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Cross-Cultural Comparisons of Unconstrained Body Responses to Argentinian and Afro-Brazilian Music

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Abstract. 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, surveys are very subjective and analyses of performances are ambiguous and multivariate. In this study we realize cross-cultural comparisons between unconstrained movement responses of Brazilian and Argentinian acculturated subjects, responding to samba and chacarera music. The analyses were realized by means of methods that track the density of kinematic events in the metrical structure. The results contrast to traditional models of metric structure by revealing an intrinsic diversity, variability and asymmetry of movement responses and metrical models. The results also show morphological characteristics connected to cultural differences.

Keywords: Cross-cultural · Movement · Rhythm · Meter · Embodiment

1 Introduction

The tradition of empirical approaches to music is rooted in the knowledge of naturalistic observation and science, whose principles are guided by formalization, search for "universals", empirical evidence and attempts to produce generalizable results supported by statistical significance [1]. The comparison between different musical cultures offers a formidable opportunity to validate such observations across the large diversity of musical phenomena [2]. Following this opportunity, the application of empirical approaches to cross-cultural research seems to respond to questions posed by ethnomusicological studies, where the search for universals in music is delineated from the comparisons between cultures. However, the disrupting diversity in music making shows that the variability of music engagement defies the very notion (or the hypothesis) of universals in music.

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Although the recent access to modern capturing technologies and media has fostered the quest for universals in culture, the actual development of empirical research in music seems to have followed an older precedent. By the end of 19th century, the interest of European scholars for non-Western cultures motivated the idea of making comparisons between Western and non-Western musics. This idea led to the emergence of Comparative Musicology (later evolved onto Ethnomusicology) [3]. At that time, the reaction of musicology was to approach non-Western music by means of analytical tools designed for the analysis of Western classical music. The use of analytical instruments developed to approach Western traditions led to a number of superficial accounts of non-Western music cultures, together with concomitant biased interpretations [e.g.: focus on the analysis of melodies, scales and intervals, as described in [4]. Later, the idea of universals in the traditional musicology was questioned both by arguments of the so called "new musicology", and by the inquiry about music cultures reported in the comparative studies and ethnomusicology [5]. Similarly, by using the modern empirical approaches designed to cope with the priorities and constraints of Western music, we might repeat the same methodological mistake that affected musicology in the past: the use of analytical instruments that shape the results according to culturally specific assumptions.

The bias that analytical views impose to the observation of cultural phenomena and the problems that such a limited epistemological view of knowledge has caused in modern sciences have been discussed under the criticism of post-modern and post-colonial literature. The main argument is that modern sciences discard "epistemological disturbances" and ignores alternative knowledge in order to preserve a single view that is necessary to build representations of certainty, evidence and generalization in modern scientific production [6]. Regardless the criticism, the accumulative set of artificial procedures, tasks and limitations necessary to capture and analyse, for example, a single movement recording, is indeed disturbing. It negatively affects the validity and generalization of findings by corrupting ecological validity. Ultimately, it dissociates the scientific observation and its representations from the phenomenon of musical culture itself. Although the conflicts between the principles of empirical methods and the elements of musical knowledge in different cultures pertain to a larger epistemological discussion, a careful design of experiment and analysis might help to develop better accounts of musicological information and to avoid the repetition of methodological problems that affected the 19th century musicology.

1.1 Empirical Approaches to Rhythm

The study of musical rhythm across different cultures is especially vulnerable to methodological problems. The relationships between musical rhythm and presumably "non-musical" activities such as dance, worship, labour or walking demonstrate that rhythm engagement in societies is not exclusively accessible through the acoustic medium [7–11]. The body and the methods capable of capturing the structure of the rhythm performed by the body may offer a key analytical channel to the structure of performance and perception of rhythm. Additionally, more comprehensive approaches to cultural diversity would require a careful assessment of the scope of the cultural

phenomenon (e.g.: internal connections between music and other modalities), the instruments of analysis and their underlying assumptions, which may only be found in interdisciplinary readings.

A review of the literature in ethnography, for example, demonstrates widespread connections between rhythm engagement and the performances of dance and body movement in different cultures. A number of musical traditions and myths attest the presence of sophisticated body responses to music [12, 13]. Ethnographic literature reports that dance and movement perform an active musical role in cultures where metrical models are not isochronous or polymetrical [7, 14] or timing deviations are modulated by participatory displays [15, 16]. Conversely, the vast majority of empirical studies on rhythm are based on information collected from the reduction of the movement of acculturated subjects to a very simplistic account of body movements, often limited to a discrete indication of time events. As such, the methodological demands reduce the window of the analysis into simplistic set of evidences, which methodologically isolates rhythm complexity from the representation. The main obstacle in this tradition of empirical research is to find alternative ways to analyse the phenomenon of metrical engagement without framing the universe of study on the basis of a narrowed (or anthropocentric) assumption of rhythm engagement. The support of the theories of embodiment in music [17, 18] and the possibility of enaction of rhythm models by acculturated subjects may provide theoretical and empirical conditions to access better accounts of rhythm in culture.

1.2 Rhythm and Embodiment

When Bohlman [19] 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 knowledge in the practice of modern scientific music research.

It is precisely due to the recovery of the meaning of the body in music cognition [17, 20, 21], together with the development of the science of evolutionary music [22, 23] and developmental musical neuroscience [24], [25] that embodied meaning in music becomes a relevant topic that is again at the centre of discussions [26]. Music *as text* loses its primacy and music *as act* is actually the force that leads current debates about experience in the multidisciplinary field of biocultural music.

Communicative musicality, that is to say, the human capacity to share and exchange rhythmic, temporal and gestural patterns during communication [27] emerges as a 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, different manifestations of musical understanding may arise out of the diversity of temporal organization that characterizes a variety of musical practices.

Concerning temporal music organization, traditional music theory modelled the theory of meter following the temporal constraints of Western academic music [28]. According to many traditional viewpoints, all other music cultural practices (so called "world music") were treated as deviations from the universal rule of time in Western music organization. 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 [29–31]. The beat has been, and it is still considered as the basic unit of analysis. It is thought about as an essential tool in order to organize the study of musical time, and to shape and guide the experimental work. 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 [32]).

Beyond the acknowledgment that time is the unavoidable human dimension that is inherent to the practice and experience of music, the multiplicity of temporal organizations found in musical cultures suggests that time research should be seriously reconsidered in all what concerns to the ways musical time is currently approached. Therefore, experimental design and testing techniques could be reframed by discussing, on the one side, the validity of the ethnocentric model of strict adjustment to the beat, as the rule against which all other events are assessed and, on the other hand, adopting a perspective of cultural diversity that guides music inquiry.

In this study, we discuss alternatives to the study of rhythm in culture by looking at the body and rhythm in culture: acculturated subjects responding to rhythm structures present in musical styles. We describe an experiment that compares metrical responses in two Latin-American cultures by means of the analysis of unconstrained body movements. The complexity encoded in the ecological setting is approached by cross-cultural comparisons supported by an exploratory analysis of body responses to music, captured by means of a motion capture system. The movement responses of acculturated subjects to samba and chacarera music styles are compared using descriptors that reveal the rhythm engagement in a diversity of representations. In our attempt to reduce the methodological bias, the methods did not explicitly assume the existence of beat and/or spatial or temporal instructions for the task, not even the subjects' awareness of metrical components. As such, we might be able to grasp a range of different mental models produced by Argentinian and Brazilian musical cultures, without sacrificing cultural idiosyncrasies in favour of traditional experimental control.

In the following sessions we describe the realization of the experiment and discuss the process of adapting empirical approaches according to the reported concerns about validity, generalization and ecological setting in the context of cross-cultural analysis of musical rhythm.

2 Methodology

The methodology used in this study involves a typical experimental setup where movement data from acculturated subjects from Argentina and Brazil is recorded and analysed using computational approaches. Procedures and analytical approaches used

in the process are specifically adapted to cope with a less constrained experimental design, which might help to reduce the bias introduced by other methods. The rationale behind each experimental procedure is discussed in the following sessions while the analytical procedure is proposed and detailed in [33].

2.1 Participants

Twelve subjects participated voluntarily in the study: 6 acculturated Argentinian subjects (3 males and 3 females, mean age = 33.2, SD = 9.9) and 6 acculturated Brazilians subjects (3 males and 3 females, mean age 24.3, SD = 3). The subjects were randomly selected from university music students both at the National University of La Plata (Argentina) and at Federal University of Minas Gerais (Brazil). All participants were informed about the characteristics of the experiment and provided formal consent to participation.

2.2 Apparatus

Participants' movements were recorded using a motion capture system (Optitrack, Natural Point) 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, totalizing 16 markers. Then, subjects were informed about the experimental setup and recordings involved in the study. Subjects were also oriented to move freely within the perimeter of the recorded area (signalized on the ground). Stimuli (monaural samples) were reproduced through one speaker connected to a sound card in a computer. Stimuli were synchronized with video and mocap recordings by means of synch markers in the audio, mocap and video. Video recordings were also produced for reference purposes.

Pre-processing of mocap files involved synchronization of files, basic filtering and cleaning using the software Motive (Natural Point). Further processing and organization of the dataset were partially realized using algorithms developed by the authors and the Mocap Toolbox [34] for Matlab (Mathworks).

2.3 Procedures

All the subjects performed two tasks, each for both 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 music. Strategies were defined and instructed as an unrestricted way to respond to the rhythm of the music being played. No other orientation, limitation or task was given, and subjects were free to move around minding the boundaries of the recording area. In the second task, the subjects were instructed to (i) choose the best movement strategy experimented in the first task; and (ii) continuously perform the chosen movement strategy until the end of the musical sequence (stimulus).

The analysis presented in this study was applied to a 12-bar length segment extracted from the second part, as illustrated in Fig. 1. In our analysis, we only considered the movement of the hands. The first two bars of the recordings were ignored in order to isolate the data from biased adaptation of the subject to the task and stimuli (Fig. 1).

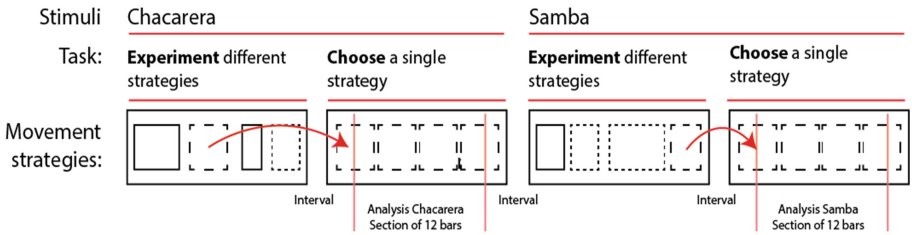

Fig. 1. Schematic representation of the phases of the experiment, tasks, type of stimuli and repetitions of the "strategies" used in the experimental trials.

In order to avoid the effects of timing (fatigue and/or bias due to temporal expectations) in task accomplishment, subjects were not explicitly informed about the duration of the stimulus. Sessions' trials lasted for approximately 60 s. After the experiment the subjects responded to questionnaires containing questions about the interaction with the experimental task, personal experience and personal details. The recordings were realized in Brazil and Argentina using the same setup, conditions and protocols.

2.4 Stimuli

Chacarera music is, along with *zamba*, *milonga*, *malambo*, and of course *tango*, one of the most representative rhythms of Argentina. Chacarera music exhibits Western metric features such as a steady beat (tactus) and a metric hierarchy that combines binary and ternary levels; the rhythmic base is organized according to a polyrhythmic structure of crossed binary and ternary meters (6/8–3/4). The rhythmic phrase of the stimulus used in the present study consists on a structure that combines 4 ternary beats-6 binary beats × 12 eighth-notes, that is to say, 12 low level metrical elements organized polyrhythmically in groups of 3 and/or 2 eighth-notes by beat, and played, respectively, at a rate of 158 BPM (6/8) or 105 BPM (3/4).

The history of Brazilian *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 a variety of syncopated rhythms. The stimulus used in this study contains real rhythm samples of *surdo*, *caxixi* and

pandeiro percussions. The rhythmic basis of the stimulus is formed by 4 beats (2 bars) × 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.

2.5 Analysis

Cross-cultural experiments raise a number of limitations that have a direct impact in the development of technical and experimental solutions for the procedures. While the interaction between the methods used to analyse behavioural data and cultural specifics is rarely discussed in the literature, analytical approaches seem to carry assumptions and concepts that often result in misrepresentation of the phenomenon, partly because they reproduce specific cultural and epistemological viewpoints [35]. Methods involved in cross-cultural analyses should ideally support and record not only a range of possible responses, but also an expected variability of individual and cultural expressions in the universe of study. In our specific context, the method should reveal the differences regarding timing, shape, organization and position of the movement actions across different musical stimuli. The challenge is how to provide such a rich and informative description of spontaneous movement responses to music without referring to a complex account of different movement profiles that cannot be compared.

The freedom to perform spontaneous movements depends on the freedom of movement of the limbs, which has a direct impact on the ecological validity and thus, the generalization of the results. It is evident that the psychological and physical state of the subject in the laboratory, the limitation and occupation of the space, and the experimental setup itself impose constraints and obstacles, which make the idea of "free" movement questionable. However, the concept of free movements used in this study reflects the condition of absence of external obstacles, fixed tasks or limits, as in typical cultural musical contexts such as a dance club, party or a private room[1]. The main challenges in the analysis of this sort of movement are (i) the lack of clear temporal demarcation of metrical accents and (ii) the lack of direct access to the subject´s experiential categories of the events. We opted to approach these challenges by (i) defining events as changes of direction and (ii) organizing the density of events across annotated categories of meter, extracted from the stimuli. The method is briefly described below.

2.5.1 Analysis of Directional Changes

The analytical approach applied here (proposed in [33]) 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 musical categories of musical meter and that both movement and annotation are synchronized. The process involves four procedures, illustrated in the Fig. 2:

[1] Environments where spontaneous body movements are performed in culture also impose other sort of limitations such as socio-cultural codes and limitations of physical space.

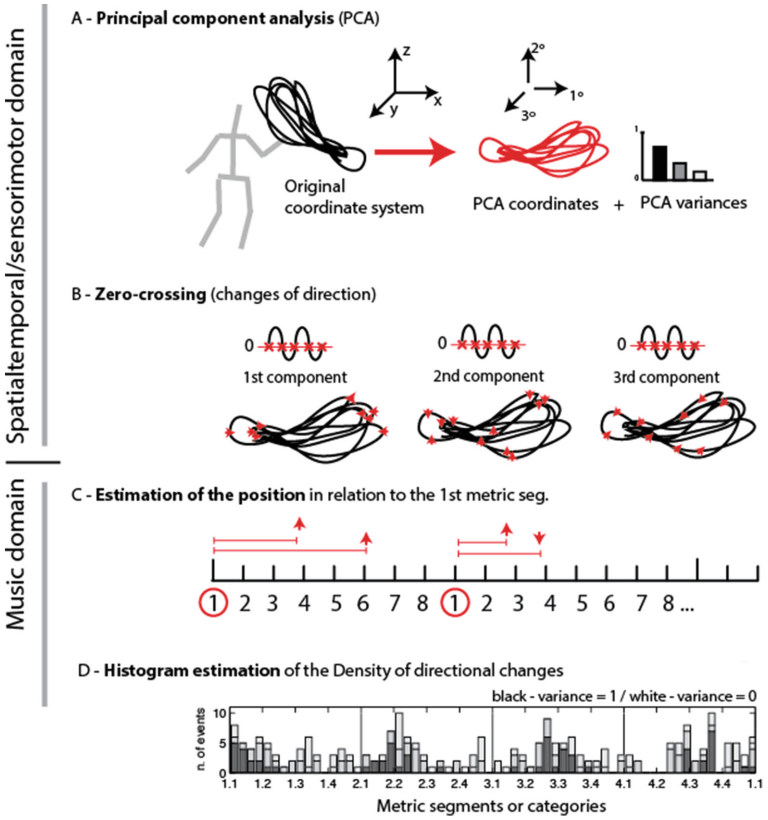

Fig. 2. Schematic representation of the processes involved in the calculation of the density of directional events.

(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 the coordinates of the original trajectories into an angle that best explains the variance in the data.

(B) **Zero-crossing detection** - For each PCA component (or dimension), the changes of direction are retrieved by detecting zero-crossing positions in the velocity patterns of each component (first order time derivative). Zero-crossing positions in the component's velocity patterns retrieve time positions that indicate when and where an orthogonal change of direction appears in the PCA component.

(C) **Estimation of metric positions** - The time points are subtracted by the time point of the first beat of the model of meter, which results in a time difference in relation to the starting time position, normalized by the length of the metric cycle annotated in the metric model of the musical stimuli. In the metric model of samba music, this cycle is composed of sixteen 16^{th}-note segments distributed across 4 beats (16 metrical segments, 4 beats, 2 bars). For chacarera stimuli we used a

metric model of twelve 8th-note segments (12/8) distributed across 4 beats (12 metrical segments, 4 beats, 1 bar).

(D) **Histogram representation of the density of directional changes -** Finally, time differences are normalized and organized in a histogram that displays the density of events across each level of the model of meter used in the annotation.

The directional changes' detection procedure is applied to all three PCA components. Once PCA has been run, zero-crossings indicate orthogonal changes of direction with respect to a coordinates system (the PCA components) that best represents the variance of the data. In other words, the method retrieves changes of direction organized across dimensions that efficiently reflect the organization of the shapes of the overall movement. It provides an elegant way to avoid the imposition of the coordinates system of the mocap recording and to reveal the organization of the gesture shape according to the subject's perspective.

2.5.2 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 movement's gestures. The concentration of the variance in one component indicates that movement profiles tend to be shaped as a "line" in the space. Variances distributed in two components indicate a "plane" morphology. Evenly distributed variances across the three components indicate "spherical" explorations of space in the trajectory of movement. Changes of direction in the components with higher variances might be more important, perceptible and cognitively relevant because the variance indicates a focus on movements across specific axes. Figure 3 shows the density of directional changes for the left-hand of a subject, and the corresponding trajectories in the 3D Cartesian space.

2.6 Processing and Organization of the Dataset

Before the analysis, the motion capture recordings were pre-processed for better adaptation to the analytical procedures and isolation of possible biases. Part of the basic filtering and cleaning were processed in the motion capture system's software (Motive, Natural Point). In Matlab, the trajectories were subjected to final cleaning and filtering. The positions and orientations of the rigid bodies placed at head, torso and hands were calculated from the set of markers using MocapToolbox [34]. In order to extract the whole-body displacement out of 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 isolates the movement of the hands from the rotations of the torso.

The data of the histogram displayed in the results (2 hands $\times$ 12 subjects $\times$ 2 stimuli = 48 sets) was organized according to the analytical scenarios that are presented in the next sections (styles; nationality x styles). Each histogram represents the density of events across 12 (chacarera) or 16 sections (samba) of the model of metric segments. The whole dataset corresponds to events recorded along 2304 musical beats. In order to

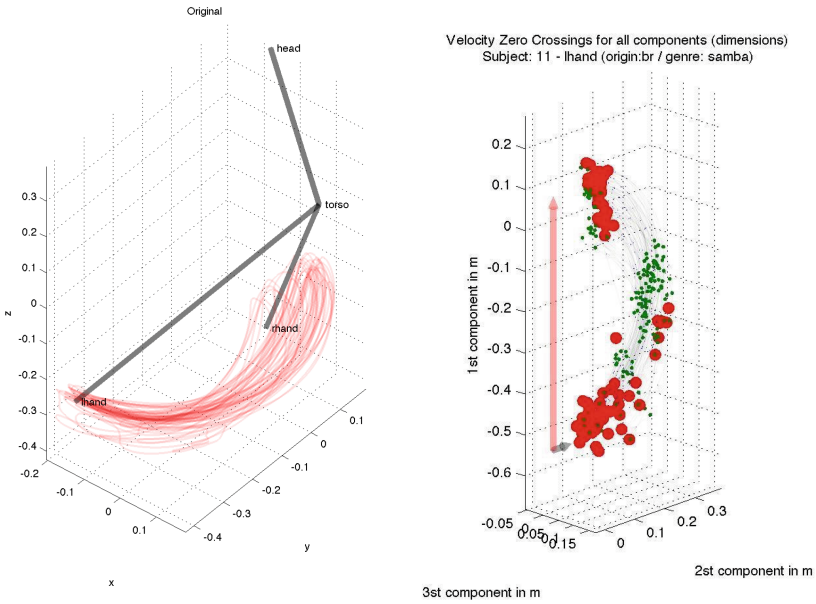

Fig. 3. Original trajectories and stick figure representation of the morphological connections between head, torso and hands. 3b. The same trajectories reoriented in order to reflect the PCA components and the directional events (red markers). The marker's size is proportional to the variance. The length and direction of the arrows indicate, repectively, the proportion of PCA variance and the orientation of the PCA component

avoid excess of bias generated by components with very low variances, events in components with less than 10 % of the total variance were ignored.

3 Results and Discussion

3.1 Variances

The distribution of the variances of PCA components for all subjects, for both hands and styles is displayed in Fig. 4 (expressed in ratios). A high variance in the first PCA component indicates in the morphology of the hand's trajectory that the movement is oriented across one single dimension. This means that most of the hand movements are displayed across a sort of "imaginary line" shape. Trajectories exhibiting less differences between variances in all components (ellipsoid distributions) are not so common in our universe of movements. Figure 5 shows several examples of such trajectories. The first row in Fig. 5 shows examples of trajectories with higher tendency to ellipsoidal distributions. The second row shows trajectories with higher differences between variances, in particular, with variances highly concentrated in the first PCA component. The examples in Fig. 5 demonstrate how the distribution of PCA variances reflect a quality of the shape of the gestures.

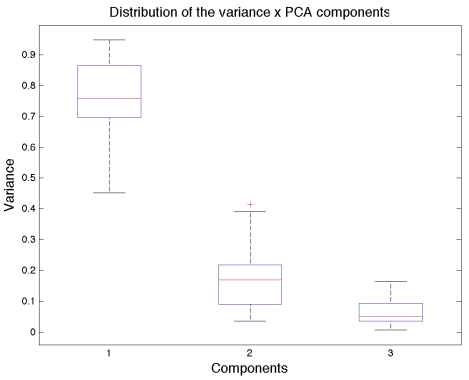

Fig. 4. Distributions of the variances for all trials (N = 48, 12 subjects, 2 hands, 2 music styles), expressed in ratios. The box-plots indicate the distributions of the variances attributed to the 3 components obtained after running PCA (1st component, mean = 0.76, SD = 0.12; 2nd component, mean = 0.17, SD = 0.01; 3rd component, mean = 0.06, SD = 0.03).

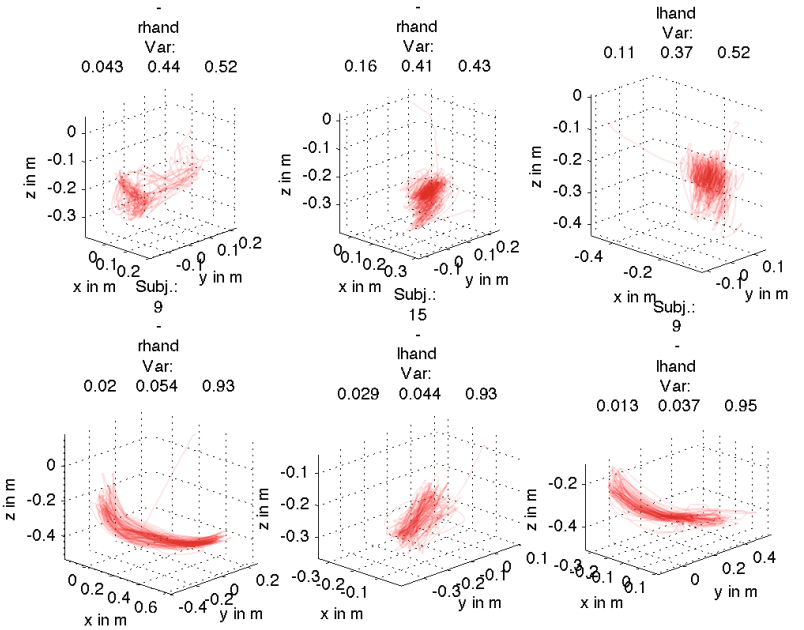

Fig. 5. Six examples of trajectories (after PCA) in the dataset (lhand and rhand indicate left and right hands, respectively. The values after Var: indicate the variances). The first row shows trajectories with lowest differences between variances in each component (indicating a tendency to spherical distributions). The second row shows the trajectories with higher differences between variances, in special gestures with variances concentrated in the first component.

3.2 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 of each music style. The metric events are also discriminated in relation to the respective PCA component (1st, 2nd, and 3rd) using three levels of grey, described in the legend. It is very important to interpret the histograms taking into account the variance distribution shown in Fig. 4. For example, the first component (black bars) should be read as changes of direction across the axis that correspond to almost 80 % of the variance (mean = 0.76, SD = 0.12). Although it is not possible to access the subjective relevance or intentionality of each directional change, the granularity of the information across metrical segments might indicate important trends about the cultural settings studied here.

The information presented in Fig. 6 shows that there are no clear events in the distribution of events across metrical segments for chacarera. Segments 1.2 and 4.1

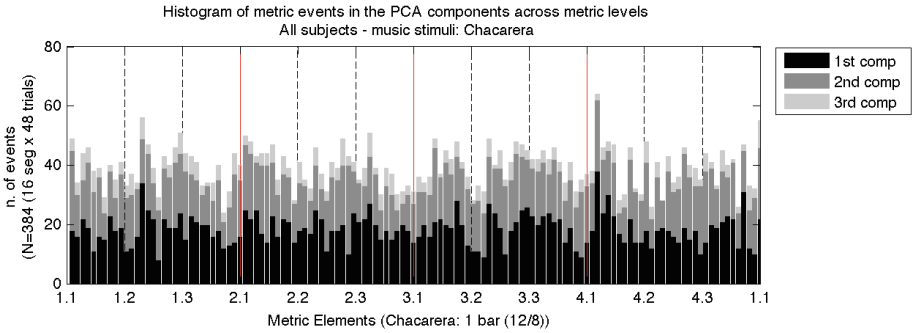

Fig. 6. Density of directional events across 1 bar (12/8), chacarera style, Argentinian and Brazilian subjects collapsed. The shades in grey indicate the quantity of events associated with each PCA component.

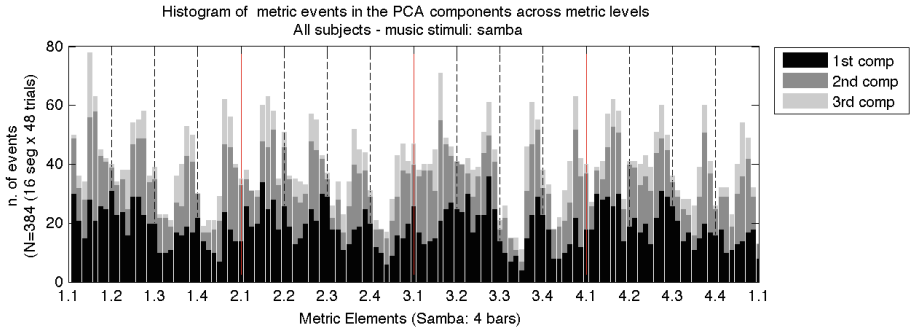

Fig. 7. Density of directional events across 1 bar (12/8), samba, Argentinian and Brazilian subjects. The shades of grey indicate the proportion of events associated with each PCA components (black = 1, white = 0).

show a small peak of activity and segments 1.3, 2.3 and 3.3 show apparent stable densities of activity. Since Argentinians and Brazilians contribute with different quantities of events to the overall result, subtle patterns may be hidden or cancelled by these contributions.

Figure 7 shows the results for samba, for all subjects. The histogram displays peaks that point at every segment of the metrical model (16^{th}-notes), if all contributions of directional changes of all PCA components are taken into account. The 1^{st} PCA component (darker graph), however, seems to be less clear in the signalization of 16^{th}-note patterns. Peaks of event densities are also delayed in relation to the start of metric segments, which suggests 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 in samba music (2/4), at 1.1–1.2 and at 3.1–3.2 segments, the event's density tends to be sustained, suggesting a detachment of metrical engagement. For example, we could hypothesize that subjects use this metrical region to perform improvisations with the hands, or simply that they loose the connection with the metrical model. The activity in response to samba music (the density of events) seems to be larger than what is observed in the responses to chacarera, in all what concerns to the quantity of events accounted for across the metric model.

3.3 Cross-Cultural Differences: Chacarera

The results displayed in Figs. 8 and 9 show direct cross-cultural comparisons, as represented from the methods used in this study.

Figures 8a and b show the concentration of events across the metric segments of chacarera music performed, respectively, by Argentinians and Brazilians. In this case, it was expected that Argentinians, as acculturated "experts", would enact a kind of ground truth for the metrical engagement. Figure 9 shows the difference between Figs. 8a and b, implemented as a simple subtractive operation. In this representation, the results of Argentinian subjects are subtracted from results of Brazilian subjects at each histogram bin. Therefore, positive results at a given metric segment reflect that Argentinians performed more changes of direction than Brazilians. Conversely, negative results indicate that Argentinians performed less changes of direction than Brazilians (or that Brazilians performed more).

The results displayed in Fig. 8 confirm that part of the constant density of events across metric levels verified in Fig. 6 (chacarera, all subjects) is a product of cancellations after subtraction between the results of Argentinians and Brazilians. While Argentinian subjects exhibit a peak of events at the beginning of metric segments, the peak of events for Brazilian subjects lies in the middle of several metric segments (see Fig. 8b). The negative-positive oscillation observed in several metric segments in Fig. 9 seems to confirm this hypothesis (in this case, oscillation results from the interaction between delays and the subtraction). The occurrence of erratic peaks across the metric segments and some relevant peak densities at the second 8^{th}-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

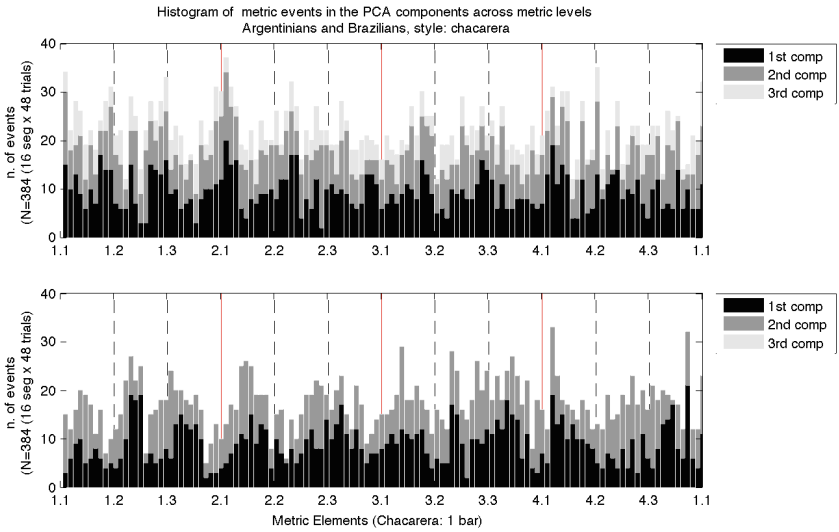

Fig. 8. a. Density of directional events across 1 bar (12/8), music style chacarera, Argentinian **subjects**. b. Density of directional events across 1 bar (12/8), music style chacarera, Brazilian **subjects**. The shades of grey indicate the proportion of events associated with each PCA components.

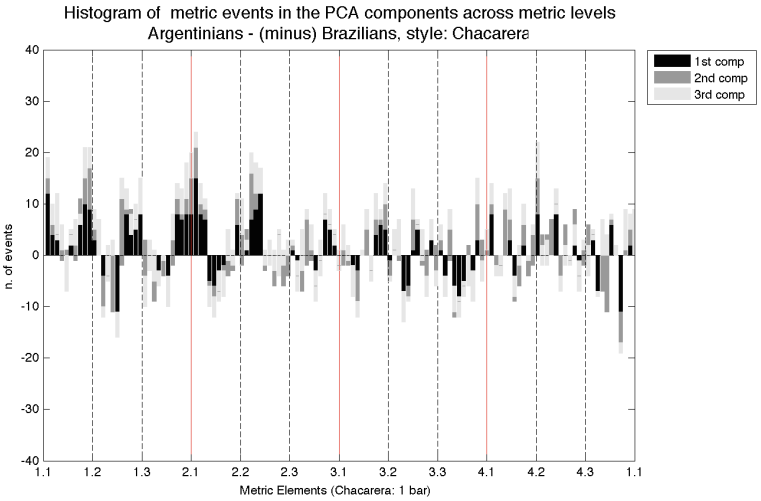

Fig. 9. Differences between densities of directional events across 1 bar (12/8), music style chacarera, results of Argentinian subjects minus the results of Brazilian subjects.

speculative and would require further verification or a different experimental design. In this specific case, a well conducted test of hypothesis could reveal how internalized metric models react to non-acculturated music.

3.4 Cross-Cultural Differences: Samba

The results displayed in Figs. 10 and 11 show the densities of directional changes for samba, as performed by Brazilians and Argentinian subjects, respectively. The main observation is the apparent intense activity that Brazilian subjects apply in response to samba music. The graphs show that the peaks observed in Fig. 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 may result from the contribution of two PCA components, or that Brazilian subjects might be using plane-like shapes (e.g. ellipses) as a form to entrain to 16th-notes. Peaks are also not synchronized with the starting point of the metric segments, which suggests that changes of direction occur just after the "head" of the metric segment or at the point of deceleration (since the range of the body is limited, changes of directions are preceded by deceleration). Deceleration, or more specifically the sensation of deceleration, could be perceived by the subjects as a form of embodiment of the 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. This musical aspect may have induced non-acculturated subjects to skip or spread changes of direction across the first beat region. As displayed in Fig. 11, there are differences in the levels of activity between subjects at the first beat positions. Differences of activity between Brazilians and Argentinians may also reflect that Argentinians entrain to

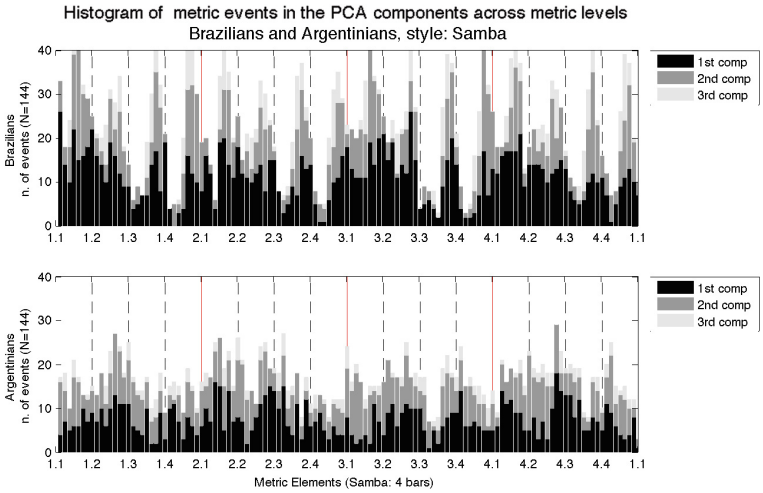

Fig. 10. Density of directional events across 1 bar (12/8), chacarera for Brazilian subjects. 10**b.** Density of directional events across 1 bar (12/8), chacarera for Argentinian subjects. The shades of grey indicate the proportion of events associated with each PCA components.

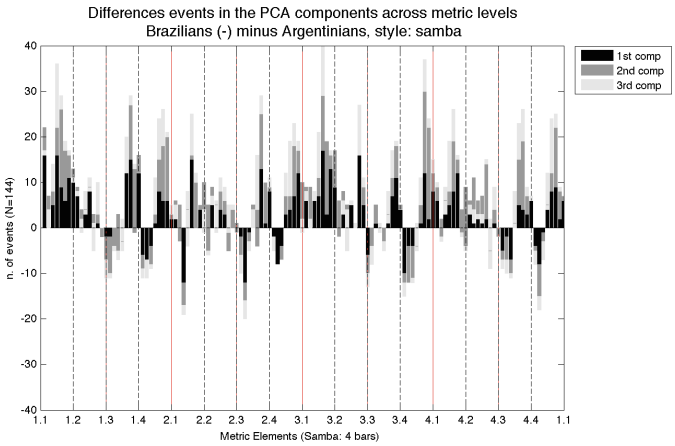

Fig. 11. Differences between densities of directional events across 2 bars (2/4), samba music, for the results of Brazilian subjects minus the results of Argentinian subjects.

musical meter by engaging into a "choreographic" motor program without clearly attuning to sharp movement changes (that generate changes of directions) as Brazilians do. 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.

4 General Discussion

In this chapter, we attempted to explore methods that are less biased by experimental control and more comprehensive to the embodied nature of musical phenomena, such as musical rhythm and dance engagement. The shift to an experimental and analytical design that is less concerned about numerical significance and hypotheses testing and more apt to the limits of ecological validity helped to reveal cultural idiosyncrasies that are less dependent on methodological assumptions and less limited by experimental control. The methods are experimental in the field of study, and, surely, many technical and conceptual issues deserve discussion and consequent improvement. However, the strategies and results might contribute both to the knowledge of cultural representations of meter and to the development of conceptual ideas about metrical models in music and dance. Even if the results encompass a small universe of musically trained individuals, they still exhibit intriguing idiosyncrasies that emerge from the exploratory analysis of the massive quantitative data resulted from the data collection.

Regarding the cross-cultural comparisons, the results show that cultural differences are reflected in the timing, the morphology of the movements and the strategy of signalization of structures of meter. Most of the unconstrained movements seem to be performed as a "line", which involves opposite movement changes (e.g.: forward-backward). Directional changes pertained to the second PCA component may indicate the emergence of movements describing a plane in space, and are present in some tendencies observed in the graphs.

The main contribution of the present study derives from the comparison between the responses of Argentinian and Brazilian participants and the kind of differences found between the musical cultures and musical structure. Brazilian subjects, for example, seem to move in a more active display and tend to delay the changes of direction in relation to metrical rules induced by music. The density of events in the same group suggests subjects' preferences to perform percussive-like gestures in relation to the metrical cues provided by music. In a different way, results of Argentinian subjects express a variable (perhaps choreographic) display of changes, but what is particularly interesting is that subjects entrain to metric segments using more accurate changes of direction in time. To the extent that the experimental settings did not include any particular constraint to shape subjects' movements, it is assumed that the resulting movement's morphology and gestural quality in both groups might be an indication of their engagement with particularities of the cultural practice of rhythm and metric in music. Further investigation, following the detail of the results reported in this study, could involve specific tests of hypothesis in experimental setups well designed for this kind of investigation. Nevertheless, more exploratory studies using robust numerical data are needed in order to provide better hypotheses for testing (for a discussion about the topic see [36]).

The discussion proposed here may also contribute with alternative methods for the assessment of metric engagement in contexts where either traditional tapping or survey techniques are not feasible (e.g.: experiments with infants or cultures that are not familiar with control tasks), or the analysis of free movement responses to music are needed. We must acknowledge that our analysis lies on the assumption that changes of direction denote subjects' enactment or embodiment of metrical accents. Even if the scope of this hypothesis is restricted to account for a full embodied engagement with metric cues in music, the recording of free movement responses simplifies data collection and provides a larger number of observations. It also facilitates the identification of characteristic features in the universe of study, the increase of sampling, and further replications of the study.

Concerning methodology, the analytical technique that was employed here 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 the evaluation, and avoid measures of centrality which, otherwise, would not be applicable due a range of assumptions necessary to avoid violations of the techniques. In this respect, responses to musical meter involve intricate interdependencies across observations in time and space. Deviations from centrality either in temporal or spatial information also cannot be considered as a result of random disturbances because they may result from culturally specific behaviours or personal intentionality (see for example [15]). Therefore, violations of assumptions about independence and homogeneity of variance would certainly make the application of traditional significance measurements unsuited (see for example the discussion presented in [37, 38], regarding human movement). Moreover, as suggested in many examples of our results, variability should be considered as a relevant form of signalization of meter and should not be underestimated given the influence of improvisation practices in Western and non-Western music.

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References

1. Honing, H.: On the growing role of observation, formalization and experimental method in musicology. Empir. Musicol. Rev. **1**, 2–6 (2006)
2. Stevens, C.: Cross-cultural studies of musical pitch and time. Acoust. Sci. Technol. **25**, 433–438 (2004)
3. Parncutt, R.: Systematic musicology and the history and future of western musical scholarship. J. Interdisc. Music Stud. **1**, 1–32 (2007)
4. Toner, P.G.: The gestation of cross-cultural music research and the birth of ethnomusicology. Humanit. Res. **14**, 85–110 (2007)
5. Beard, D., Gloag, K.: Musicology: The Key Concepts. Theatre Arts Books, New York (2005)
6. Santos, B.: Toward an epistemology of blindness why the new forms of 'Ceremonial Adequacy' neither regulate nor emancipate. Eur. J. Soc. Theor. **4**, 251–279 (2001)
7. Clayton, M.: The social and personal functions of music in cross-cultural perspective. In: Hallam, S., Cross, I., Thaut, M. (eds.) The Oxford Handbook of Music Psychology, pp. 35–44. Oxford University Press, Oxford (2008)
8. Clayton, M., Sager, R., Will, U.: In time with the music: the concept of entrainment and its significance for ethnomusicology. ESEM CounterPoint **1**, 1–82 (2004)
9. Styns, F., van Noorden, L., Moelants, D., Leman, M.: Walking on music. Hum. Mov. Sci. **26**, 769–785 (2007)
10. Desmond, J.: Embodying difference: issues in dance and cultural studies. Cult. Crit. **26**, 33–63 (1994)
11. Hanna, J.L.: To Dance is Human: A Theory of Nonverbal Communication. University of Chicago Press, Chicago (1987)
12. Sodré, M., Samba, O.: Dono do Corpo. Codecri, Rio de Janeiro (1979)
13. Browning, B.: Samba: Resistance in Motion. Indiana University Press, Bloomington (1995)
14. London, J.: Hearing Rhythmic Gestures: Moving Bodies and Embodied Minds. (2003)
15. Keil, C.: Participatory discrepancies and the power of music. Cult. Anthropol. **2**, 275–283 (1987)
16. Gerischer, C.: Osuingue baiano: rhythmic feeling and microrhythmic phenomena in Brazilian percussion. Ethnomusicology **50**, 99–119 (2006)
17. Leman, M.: Embodied Music Cognition and Mediation Technology. MIT Press, Cambridge (2007)
18. Varela, F.J., Thompson, E., Rosch, E.: The Embodied Mind: Cognitive Science and Human Experience. MIT Press, Cambridge (1991)
19. Bohlman, P.V.: Ontologies of music. In: Rethinking Music, pp. 17–34 (1999)
20. Johnson, M.: The body in the Mind: The Bodily Basis of Meaning, Imagination, and Reason. University of Chicago Press, Chicago (2013)

21. Larson, S.: Musical Forces: Motion, Metaphor, and Meaning in Music. Indiana University Press, Bloomington (2012)
22. Cross, I.: The evolutionary nature of musical meaning. Musicae Sci. **13**, 179–200 (2009)
23. Cross, I.: Music and meaning, ambiguity and evolution. In: Miell, D., Macdonald, R., Hargreaves, D. (eds.) Musical Communication, pp. 27–43 (2005)
24. Gallese, V., Lakoff, G.: The brain's concepts: the role of the sensory-motor system in conceptual knowledge. Cogn. Neuropsychol. **22**, 455–479 (2005)
25. Trevarthen, C.: Musicality and the intrinsic motive pulse: evidence from human psychobiology and infant communication. Musicae Sci. **3**, 155–215 (2000)
26. Cross, I., Morley, I.: The evolution of music: theories, definitions and the nature of the evidence. In: Communicative Musicality, pp. 61–81 (2009)
27. Malloch, S., Trevarthen, C.: Communicative Musicality: Exploring the Basis of Human Companionship. Oxford University Press, Oxford (2009)
28. Christensen, T.: The Cambridge History of Western Music Theory. Cambridge University Press, Cambridge (2002)
29. Deutsch, D.: Psychology of Music. Elsevier, San Diego (2013)
30. Sloboda, J.A.: The Musical Mind: The Cognitive Psychology of Music. Oxford University Press, Oxford (1985)
31. Krumhansl, C.L.: Cognitive Foundations of Musical Pitch. Oxford University Press, New York (1990)
32. 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 (2012)
33. Naveda, L., Martínez, I., Damesón, J., Pereira Ghiena, A., Herrera, R.: Methods for the analysis of rhythmic and metrical responses to music in free movement trajectories. In: Aramaki, M., Kronland-Martinet, R., Ystad, S. (eds.) Proceedings of the 11th International Symposium on Computer Music Multidisciplinary Research (CMMR), pp. 248–262. The Laboratory of Mechanics and Acoustics, Marseille (2015)
34. Toiviainen, P., Burger, B.: MoCap Toolbox Manual. University of Jyväskylä, Jyväskylä (2011)
35. Santos, B.: A non-occidentalist west? Learned ignorance and ecology of knowledge. Theor. Cult. Soc. **26**, 103–125 (2009)
36. Cumming, G.: The new statistics why and how. Psychol. Sci. **25**, 7–29 (2014)
37. Stergiou, N., Harbourne, R.T., Cavanaugh, J.T.: Optimal movement variability: a new theoretical perspective for neurologic physical therapy. J. Neurol. Phys. Ther. **30**, 120–129 (2006)
38. Stergiou, N.: Innovative Analyses of Human Movement. Human Kinetics Publishers, Champaign (2004)