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Cross-cultural differences in free body movement responses to Argentinian and Afro-Brazilian music

Luiz Naveda[1], Isabel C. Martínez[2], Javier Dameśón[2], Alejandro Pereira Ghiena[2], Romina Herrera[2], M. Alejandro Ordás[2],

1 School of Music - State University of Minas Gerais
2 Laboratorio para el Estudio de la Experiencia Musical. Facultad de Bellas Artes. Universidad Nacional de La Plata
luiznaveda@gmail.com

Abstract. From all hidden assumptions behind the models of musical meter and rhythm, the notion that all individuals understand the periodic structure of music in the same way might be the most intractable and risky one. A number of evidences show that musical cultures differ in a number of aspects including cognitive priorities, musical function and relationships between music, movement and dance. From the methodological point of view, it is very difficult to describe the understanding of rhythm structures: tapping methods are limiting and biased, surveys can be too subjective and analyses of performances are ambiguous and multivariate. From the point of view of culture, cultural preferences may be subtle and comparisons between contrasting cultures might be unreliable. In this study we realize cross-cultural comparisons between free movement responses to musical cultures of samba and chacarera music, executed by Brazilian and Argentinian acculturated subjects. We use methods that track the density of kinematic events in the metrical grid at each level of the metrical structure. The results contrast to traditional models of metric structure by exposing an intrinsic diversity, variability and asymmetry of movement responses. The results also show morphological characteristics connected to cultural differences.

Keywords: cross-cultural, movement, rhythm, meter, embodiment

1 Introduction

Cross-cultural studies have received some attention from empirical approaches to music in the last years. Empirical studies are rooted in the traditions of naturalistic observation and sciences, whose principles are often guided by the search for "universals" and a quest for generalizable results, empirical evidence and statistical significance. Much of the attention to cross cultural studies seem to respond to questions posed by the ethnomusicological studies that generally claim that universals in music could only be traced from the comparison between cultures. Indeed, the diversity in music making exposed by ethnomusicology, gender studies, music education among other fields shows that the variability of music engagement defies the notion (or the hypothesis) of universals in music.

However, the search of the empirical studies for universals seems to follow a precedent. By the end of the XIX century, the interest of Europeans for non-Western cultures motivated the idea of comparison between Western and non-Western musics, resulting in the development of the comparative musicology (later evolved to ethnomusicology) [1]. Likewise, the tendency to search for universals in traditional musicology was questioned by the "new" music and music cultures presented by the comparative studies. The reaction of musicology was to approach non-Western music with the analytical tools used in the analysis of Western music. As expected, the use of analytical instruments designed to comply with to modalities of Western traditions lead to disastrous interpretations and a number of superficial accounts of non-Western music cultures. By applying empirical approaches designed to cope with the priorities and limitations of Western music, we may repeat the very same methodological bias that affected traditional musicology in the past: the use analytical instruments that shape the results according to contextual and specific assumptions.

A change in the universe of study, in this case, requires a close evaluation of the new universe of inquiry, the instruments of analysis and their underlying assumptions. Ethnography, for example, has profusely reported that rhythm engagement in non-Western musical cultures are very often related to dance and body movement. Traditions, myths, reports and all sort of ethnographical literature acknowledges the emergence of complex body engagement to music and other complexities in cultures where metrical isochrony is unclear, multiple metrical models are omnipresent, participatory displays drive music making, and timing deviations are systematic. However, the vast majority of empirical studies on rhythm make use of methods that reduce the context to discrete time annotations, such as tapping. The main problem of this study is to find solutions to analyze different cultural accounts of metrical engagement without framing the universe of study in a narrowed assumption of rhythm engagement.

In this study, we attempt to compare metrical responses in two Latin-American cultures by means of the analysis of unconstrained body movements. The movement responses of acculturated subjects to samba and chacarera music styles are analyzed and represented in descriptions that allow the subjects to express rhythm engagement in a diversity of ways. The methods do not explicitly assume the existence of beat or even spatial or temporal instructions for the task not even assume the awareness of any metrical component. The study aims at understanding the different mental models produced by Argentinian and Brazilian musical cultures without sacrificing the idiosyncrasies of cultures in favor of traditional experimental control.

In the next sections we present a review of literature on the topics of cross-cultural analysis of rhythm, rhythm and movement and movement analysis techniques.

2 Review of the literature

When P. Bohlman [2] developed his essay on the ontologies of music, he posited an ontology that considered music *in the body and/or beyond the body* (p. 32). The idea that a part of musical meaning is related to its mapping with *the* physical, and also that music is embodied in ritual and dance practice, puts, on the one hand, an emphasis on the consideration of the body at the core of musical fabric, and on the other, discusses the value of Western categories used so far to account for what is the true knowledge in the practice of scientific music research.

It is precisely due to the recovery of the meaning of the body in music cognition [3], [4], [5], together with the development of the science of evolutionary music [6], [7] and developmental musical neuroscience [8], [9] that embodied meaning in music becomes a relevant topic that is again at the center of discussions [10]. Music as text loses his primacy and music as an act is the force that leads current debates about experience in the multidisciplinary field of biocultural music.

Communicative musicality, that is to say, the human capacity of being together sharing time [11] emerges as a basic core concept that describes the state of affairs in the cultural practice of music. It is around this basic embodied knowledge that the practice of music and dance can evolve in different cultural contexts. Moreover, musical understanding may adopt different manifestations according to the diversity of temporal organization that the musical practices adopt.

Concerning temporal music organization, traditional music theory has modeled the theory of meter according to the constraints that rule Western forms of the academic repertoire [12]. According to many traditional viewpoints, all other music cultural practices (so called “world music”) were treated as deviations from the universal rule of Western organization of music. Cognitive psychology pursued for the last four decades the investigation of the cognitive reality of music theoretical constructs, among them those of musical time and metric structure [13,14,15]. The beat has been, and it is still considered as the basic unit of analysis that organizes time modeling and guides experimentation. Even the most complex rhythmic organizations of some cultural traditions are forced to enter into the corset of the beat (see for example the analysis of the *agbekor* African tradition in [16]).

Beyond the acknowledgment that time is the unavoidable human dimension that is essential in music experience and practice, the multiple forms that temporal organization acquire in musical cultures require a serious reconsideration of the ways time research is currently accomplished. Therefore, experimental design and testing techniques can be reframed discussing, on the one side, the validity of the ethnocentric model of strict adjustment to the beat as the rule against which all other the events are assessed and, on the other hand, adopting a perspective of cultural diversity that guides the musical inquiry.

The aim of the present study is to account for a cross-cultural comparison of the embodied practice of meter in music and dance.

3 Methodology

3.1 Participants

Twelve subjects participated in the study: 6 acculturated Argentinian subjects (3 male and 3 female, mean age = 33.2, SD=9.9) and 6 acculturated Brazilians (3 male and 3 female, mean age 24.3, SD=3). The subjects were randomly selected from music students in the University of La Plata (Argentina) and Federal University of Minas Gerais (Brazil). All participants were informed about experiment and provided a formal consent.

3.2 Apparatus

The movements of the participants were recorded using a motion capture system (Optitrack) equipped with 8 infrared cameras and a control system (PC). Before the experiment, 4 rigid-bodies (groups of markers) were placed at the torso (4 markers), head (4 markers), left (4 markers) and right (4 markers) hands of the subjects, in total of 16 markers. After the placement of markers, the subjects were informed about the experimental setup and recordings involved in the study. The subjects were also oriented to move freely respecting a limit at the center of the recorded area (signalized on the ground). The stimuli (monaural samples) were played through one speaker attached to a sound card and a computer. The stimuli were synchronized with video and mocap recordings by means of sync markers in the audio, mocap and video. Video recordings were realized for reference purposes.

The pre-processing of mocap files involved the preparation for synch, basic filtering and cleaning in the software Motive (Natural Point). Further processing, organization and calculation of features was realized using algorithms and tools from Mocap Toolbox [17] and Samba toolbox [18], for Matlab (Mathworks).

3.3 Materials and procedures

The subjects performed two tasks for two styles of music stimuli: chacarera and samba. In the first task the subjects were asked to try free and spontaneous movement “strategies” in response to the music stimuli. Strategies were defined and instructed as a way to respond to the rhythm of music being played. No other orientation, limitation or task was given and subjects were free to move around the recording area.

In the second task the subjects were instructed to choose the best movement strategy experimented in the first part. Then, the subjects were asked to continuously perform the chosen strategy until the end of the musical sequence (stimulus). The analysis presented in this study is applied to 12-bar length segment selected from the second part, as illustrated in the Fig. 2. In this study, we only consider the movement of the hands. The first two bars of the recordings were ignored.

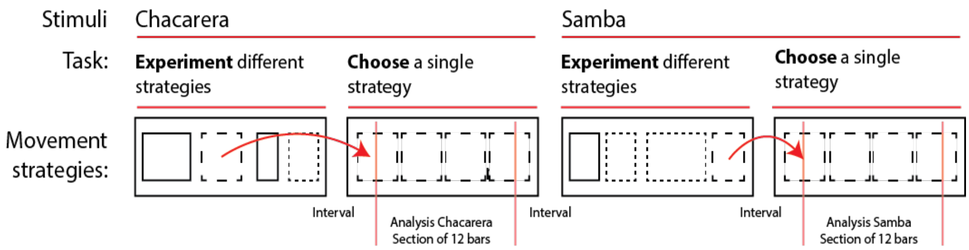

Fig. 1. Schematic representation of the phases of the experiment, tasks, type of stimuli and repetitions.

In order to avoid effects of timing, subjects were not explicitly informed for how long the stimulus was played and sessions lasted for approximately 60 seconds. After the experiment the subjects responded to questionnaires containing questions about the interaction with the experiment, personal experience and personal details. The recordings were realized in Brazil and Argentina using the same setup, conditions and protocols.

3.4 Stimuli

Chacarera music is, along with *zamba*, *milonga*, *malambo*, and of course tango, one of the most representative rhythms of Argentina. Chacarera music exhibits clear Western metrical characteristics such as the beat (tactus) and bar metric levels; however, the rhythm basis is a polyrhythmic structure of crossed binary and ternary meters (6/8-3/4). The rhythmic basis used in the present study is formed by 4 ternary beats-6 binary beats x 12 eighth-note structure, that is to say, 12 metrical elements organized polyrhythmically in groups of 3 and/or 2 eighth-notes by beat and played at 158 BPM (6/8) or 105 BPM (3/4).

The history of samba music is often seen as an outcome of the lundu-maxixe-samba genealogy of styles in Brazil. These styles denote not only a group of music styles but also related dance forms that influenced each other in an intricate cross-fertilization between styles and modalities. Modern samba music is generally described as having a binary meter music form (2/4), with accentuation in the second beat, and a rhythmic texture that is characterized by syncopated rhythms. The stimulus used in this study contains real rhythm samples of *surdo*, *caxixi* and *pandeiro* percussion. The rhythmic basis used in the present study is formed by 4 beats (2 bars) x 16 sixteenth-note structure, that is to say, 16 metrical elements organized polyrhythmically in groups of 4 sixteenth-notes per beat, played at 95 BPM.

4 .4 Analysis

There are ethnographical and cognitive problems that result in technical challenges for cross-cultural approaches to music and movement. While the interaction between the methods and cultural specifics remains poorly discussed in the literature, analytical approaches seem to carry assumptions that result in method bias, partly because they reproduce specific cultural and epistemological viewpoints. Methods involved in cross-cultural analyses must ideally encompass a range of responses and cope with expected variability of individual and cultural expressions in the universe of the study. In our specific context, the method should expose the differences regarding timing, shape, organization and position of the movement actions across different stimuli. How to provide such a rich description for spontaneous movement responses to music?

The freedom to perform spontaneous movements (which improves the power of generalization of the results) depends on freedom of movement of the limbs. It is evident that the body and psychological state of the subject, its limits, occupation in space and the experimental setup itself impose limits and obstacles, which makes the notion of "free" movement questionable. However, the concept of free movements used in this study stress the attempt to drastically decrease the influence of artificial experimental interferences and increase the similarity with real music contexts. The main cognitive challenges in the analysis of this sort of movement are (1) the lack of clear temporal demarcation of events and (2) the lack of direct access to the individual subjective categories of the events. We opted to approach these challenges by defining events as (1) changes of directionality and (2) by organizing the density of events across annotated categories of meter extracted from the stimuli. The method is briefly described below.

3.4.1 Analysis of directional changes

The analysis proposed in [19] uses (i) a sequence of trajectories in the 3D space and (ii) the time based categories extracted from the annotation. In our case, it is assumed that movements respond to the annotated musical categories and that both movement and annotation are synchronized. The process involves 4 procedures, illustrated in the Fig. 1:

- **A) PCA analysis -** The original trajectories are reconstructed from the components of a Principal Component Analysis (PCA). Practically, the PCA applies a linear transformation of the three-dimensional vectors that results in a sort of rotation of coordinates of the original trajectories to an angle the best explains the variance in the data.
- **B) Zero-crossing detection** - For each component (or dimension), the changes of direction are demarcated using the zero-crossing positions applied to the velocity patterns of each component (first order time derivative). The zero-crossing applied to the velocity results in time positions that inform when and where an orthogonal change of direction occur in the PCA component.
- **C) Estimation of metric positions** - The time positions are then subtracted by the starting time position of each metrical cycle (annotated in the stimuli), which results in a collection of time periods in relation to the metric segments. For the samba music, this cycle is composed of sixteen 16th-note segments distributed across 4 beats (16 metrical segments, 4 beats, 2 bars). For chacarera stimuli we used a model of twelve 8th-note segments (12/8) distributed across 4 beats (12 metrical segments, 4 beats, 1 bar).

D) **Histogram representation of the densities -** Finally, the time positions in relation to the metric segments are organized in a histogram that displays the density of changes across the each level of the model of meter.

These processes are applied to all three PCA components. After the PCA, the zero-crossings indicate orthogonal changes of directions with respect to the coordinate system that best represents the variance of the data. In other words, the method collects changes of directions organized across dimensions that should efficiently describe the shape of the movement sequence.

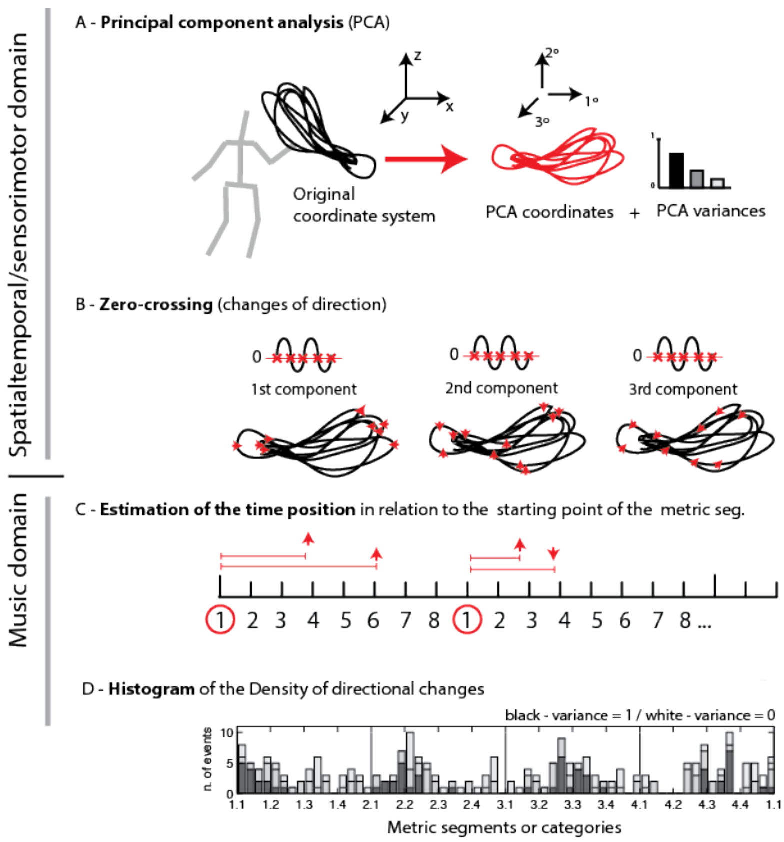

Fig. 2. Schematic representation of the processes involved in the calculation of the density of directional events.

3.4.2 Variances

The variances of the components after PCA are expressed in ratios. They are important cues to evaluate the relevance of events and the morphology of the movement gestures. The concentration of the variance in one component suggests that the movement profiles tend to be performed as a "line". Variances distributed in two components indicate a "planar" morphology. Evenly distributed variances across the 3 components indicate "spherical" trajectories in the space. Therefore, changes of directions in components with higher variances imply that these changes might be more important, perceptible and cognitively relevant. Figure 3 shows the density of directional changes for the left-hand of a Brazilian subject and its respective trajectories in the 3D Cartesian space. The variances indicate a large prevalence of the first component, reflecting the line-like shape of the movements.

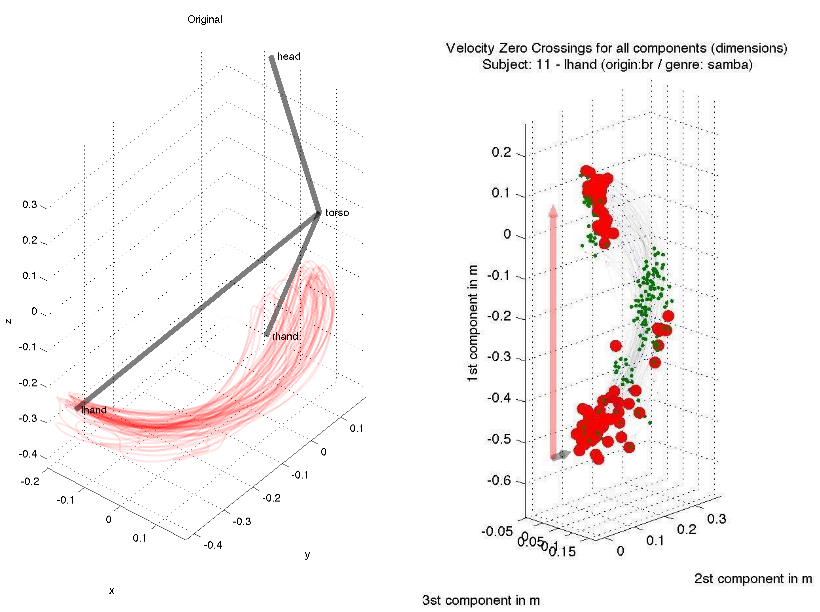

Fig. 3a. Original trajectories and stick figure representation of the connections between head, torso and hands. **3b** Trajectories reoriented by the PCA components and the directional events detected. Size of markers are proportional to variances. The length and direction of the arrows indicate the orientation of the PCA component and proportion of the PCA variances.

3.5 Pre-processing and organization of the dataset

Before the analysis, the motion capture recordings are pre-processed for better adaptation to the analytical procedures and isolation of possible bias. Part of the basic filtering and cleaning is processed in the motion capture system's software (Motive, Natural Point). In Matlab, the trajectories are subjected to final cleaning and filtering. The positions and orientations of rigid bodies for the head, torso and hands are calculated from the set of markers using MocapToolbox [17]. In order to extract the whole-body displacement from the movement of the hands, trajectories were normalized frame-by-frame in relation to the geometrical centroid of the body. The orientations of the markers were also normalized in relation to the angles of the plane formed by the markers attached to the torso. The last process attempts to isolate the movement of the hands from the rotations of the torso.

The data of each histogram (2 hands x 12 subjects x 2 stimuli = 48 sets) is organized according to analytical scenarios presented in the next sections (styles and nationality x styles). Each histogram represents the density of events collected during 12 or 16 sections of the metric segments (60 seconds). The whole dataset corresponds to events performed during 2304 musical beats. In order to avoid excess of bias generated by components with very low variances, components with less than 10% of the total variance were ignored.

4 Results and discussion

4.1 Variances

The distributions of the variances of the PCA components are displayed in Fig. 4 (expressed in ratios). The high concentration of variances in the first PCA component indicates that the morphologies of the hand trajectories are very often concentrated in one single direction. This means that most of the hand movements are designed across a sort of “imaginary line”. Trajectories exhibiting more equal variances in all components (ellipsoid distributions) are not so common in the dataset and the few examples seem to result from the motor variability associated to small movements (lower range). Fig. 5 shows several examples: the first row shows trajectories with higher tendency to ellipsoidal distributions; the second row shows the trajectories with higher differences between variances, in special with variances highly concentrated in the first PCA component.

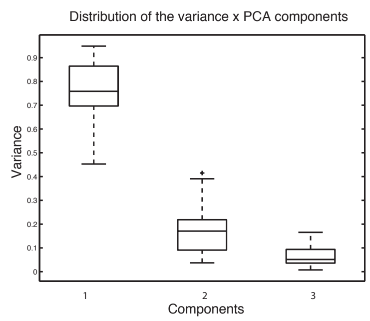

Fig. 4. Distributions of the variances for all trials (N=48), expressed in ratios. The box plots indicate the distributions of the variances attributed to the 3 components resulted from PCA (1st component, mean=0.76, SD=0.12; 2nd component, mean=0.17, SD=0.01; 3rd component, mean=0.06, SD=0.03)

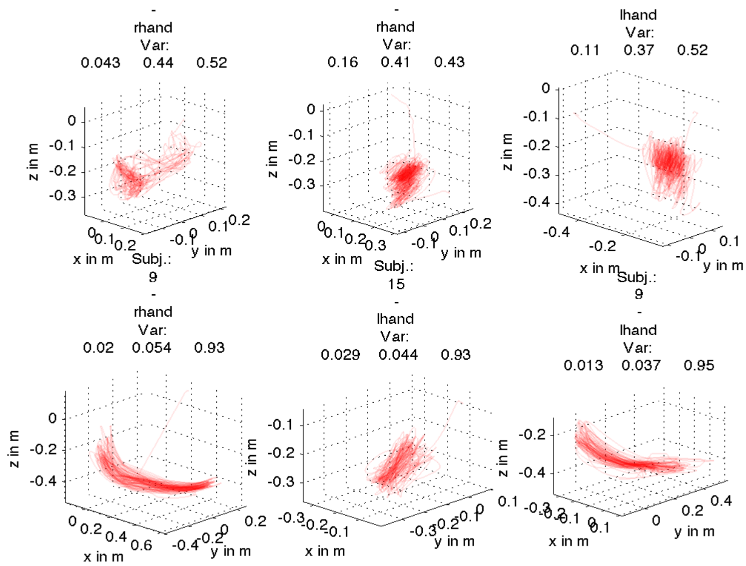

Fig. 5. Six examples of trajectories (after PCA) in the dataset (lhand and rhand indicate left and right and left hands, respectively. The values below "Var:" indicate variances). The first row shows trajectories with more equal component variances (indicating a tendency to spherical distributions). The second row shows the trajectories with higher differences between variances, in special with variances highly concentrated in the first component. They show a tendency to a line-like shape.

4.2 Differences between music styles (all subjects)

Figures 6 and 7 show the density of directional changes for chacarera and samba, respectively, for all subjects and for both hands. The graphs display the number of events and their distribution across the model of meter for each music style (stimuli). The events are also discriminated in relation to the respective PCA component and it is very important to interpret the histogram taking into account the variances in Figure 4. For example, the first component (black bars) should be read as changes of directions across the axis that responds to almost 80% of the variances (mean=0.76, SD=0.12). Although it is not really possible to access the subjective relevance or intentionality of each directional change, the tendencies of the data presented in the graphs might indicate important tendencies about the cultural settings studied here.

The information present in the Fig. 6 shows that there are not clear events in the distribution of events across metrical segments for chacarera. Some tendencies to reinforce 1.2 and 4.1 segments seem to emerge as well as stable patterns at the 1.3, 2.3 and 3.3 segments. Since Argentinians and Brazilians contribute with different quantities of events to the overall result, subtle patterns may be hidden or canceled by these contributions.

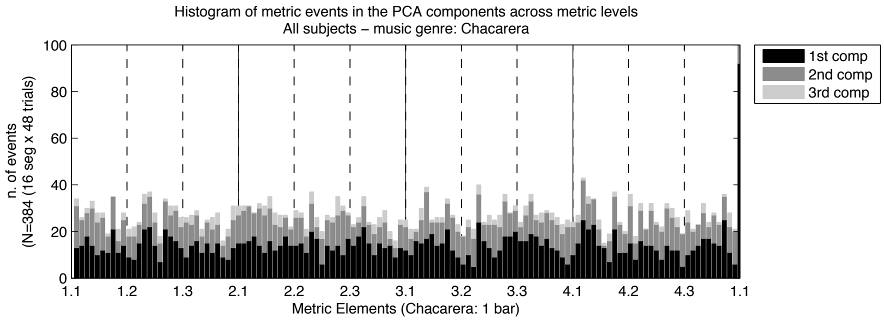

Fig. 6. Density of directional events across 1 bar (12/8), style chacarera, Argentinian and Brazilian subjects. The shades of gray indicate the quantity of events associated with each PCA component.

Fig. 7 shows the results for samba, for all subjects. The histogram displays peaks that mark every segment of the metrical model (16th-notes) if one looks at the contributions of all PCA components. The 1st PCA component (darker graph), however, seems to be less clear in the signalization of 16th-note patterns. Peaks of events are also delayed in relation to the beginning of metric segments, suggesting several possibilities: (1) a flexible movement-metrical relationship, (2) an intentional delay or a (3) fuzzy contribution resulted from the inherent motor variability. In the first half-beat of every bar for samba music (2/4), at 1.1-1.2 and 3.1-3.2 segments, there is tendency for constant event density suggesting a detachment of metrical engagement in the form of changes of directions. For example, we could speculate that subjects could use this region to perform to improvisations with the hands or simple lose the connection with metrical structure. Activity responses to samba music seem to be larger than chacarera in the form of more events across the model.

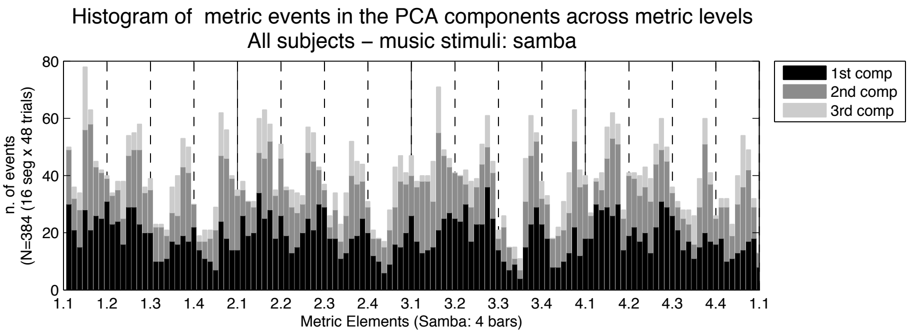

Fig. 7. Density of directional events across 1 bar (12/8), samba, Argentinian and Brazilian subjects. The shades of gray indicate the proportion of events associated with each PCA components (black = 1, white = 0).

4.3 Cross-cultural differences: chacarera

The results displayed in figures 8 and 9 show the overall results concerning objective cross-cultural differences, as represented from the methods used in this study.

Figures 8a and 8b show the concentration of events across metric segments performed by Argentinians and Brazilians, for the musical stimulus chacarera. As such, it is expected that Argentinians reflect a kind of model for the metrical engagement. Figure 9, shows the difference between figure 8a and 8b, implemented as a simple subtractive operation where the results of Argentinian subjects are subtracted from the results of Brazilian subjects for every histogram bin. Therefore, for every metric segment, positive results reflect that Argentinians performed more changes of directions than Brazilians. Conversely, negative results indicate that Argentinians performed less changes of directions than Brazilians (or that Brazilians performed more).

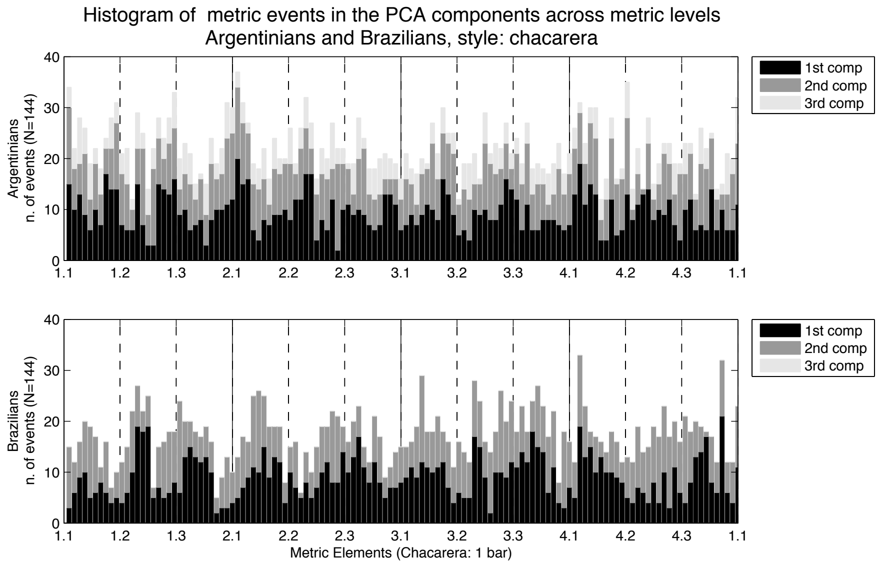

Fig. 8a. Density of directional events across 1 bar (12/8), music style chacarera, **Argentinian subjects**. **8b.** Density of directional events across 1 bar (12/8), music style chacarera, **Brazilian subjects**. The shades of gray indicate the proportion of events associated with each PCA components.

The results displayed in figure 8 confirm that part of the constant density of events across metric levels verified in figure 6 (chacarera, all subjects) is a product of cancellations between the results of Argentinians and Brazilians. While Argentinian subjects exhibit a peak of events in the beginning of metric segments, the peak of events for Brazilian subjects lies in middle of several metric segments (see fig. 8b). The negative-positive oscillation seen in several metric segments in figure 9 confirms this information (in this case, oscillation indicates subtractive effects of delays). The occurrence of erratic peaks across the metric segments and some relevant peaks densities at the second 8th-note of every beat for Brazilian subjects may suggest an attempt to entrain into a binary division across the compound ternary subdivision of chacarera. However, this hypothesis is very speculative and would require further verifications or a different experimental design.

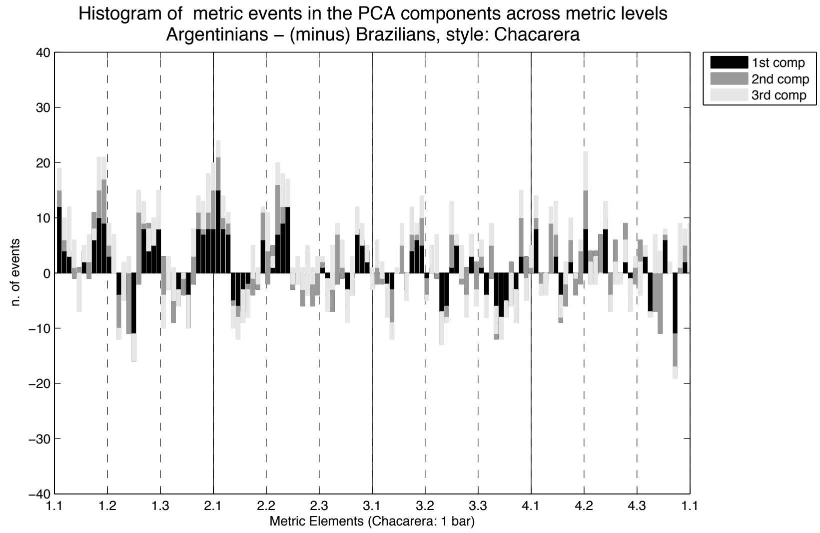

Fig. 9. Differences between densities of directional events across 1 bar (12/8), music style chacarera, results of Argentinian subjects minus the results of Brazilian subjects.

4.4 Cross-cultural differences: samba

The results displayed in Figures 10 and 11 show the densities of directional changes for samba as performed by Brazilians and Argentinian subjects, respectively. The first interesting characteristic is the apparent intense activity that Brazilian subjects apply when responding to samba music. The graphs show that the peaks observed in Figure 7 are indeed a contribution of the activity of Brazilian subjects. However, peaks of the 1st component do not reflect this observation so clearly. This suggests that 16th-note peaks are contributions of 2 two components: Brazilian subjects might be using plane-like shapes to entrain to 16th-notes. Peaks are also not synchronized with the starting point of metric segments, which suggests that changes of direction occur just after the "head" of the metric segment or at the point of deceleration (deceleration is necessary to change directions). Deceleration, or more specifically the sensation of deceleration, could be felt as a form of embodiment of metric accent.

Brazilian subjects also show a curious lack of activity on the 4th 16th-note in every beat. Such clear lack of activity may reflect a kind of "bridge" where the hands consistently travel across two points without interruptions (changes of direction). Argentinian subjects show less activity in the first beats of the 2/4 bars (1.1 and 3.1 segments). It must be noted that samba music is characterized by a hidden 1st-beat (marked by a dumped low drum attack) while the second beat is often stressed. Such a peculiarity may have induced non-acculturated subjects to spread changes of direction across the muted first beat region. As displayed in figure 11, there are differences of levels of activity between subjects in the first beat positions. The difference of activity between Brazilians and Argentinians may also reflect that Argentinians entrain to musical meter by engaging into a "choreographic" motor program without clearly attuning to frequent sharp movement changes (that generate changes of directions). Another possibility is that Argentinians attune to morphological cues such as a shape or region in space. The profile of events for Argentinian subjects also shows the emergence of offbeat accents in every beat.

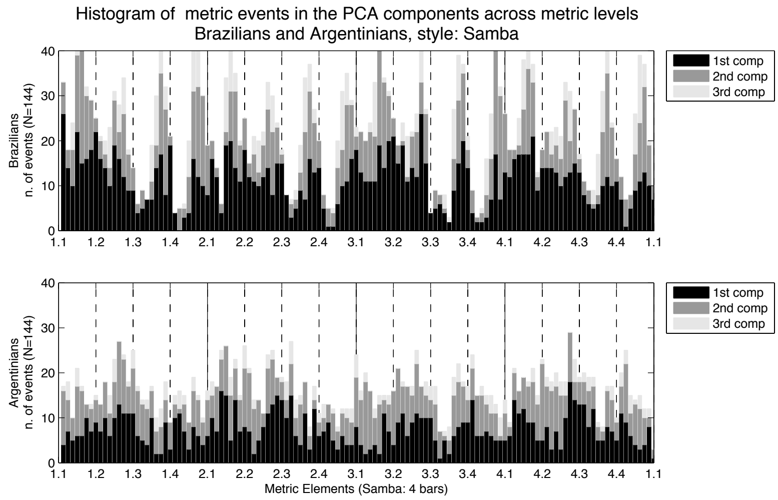

Fig. 10. Density of directional events across 1 bar (12/8), chacarera for Brazilian subjects. 10**b.** Density of directional events across 1 bar (12/8), chacarera for Argentinian subjects. The shades of gray indicate the proportion of events associated with each PCA components.

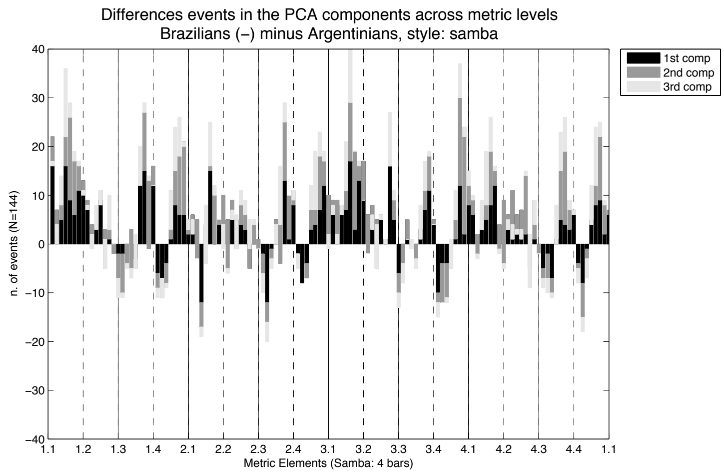

Fig. 11. Differences between densities of directional events across 2 bars (2/4), samba music, for the results of Brazilian subjects minus the results of Argentinian subjects.

5 Concluding remarks

The present study is an attempt to uncover cultural idiosyncrasies using methods that are more comprehensive to the real-world phenomena of dance and music and less dependent on assumptions and control of rhythm tasks. The methods are experimental and many technical and conceptual issues must be discussed and improved. However, the study seems to provide contributions to the knowledge of cultural representations of meter and conceptual ideas about accessing metrical models. Even if the results comprehend a small universe of musically trained individuals, they still exhibit intriguing idiosyncrasies that emerge from robust quantitative data. The study seems to demonstrate that it is not entirely necessary to impose rigorous control of tasks detached from real-world musical engagement in order to compute and access significant responses to musical meter.

The results show that cultural differences are reflected in timing and signalization of structures of meter and also affect the morphology of movements. Most of the movements seem to describe a “line”, which involves opposite movement changes (e.g., forward-backward, which naturally impose binary divisions to the body constraints). Changes pertained to the second PCA component may indicate movements follow a plane and are present in some tendencies observed in the graphs.

The main contribution of the results focuses on the differences between the responses between Argentinian and Brazilian musical cultures. Brazilian subjects, for example, seem to move in a more active display and delay changes of direction in relation to metrical rules. The density of events for the same group suggests a priority to perform percussive gestures in relation to the metrical structure. Results of Argentinian subjects express a variable (perhaps choreographic) display of changes but subjects entrain to metric segments using more accurate changes of direction in time.

The study also contributes with alternatives for assessment of metric engagement in contexts where traditional tapping or survey techniques are impractical (e.g. experiments with infants or cultures that are not familiar with control tasks) or the analysis of open movement responses to music are needed. We must acknowledge that the analysis lies in the assumption that changes of directions denote the enactment of metrical accents. Even if the hypothesis is considered weak for some conditions, the recording of free movements movement responses simplify the data collection and provides a larger number of observations, facilitating the observation of characteristics of the universe of study and further replication of the study.

The technique present in the methods makes use of simple algorithms that are novel in their combination and application but involve trivial and widely available computer methods. The information is represented almost entirely as data visualization, which helps evaluation, and avoid measures of centrality. In this respect, responses to musical meter involve intricate interdependencies across many points of observation. Deviations also cannot be considered as a result of random disturbances. Therefore, the violations of assumptions of independence and homogeneity of variance would invalidate the application of traditional significance measurements. In fact, as suggested in some examples, variability may be considered a form of signalization of meter and should not be underestimated given the influence of improvisation practices in Western and non-Western music.

Future work

The methods and design of this study can be greatly improved by looking at more options for data visualization or data reduction techniques. Correlations and other verifications of relationships across the dataset can be added to the set of observations. The number of subjects could be expanded as well as replications of the experiment. This would provide a better estimation of the reliability of the experimental design and maybe confirm actual observations.

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References

1. Parncutt, R.: Systematic Musicology and the History and Future of Western Musical Scholarship. Journal of Interdisciplinary Music Studies. 1, 1–32 (2007).
2. Bohlman, P.V.: Ontologies of Music. In: Cook, N., Everist, M. (eds.) Rethinking Music, pp 17--34. Oxford University Press, Oxford (1999)
3. Johnson, M.: The body in the mind. The University of Chicago Press, Chicago (1987)
4. Larson, S.: Musical Forces. The University of Chicago Press, Chicago (2012)
5. Leman, M.: Embodied Music Cognition and Mediation Technology. MA: MIT Press, Cambridge, Massachussets (2008)
6. Cross, I.: The nature of Music and is Evolution. In: Hallam, S., Cross, I., Thaut, M. (eds.) The Oxford Handbook of Music Psychology, ch. 8, pp. 3--13. Oxford University Press, Oxford (2009)
7. Cross, I.: Musicality and the human capacity for culture. Music. Sci. SI,12, 147--167 (2008)
8. Gallese, V., Lakoff, G.: The brain´s concepts: the role of the sensory-motor system in conceptual knowledge. Cognit. Neuropsychol. 22/3-4, 445--479 (2005)
9. Trevarthen, C.: Musicality and the intrinsic motive pulse: evidence from psychobiology and infant communication. Music. Sci., Special Issue, 155--211 (1999-2000)
10. Cross, I., Tolbert, E.: Music and meaning. In: Hallam, S., Cross, I., Thaut, M. (eds.) The Oxford Handbook of Music Psychology, ch. 8, pp. 24--34. Oxford University Press, Oxford (2009)
11. Malloch, S., Trevarthen,C.: Communicative Musicality. Oxford University Press, Oxford (2009)
12. Christensen, T.(ed.): The Cambridge History of Western Music Theory. Cambridge University Press, Cambridge (2002)
13. Deutsch, D. (ed.): The Psychology of Music. Sec. Ed. Academic Press, San Diego (1999)
14. Sloboda, J.A.: The Musical Mind. Oxford University Press, Oxford (1985)
15. Krumhansl, C.L.: Cognitive foundations of musical pitch. Oxford University Press, Oxford (1990)

16. Fitch, W.T.: The biology and evolution of rhythm: Unraveling a paradox. In Rebuschat, P., Rohrmeier, M., Hawkins, J.A., Cross, I. (eds.) Language and music as cognitive systems, pp. 73--95. Oxford University Press, New York (2012)
17. Burger, B., Toiviainen, P.: MoCap Toolbox – A Matlab toolbox for computational analysis of movement data. In: 10th Sound and Music Computing Conference, (SMC), pp. 172--178. KTH Royal Institute of Technology, Stockholm, (2013).
18. Naveda, L.: SambaLib - a set Matlab tools for cross-modal analysis of music and movement. , Belo Horizonte, Brazil (2015). http://naveda.info/sambalib
19. Naveda, L., Martinez, I., Damesón, J., Ghiena, A., Romina, H., Ordás, Alejandro: Methods for the analysis of rhythmic and metrical responses to music in free movement trajectories.11th International Symposium on Computer Music Multidisciplinary Research (2015).