

**[2D] Music and Movement 2**

LIÈGE 16:30-18:30 Monday 4 Aug 2014

**RHYTHMICAL STRUCTURES IN MUSIC AND BODY MOVEMENT IN SAMBA PERFORMANCE***Mari Romarheim Haugen<sup>1</sup>, Rolf Inge Godøy<sup>1</sup>*<sup>1</sup>*Department of Musicology, University of Oslo, Norway*

Time: 16:30

**ABSTRACT**

Samba groove is often characterized by its complex rhythmical patterns. Recent studies, based on audio recordings of samba music, report that the 3<sup>rd</sup> and the 4<sup>th</sup> 16<sup>th</sup>-notes are played slightly ahead of their corresponding quantized position, and that this seems to be a prominent feature of samba groove. Considering that samba derives from a culture where music and body motion are intrinsically related, may suggest that we should include both sound and motion data in studies of its rhythmical structures. In this paper we investigate whether the microtiming features, previously shown in samba music, may also be represented in the body motion of performers playing and dancing samba. We report from a motion capture experiment where two skilled samba performers, a percussionist and a dancer, were recorded using an advanced optical infrared motion capture system. Our audio analysis confirms the existence of systematic microtiming patterns on the 16<sup>th</sup>-note level in samba music. In addition, motion analysis of the percussionist's heel tapping and the dancer's steps revealed motion patterns in synchrony with the systematic microtiming features found in samba music. These observations support the view that the systematic micro timing of 16<sup>th</sup>-notes in samba playing is not a deviation from an underlying perceived pulse with isochronous subdivisions, but rather constitutes an essential feature of samba.

**1. INTRODUCTION**

The groove of samba is often characterized by its complex rhythmical patterns, and it is suggested that systematic microtiming is an essential feature of samba groove. In a study of rhythmical structures in Brazilian percussion based on analyses of field recordings (audio) and interviews, Gerischer (2006) documents a prominent medium – short – medium – long duration pattern on 16<sup>th</sup>-note level, and the existence of the both extended (in duration) and accentuated 4<sup>th</sup> 16<sup>th</sup>-note in a beat in particular, related to the production of samba groove. Gerischer refers to the concept of participatory discrepancies (PDs) (Keil 1987) and the hypothesis of systematic variations of durations (SYVAR) in music performance (Bengtsson 1987, Gabriellsson 1982), and emphasizes that the microtiming features in samba groove constitute essential aspects of style. Similar findings are presented in Gouyon's (2007) study of microtiming features in samba. Based on computer analysis of audio excerpts with traditional samba music, Gouyon found that the 3<sup>rd</sup> and the 4<sup>th</sup> 16<sup>th</sup>-notes in samba groove are played slightly ahead of their corresponding quantized position. However, thinking of systematic microtiming in terms of deviations, indicates a culturally biased norm with isochronous time marks as starting point (Bengtsson 1987, Kvifte 2004). In an attempt to sidestep this cultural bias, Kvifte (2004) suggest a *pattern concept*, using "participatory pattern" instead of PDs and "durational pattern" instead of SYVAR. In addition, based on the view that rhythm is intrinsically related to motion, both physical and virtual, (see e.g. Blom & Kvifte 1986, Shove & Repp 1995, Iyer 2002), motions of perceivers and performers may offer a more perceptual relevant reference structure for rhythm studies than an abstract fixed clock pulse (Blom 1981, Bengtsson 1987, Kvifte 2007). Baily (1985) states that human motion is the process through which musical patterns are produced, and emphasizes the need to investigate the relationship between motion and music in the process of music making. In his studies of Norwegian folk music and dance, Blom (1981) takes as his point of departure that musical rhythm is intimately related to our bodily experiences, and that our concepts of rhythm are mirrored by the way in which we move our body in synchrony with music.

Samba music is based on oral traditions and elements of African and Afro-Brazilian rituals, on cultures where music and motion are intrinsically related (Mariani 1998, Carvalho 1999, Gerischer 2006, Naveda 2011). In some African languages, there is no word for music that does not also include the act of dancing (Grau 1983, Baily 1985, Kubik 1990). In a study of Brazilian drum patterns, Kubik (1990) emphasizes that percussionists' inner "elementary pulsation", either objectified by actual strokes or by being silent, serves as the most important temporal orientation for the performers. When transcribing the drum rhythms, Kubik found that the easiest way to identify the performer's "common beat" and also the position of the first beat (inner "reference beat"), was to look at the body motion of performers and dancers.

Considering that samba derives from a culture where music and dance are intrinsically related, suggest that we should include dance motions when studying rhythmical structures in samba. In addition to dance motions, body motion of percussionists may also contribute to a better understanding of rhythmical structures in samba. In the present study we aim to investigate whether the microtiming features, previously shown in the sound of samba, may also be reflected in the body motion of performers playing and dancing samba.

**2. METHOD**

Two skilled samba performers, a percussionist and a dancer, participated in the study. The percussionist played a samba groove on a pandeiro, a Brazilian hand frame drum with jingles (platinelas). A pandeiro is typically between 10" and 12" in diameter with sound in middle to high frequency registers (Naveda 2011). The drum is held in one hand and played on by the other. In our experiment, a small microphone connected to an amplifier was attached to the frame of the pandeiro to augment the low frequent bass sounds from the drum. The dancer performed a dance in samba-no-pé style, an individual dance that can be performed both with and without improvisation (Naveda 2011). The dance was also performed both with and without high-heeled shoes.

The participant's motions were recorded using an advanced optical motion capture system from Qualisys. The system tracked the motions of reflective markers at a frame rate of 200 Hz. All sessions were videotaped using a digital video camera (SONY HandyCam). In addition, sound was recorded using Logic Pro software running on a MacBook computer. A total of 31 reflective markers were attached to each participant's body (Figure 1). The placement of the markers on the percussionist and the dancer were identical.

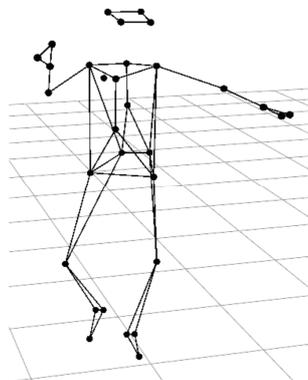


Figure 1: The placement of the markers attached to the participants' bodies.

Ten recordings, with three different setups, were carried out (Table 1). First, we did two recordings of the percussionist alone. Second, we did three solo recordings of the dancer dancing to the music recorded in the second percussion recording. Third, we did five recordings of the percussionist and the dancer together.

Table 1: An overview of the ten recordings made in this experiment. In session I we did recordings of the percussionist alone, in session II we did solo recordings of the dancer dancing to the recorded music from session I, and in session III the percussionist and the dancer were recorded together.

Recordings		Comments
I. Percussionist (solo)	a.	Motion capture and sound recording
	b.	Motion capture and sound recording Sound recording is being used in II.
II. Dancer (solo)	a.	Samba no pé
	b.	Samba no pé
	c.	Samba no pé with variations
III. Percussionist and dancer	a.	Samba no pé with variations
	b.	Samba no pé
	c.	Samba no pé with shoes
	d.	Samba no pé with shoes
	e.	Dance improvisation

### 3. ANALYSES AND RESULTS

The sound data from the recordings were analyzed using the MIR Toolbox for MatLab (Lartillot & Toiviainen 2007), a toolbox that is developed for extracting musical features like timbre, tonality and rhythm, from audio files. The motion data, obtained from the motion capture recordings, were analyzed using the MoCap Toolbox for Matlab (Burger & Toiviainen 2013). The MoCap Toolbox contains a set of functions for analyzing motion data and is developed for studies of music-related motion. All statistical analyses were performed using SPSS version 21.

#### 3.1. Sound

In the present study, the samba groove was played on a pandeiro. Different stroke techniques on the drum produce different sounds that can be classified as followed: low-pitched bass sound (thumb), high-pitched bass sound (thumb), slap sound (fingers) and jingle sound (fingertips, thumb and palm) (Roy et al. 2007). A typical pandeiro rhythm emerges by alternating between the strokes of the thumb, fingertips and palm. In addition, a quick turn made by the hand holding the drum, makes an accentuated jingle sound.

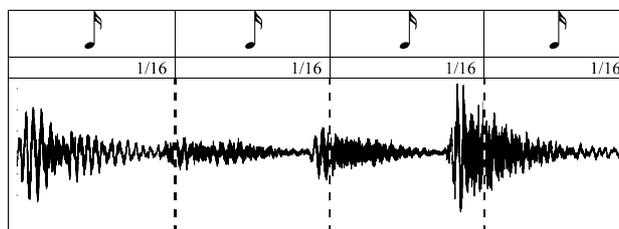
The samba groove was notated in 2/4 meter. The second beat in a bar is accentuated by a low frequency bass sound, something that is in accordance with previous descriptions (Gerischer 2006, Naveda 2011). In addition, the groove has a four bar periodicity, indicated by a variation played at the end of every fourth bar (sometimes in the end of the second bar). Before the groove starts, a short start break, normally consisting of two 8th-notes, is played. A transcription of the samba groove pattern (simplified) played on pandeiro is shown in Figure 2. The accented jingle sound, caused by the quick turn of the drum, is marked as accents above the notated jingles.



**Figure 2: Transcription of the start break and the samba groove played on pandeiro.**

Here we are mainly interested in rhythmical patterns in the sound of samba groove, meaning musical events in time. According to previous research on the groove of samba, the temporal positions of the 16<sup>th</sup>-notes are of particular interest. Since all the 16<sup>th</sup>-notes are played, and consequently present in the sound, their temporal positions could be estimated using the onset detection function in the MIR Toolbox (Lartillot & Toiviainen 2007). The onsets calculated from the audio signal may not represent the 16<sup>th</sup>-notes’ perceptual attack points, but since we primarily are interested in the rhythmical pattern, and not necessarily the exact position of the notes, the main concern is that all the onsets are measured in the same manner.

A sound analysis based the second solo recording of the percussionist (I b.) was carried out (see Table 1). The onset data confirmed the above-mentioned systematic micro timing at 16<sup>th</sup>-note level, that is, the 3<sup>rd</sup> and the 4<sup>th</sup> 16<sup>th</sup>-notes are ahead of their quantized position (Figure 3).



**Figure 3: Illustration of the audio waveform and metrical structure of samba at the 16<sup>th</sup>-note level. The 3<sup>rd</sup> and the 4<sup>th</sup> 16<sup>th</sup>-notes are ahead of their corresponding quantized position.**

In accordance with Kvifte’s (2004) *pattern concept*, we wanted to investigate the duration pattern of the samba groove. The durations of the 16<sup>th</sup>-notes were calculated measuring the time from the estimated onset of one 16<sup>th</sup>-note to the estimated onset of the next 16<sup>th</sup>-note. The durations of the 16<sup>th</sup>-notes were measured in seconds with four decimals. Subsequently, the calculated 16<sup>th</sup>-note durations were converted to percent, according to their percentage of the bar. The duration of 16<sup>th</sup>-notes in four bars in the beginning of the recording (bar 1 – 4) and four bars in the middle of the recording (bar 13 – 16) were calculated, that is a total of 64 16<sup>th</sup>-note durations. The mean durations of the 16<sup>th</sup>-notes, measured in percent, are presented in Table 2.

Sixteenth notes	Mean duration (in %)	SD
First 16 <sup>th</sup> -note	23.0	3.9
Second 16 <sup>th</sup> -note	23.6	6.3
Third 16 <sup>th</sup> -note	22.8	4.4
Fourth 16 <sup>th</sup> -note	30.7	2.1

**Table 2: Mean duration and standard deviations (SD) for the first, second, third and fourth 16<sup>th</sup>-note in a bar (N=64).**

Analysis of variance showed significant differences between the durations ( $p < 0.001$ ), and Bonferroni corrected post-hoc tests showed significant differences between the duration of the 4<sup>th</sup> 16<sup>th</sup>-note and the 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> (all  $p < 0.001$ ). However, no significant differences between the duration of the 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup> 16<sup>th</sup>-notes were found (all  $p > 0.99$ ). A boxplot of the 16<sup>th</sup>-note durations (Figure 4), and also the standard deviations in Table 2, indicate that not only do the 4<sup>th</sup> 16<sup>th</sup>-notes in a beat seem to be of longer duration than the 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup> 16<sup>th</sup>-notes, but they also seem to be spread out over a smaller range of values than the others. This supports the idea that the long 4<sup>th</sup> 16<sup>th</sup>-note in a beat plays a significant role in the groove of samba.

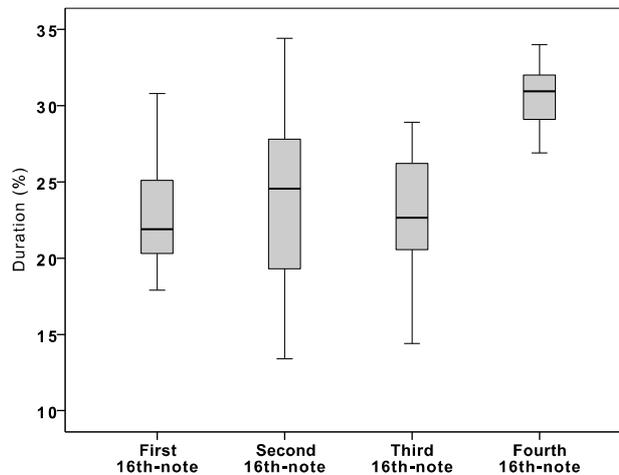


Figure 4: Boxplot showing the distribution of the duration of the 16<sup>th</sup>-notes in 8 bars. The 4<sup>th</sup> 16<sup>th</sup>-note in a beat has longer duration than the 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> 16<sup>th</sup>-notes. In addition, the 4<sup>th</sup> 16<sup>th</sup>-note durations seem to be spread out over a smaller range of values than the others.

### 3.2.Motion

#### The percussionist’s feet movements

While playing, the percussionist moves his heels up and down. We wanted to investigate whether the percussionist’s heel movements corresponded to the beat level in the sound, and consequently may be interpreted as the percussionist’s perceptual pulse (“inner pulsation”). By plotting the heels’ vertical position over time we got a visualization of the heels up/down movements. The points where the heels met the floor seems to be in synchrony with the 1<sup>st</sup> 16<sup>th</sup>-note in a beat (pulse level) in the sound of samba. Since the lifting of the heels also seems to be periodic, we measured the vertices (local maximum) of the movements of the heels. Comparing the measured vertices of the heel movements with the sound analysis revealed that the lifting of the heels seems to be in synchrony with the 4<sup>th</sup> 16<sup>th</sup>-note in a beat (Figure 5a and 5b). Hence, motion analysis of the percussionist’s foot movements revealed a motion pattern, not only in correspondence with every 1<sup>st</sup> 16<sup>th</sup>-note in a beat, indicating a perceptual pulse level, but also with every 4<sup>th</sup> 16<sup>th</sup>-note in a beat, supporting the hypothesis of the essential role of a long 4<sup>th</sup> 16<sup>th</sup>-note in a beat in samba.

#### The dancer’s feet movements

The feet movements in samba dance are repetitive and periodic, and we wanted to investigate whether the dancer’s feet movements correspond to rhythmical pattern in the sound. Motion data from the second recording of the dancer (II b.) were analyzed (see Table 1). Using the MoCap Toolbox, we made a plot of the vertical movements of the dancer’s feet. Next, we manually measured the temporal points where the feet hit the floor, and compared them with the onset data from the sound analysis. The dancer’s vertical feet movements seem to be in synchrony with the three first 16<sup>th</sup>-notes in a beat (Figure 6).

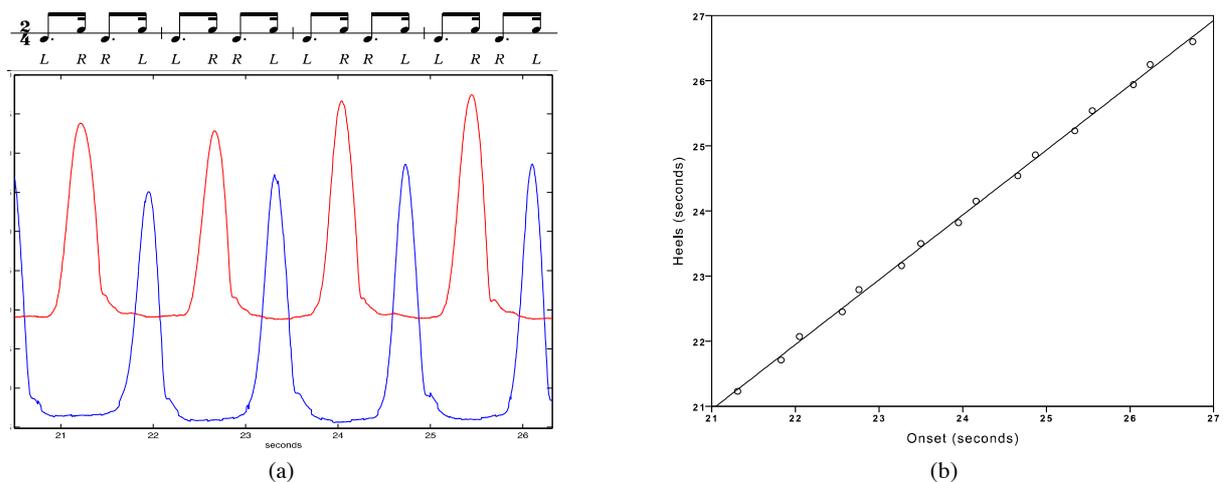
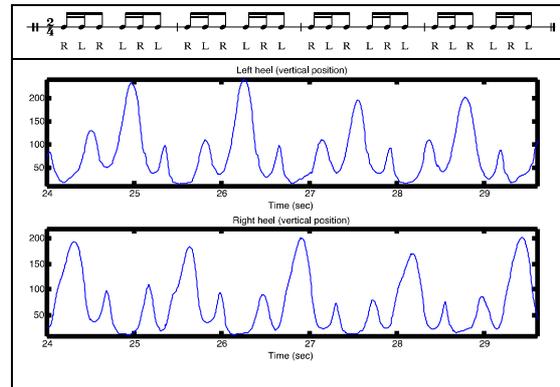


Figure 5: (a) Plot of the vertical movements of the percussionist’s heels, left heel = L (blue) and right heel = R (red). The percussionist’s heel movements seem to be in synchrony with both the 1<sup>st</sup> (pulse level) and the 4<sup>th</sup> 16<sup>th</sup>-note in a beat. (b) A scatterplot showing the relation between the onsets (sound) and the percussionist’s vertical heel motion.



**Figure 6:** A visualization of the vertical movements of the dancer’s heels. The dancer’s heel movements seem to be in synchrony with the first three 16<sup>th</sup>-notes in a beat.

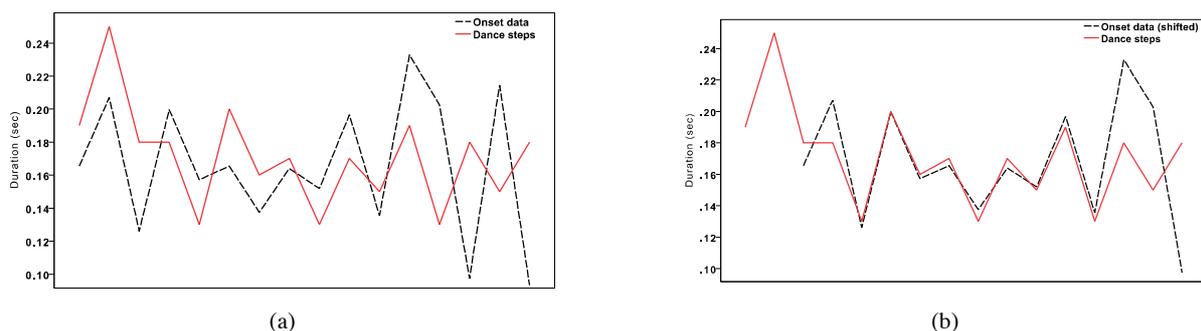
The sound analysis showed that the durations of the first three 16<sup>th</sup>-notes in the sound seem to fluctuate considerably, and we wanted to investigate how that may influence the dance steps. Equivalent to the beat duration calculations in the sound analysis, we calculated the duration of every step, that is the time between every time the dancer places either of her feet to the floor. The durations of the dancer’s steps in bar 13-16 were calculated (N=24). The mean durations of the 16<sup>th</sup>-notes, measured in percent, are presented in Table 3.

Sixteenth notes	Mean duration (in %)	SD
First 16 <sup>th</sup> -note	22.9	4.5
Second 16 <sup>th</sup> -note	24.1	2.6
Third + Fourth 16 <sup>th</sup> -note	53.0	3.9

**Table 3:** Mean duration and standard deviations (SD) of the first, second and the sum of the durations of the third and fourth 16<sup>th</sup>-notes in a bar (N=24).

Analysis of variance showed significant differences between the durations ( $p < 0.001$ ), and Bonferroni corrected post-hoc tests showed significant differences between the duration of the sum of the 3<sup>rd</sup> and 4<sup>th</sup> 16<sup>th</sup>-notes and the 1<sup>st</sup> and 2<sup>nd</sup> 16<sup>th</sup>-notes (all  $p < 0.001$ ). No significant differences between the duration of the 1<sup>st</sup> and 2<sup>nd</sup> 16<sup>th</sup>-notes were found ( $p > 0.99$ ). This corresponds to the results in the audio analysis (see Table 2).

A comparison of the durations of the dancer’s steps and the 16<sup>th</sup>-note duration in the sound, revealed that the dancer seem to copy the 16<sup>th</sup>-note durations in sound from the previous bar (Figure 7). If this is the case, it may testify to how sensitive humans are to small variations in rhythm, and how these fine-meshed rhythmical patterns can be perceived and reproduced with high accuracy.

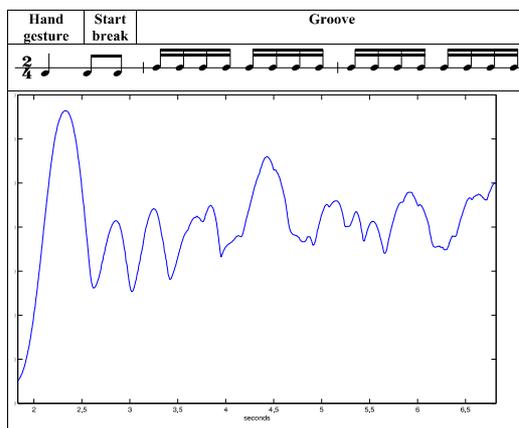


**Figure 7:** (a) A visualization of 16<sup>th</sup>-note duration in seconds (y-axis) over time (first two 16<sup>th</sup>-notes in four bars), for onset data (black) and the dancer’s steps (red). (b) The duration of the first two 16<sup>th</sup>-notes in four bars, onset data (black) shifted one bar. The dancer may copy the durations of the first two 16<sup>th</sup>-notes from previous bar in the sound.

### Establishing the groove

The percussionist always starts the samba groove by playing a start break, generally consisting of two low frequency 8<sup>th</sup>-notes played on the drum skin with right thumb. Before he starts playing the start break, he makes a smooth rise/fall hand gesture. A plot of the vertical movement of the right hand enabled us to measure the duration of this hand gesture. The hand gesture duration in the two solo

recordings of the percussionist (see Table 1) was measured to 0.75 seconds, which corresponds to the duration of one beat in the samba groove. In other words, the hand gesture together with the start break, which also equals the duration of one beat, has a total duration of a bar (Figure 8). This suggests that the groove is established in the percussionist's body before he starts playing, as an inner simulation of the groove, and that this groove experience is expressed through this hand gesture. This indicates that body motion is intrinsically related to the experience of groove. If the experience of groove, including the groove-related body motion, exists before the percussionist starts to play, it supports the idea that body motion is not only a response to musical sound, but that music and body motion are intrinsically related.



**Figure 8: A plot of vertical movement of the percussionist's right hand. The duration of the hand gesture before the start break equals the duration of one beat in the samba groove, suggesting that the groove is established in the percussionist's body before he starts playing.**

#### 4. DISCUSSIONS AND FUTURE WORK

We suggest that when investigating microtiming features in samba, body motion may offer a more significant reference level than a more abstract timeline of isochronous points. Consequently, the rhythmical structures of samba were analyzed in terms of durational patterns instead of deviations from quantified durations. The results from our audio analysis of this samba groove, suggest a medium (23%) – medium (23.6%) – medium (22.8%) – long (30.7%) duration pattern on 16<sup>th</sup>-note level (Table 2). Converting this result to a time line approach, it confirms the so-called anticipation of the 3<sup>rd</sup> and the 4<sup>th</sup> 16<sup>th</sup>-note in a beat, since the combination of the long 4<sup>th</sup> 16<sup>th</sup>-note duration and medium 3<sup>rd</sup> 16<sup>th</sup>-note duration would cause their onsets being ahead of their corresponding quantized position. However, our result does not correspond to the medium – short – medium – long duration pattern suggested by Gerischer (2006). One explanation may be that Gerischer's analyses are based on samba performances of percussionists from the region of Bahia, while our participants are from outside Rio de Janeiro, i.e. there may very well be local dialects of samba. In addition, our result is based on analysis of only eight bars from one recording of one performer, so the difference may also be due to personal expressive timing. To investigate whether this pattern may be a feature of samba, a larger number of performances need to be investigated.

Our results support the hypothesis from previous research that the 4<sup>th</sup> 16<sup>th</sup>-note seems to play a prominent role in samba groove. This hypothesis is also supported by our analysis of the percussionist's movement of the heels, revealing a motion pattern in synchrony with the 1<sup>st</sup> and the 4<sup>th</sup> 16-notes in a beat. To investigate the medium – medium – medium – long duration pattern, found in the sound, in relation to body motion, a motion pattern in synchrony with all the 16<sup>th</sup>-notes is essential. Since, the percussionist's heel movement is only in synchrony with the 1<sup>st</sup> and the 4<sup>th</sup> 16-notes and the dancers feet steps are only in synchrony with the 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> 16<sup>th</sup>-notes, it does not offer a complete picture of an "inner pulsation". Samba dance is often described as complex full-body movement (Browning 1995), and Mariani (in Naveda 2011) points out that the pulsating rhythm of samba dance originates in the torso. This suggests that the pulsation of samba groove may be integrated in the movement of the hip and torso in samba dancing. In future work this will be investigated further.

In this paper we have analyzed short excerpts of the groove, focusing on rhythmical patterns as musical events in time. In further analysis, we are interested in investigating correspondences between fluctuations in amplitude in the sound and acceleration in the body motion. To get a better understanding of the correspondences between music and body motion in samba, in future work more samba performance recordings, including both musicians and dancers, would be included.

#### 5. CONCLUSIONS

The results of this study point out the importance of including motion data in addition to audio data when analyzing rhythmical structures in samba. Studying rhythmical structures in samba based on recordings of performances, gathering both sound and motion data, allow us to investigate microtiming features in relation to body motion instead of to a constructed time line with isochronous time marks. Our audio analysis confirms systematic microtiming on 16<sup>th</sup>-level in samba music, and also a synchronized systematic microtiming pattern was discovered in the percussionist's heel tapping and the dancer's steps. These observations support the view that the systematic

microtiming of 16<sup>th</sup>-notes in samba performance is not a deviation from an underlying perceived pulse with isochronous subdivisions, but constitutes an essential feature of samba.

## 6. ACKNOWLEDGEMENT

The authors wish to thank Kristian Nymoen for technical assistance during the motion capture recordings, Kathrine Frey Frøslie for helping with the statistical analyses and the percussionist Célo de Carvalho and the dancer Lidia Pinheiro for participating in the study.

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## CAPOEIRA INTERACTION AS A MODEL OF EXPECTATION FORMULATION AND VIOLATION IN REAL-TIME IMPROVISED PERFORMANCE

*sempre:*  
Society for Education, Music  
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Time: 17:00

### ABSTRACT

Capoeira is an Afro-Brazilian martial art uniquely driven by music. Paired bouts (called “games”) are characterized by continuous stepping, kicking, and sweeping movements performed to live music. Capoeira movements can be executed with the intention to maintain a cooperative, fluid interaction with the opponent, or as overt attacks (sweeps, strikes, or takedowns), and thus integrate patterns that generate high expectation with temporal surprise. We interpret the predictive aspect of the capoeira bout as a useful model for studying expectation formulation, realization, and violation in an improvisatory context analogous to musical engagement by music