagana 2		Bagana 3		Bagana 4		Bagana 5		Bagana 6		Bagana 7		Bagana 8		All	
	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
AttackDuration	0.09	0.23	0.11	0.15	0.1	0.18	0.18	1.05	0.1	0.15	0.1	0.19	0.15	0.7	0.1	0.16	0.12	0.35
Incr. Slope	10.7	0.19	8.76	0.17	10.08	0.15	8.7	0.48	9.49	0.11	9.61	0.13	9.11	0.37	9.61	0.16	9.51	0.22
Decr. Slope	-3.24	-0.87	-2.98	-0.33	-1.79	-0.51	-1.82	-0.41	-2.52	-0.21	-1.89	-0.56	-1.88	-0.53	-1.65	-0.42	-2.22	-0.48
Effect. Dur.	0.52	0.53	0.42	0.28	0.64	0.32	0.66	0.39	0.47	0.16	0.59	0.22	0.64	0.31	0.73	0.25	0.58	0.31
Tot. En.(med)	0.02	1.96	0	1.1	0.01	0.93	0.01	1.31	0.01	0.72	0.01	1.47	0.01	0.62	0	1.17	0.01	1.16
Total En. (iqr)	0.09	1.75	0.019	0.88	0.04	1.43	0.04	0.99	0.07	1.06	0.04	1.1	0.03	0.92	0.02	1.26	0.04	1.17
TriStim1 (med)	0.13	1.01	0.08	0.91	0.27	1.16	0.1	0.8	0.15	1.47	0.21	0.91	0.1	1.38	0.27	0.64	0.16	1.04
TriStim2 (med)	0.52	0.4	0.4	0.54	0.43	0.47	0.49	0.26	0.45	0.37	0.4	0.21	0.61	0.12	0.57	0.25	0.48	0.33
TriStim3 (med)	0.31	0.71	0.3	0.55	0.31	0.77	0.38	0.53	0.29	0.75	0.36	0.58	0.27	0.59	0.13	0.4	0.31	0.61
TriStim1 (iqr)	0.2	0.77	0.11	1.13	0.11	1.06	0.07	0.46	0.08	1.19	0.15	0.88	0.06	0.54	0.19	0.48	0.12	0.81
TriStim2 (iqr)	0.16	0.99	0.15	0.73	0.17	0.61	0.09	0.42	0.21	0.34	0.14	0.59	0.09	0.58	0.17	0.42	0.15	0.58
TriStim3 (iqr)	0.12	0.66	0.16	0.72	0.13	0.9	0.11	0.54	0.18	0.51	0.15	0.58	0.09	0.7	0.12	0.53	0.13	0.64
SpecCentr. (med)	348.3	0.32	366.32	0.57	314.42	0.3	360.26	0.15	325.7	0.24	323	0.29	282.26	0.13	260.88	0.12	322.64	0.27
SpecCentr. (iqr)	51.02	0.69	135.76	0.95	62.5	0.3	83.71	0.82	100.74	0.4	73.04	0.5	25.46	0.54	85.5	0.51	77.22	0.59
RollOff (med)	799.42	0.33	985.14	0.75	790.78	0.28	916.73	0.35	785.83	0.33	771.56	0.4	673.63	0.19	623.52	0.16	793.33	0.35
RollOff (iqr)	226.59	0.46	516.08	1.23	206.1	0.33	280.68	0.67	196.99	1.15	237.89	0.84	299.36	1.08	204.42	0.22	271.01	0.75
Roughness	5.04	0.63	23.73	0.69	9.27	1	6.42	0.36	11.55	1.05	4.14	0.44	3.43	1.29	1.47	1.03	8.13	0.81
Inharmonicity	0.43	0.23	0.44	0.16	0.4	0.16	0.41	0.18	0.4	0.28	0.37	0.3	0.36	0.31	5.67	0.94	1.06	0.32
MeanCV		0.63		0.62		0.55		0.52		0.56		0.50		0.55		0.46		0.55

Table 2. Mean Values and Coefficient of Variation for descriptors calculated for bagana 1-8 sounds without buzzers: Attack Duration, Increase Slope (Incr. Slope), Decrease Slope (Decr. Slope), Effective Duration (Eff. Dur.), Total Energy (Tot. Energy), Tristimulus (TrisTim.) 1 to 3, Spectral Centroid (SpecCentr.), Spectral Rolloff (RollOff), Roughness and Inharmonicity For spectral descriptors and Total Energy, median (med.) and interquartile (iqtr.) values are included.

	Bagana 1		Bagana 2		Bagana 3		Bagana 4		Bagana 5		Bagana 6		Bagana 7		Bagana 8		All	
	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
Attack Duration	0.07	0.06	0.09	0.26	0.08	0.14	0.08	0.06	0.08	0.08	0.08	0.05	0.08	0.06	0.1	0.39	0.08	0.14
Incr. Slope	12.83	0.06	11.05	0.18	12.03	0.12	11.45	0.06	11.81	0.09	11.97	0.05	11.77	0.06	9.88	0.29	11.60	0.11
Decr. Slope	-4.95	-0.51	-4.13	-0.58	-2.84	-0.66	-1.99	-0.34	-2.7	-0.47	-2.9	-0.44	-4.19	-0.53	-1.82	-0.22	-3.19	-0.47
Effect. Dur.	0.32	0.53	0.35	0.34	0.48	0.44	0.56	0.28	0.47	0.33	0.44	0.29	0.36	0.43	0.62	0.17	0.45	0.35
Tot. En. (med.)	0.01	0.48	0.002	0.95	0.01	1.51	0.003	0.56	0.002	0.72	0.005	0.78	0.001	0.87	0	0.29	0.00	0.77
Total En. (iqtr.)	0.02	0.98	0.004	0.92	0.01	0.71	0.01	0.61	0.01	0.47	0.02	0.66	0	0.9	0.01	0.43	0.01	0.71
TrisTim 1 (med.)	0.28	0.46	0.35	0.9	0.4	0.48	0.28	0.42	0.32	0.86	0.37	0.58	0.25	1.24	0.42	0.52	0.33	0.68
TrisTim 2 (med.)	0.58	0.22	0.51	0.51	0.47	0.36	0.57	0.14	0.5	0.36	0.45	0.32	0.57	0.45	0.5	0.37	0.52	0.34
TrisTim 3 (med.)	0.12	0.4	0.13	0.53	0.1	0.55	0.14	0.5	0.17	0.51	0.16	0.82	0.17	0.48	0.07	0.15	0.13	0.49
TrisTim 1 (iqtr.)	0.17	0.6	0.16	1.03	0.19	0.37	0.18	0.73	0.14	0.53	0.15	0.37	0.07	0.51	0.17	0.29	0.15	0.55
TrisTim 2 (iqtr.)	0.15	0.48	0.14	0.65	0.19	0.33	0.13	0.69	0.14	0.41	0.11	0.45	0.09	0.37	0.16	0.45	0.14	0.48
TrisTim 3 (iqtr.)	0.07	0.37	0.06	0.19	0.05	0.63	0.07	0.34	0.12	0.82	0.07	0.42	0.08	0.68	0.03	0.2	0.07	0.46
SpecCentr. (med.)	232.81	0.19	268.3	0.21	220.01	0.14	245.17	0.16	199.94	0.06	204.38	0.1	246.55	0.2	235.73	0.06	231.61	0.14
SpecCentr. (iqtr.)	36.82	0.43	46.02	0.86	29.45	0.38	36.76	0.19	44.98	0.56	39.98	0.53	33.04	0.32	31.94	0.16	37.37	0.43
RollOff (med.)	500.2	0.18	574.11	0.28	509.84	0.12	536.98	0.24	497.01	0.08	480.06	0.13	638	0.16	566.32	0.2	537.82	0.17
RollOff (iqtr.)	96.52	0.49	267.87	0.92	182.74	0.65	121.71	0.73	119.42	0.37	87.59	0.25	174.01	0.43	211.85	0.49	157.72	0.54
Roughness	0.48	0.65	0.52	0.54	0.38	0.3	0.49	0.51	0.57	0.75	0.55	0.47	0.51	0.46	0.25	0.57	0.47	0.53
Inharmonicity	0.39	0.26	0.42	0.16	0.41	0.2	0.43	0.17	0.43	0.16	0.38	0.21	0.42	0.15	0.36	0.09	0.41	0.18
Mean CV		0.35		0.49		0.38		0.33		0.37		0.34		0.4		0.27		0.37