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C14 CHAPTER 14

NON-ISOCHRONOUS METRE IN MUSIC FROM MALI

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C14.P1 The present chapter concerns the uneven subdivision of metric beats in various traditional forms of music from Mali. In this repertoire, beats are strictly isochronous, but subdivisions often seem to be governed by ratios that fall somewhere in between isochrony (1:1) and a shuffle rhythm (2:1). From the commonly accepted point of view which equates metric regularity with isochrony, such uneven beat subdivisions are generally regarded as expressive performance deviations from some underlying, structurally isochronous reference framework. Indeed, this concept of expressive microtiming variation or participatory discrepancy (Keil 1987) represents the standard interpretation of the well-researched timing of the 'swing eighths' in jazz performance (Benadon 2006; Butterfield 2011; Honing and de Haas 2008; Prögler 1995; Wesolowski 2015). By contrast, my long-term, participatory ethnographic experience with jembe-centred, dance-oriented drum ensemble music from southern Mali has convinced me that, in the context of this musical culture, uneven subdivisions, which are governed by ratios other than 1:1, may constitute temporal references structures in their own right. This chapter will (1) consider the roles that isochrony and non-isochrony play in various theories of rhythm and metre, (2) elaborate the hypothesis of non-isochronous subdivision-based metre, and (3) provide summaries of five empirical research projects that incrementally provide evidence for the hypothesis. Finally (4), I will summarize the empirical findings and discuss some of their implications for the psychology of rhythm perception, suggesting a strong role of culture and the specifics of cultural environments for perceptual capacities.

C14.S1

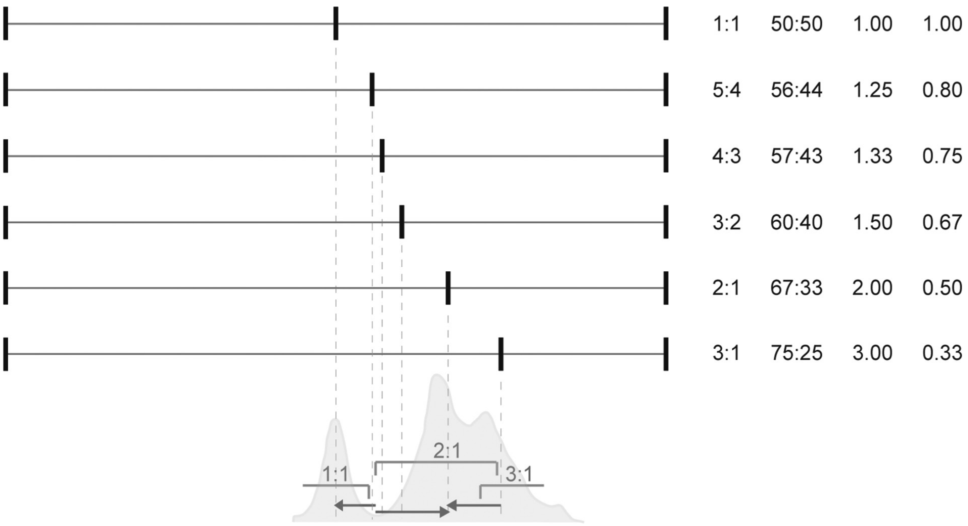
Isochrony and Non-isochrony in Theories of Rhythm and Metre

C14.P2 Most theories of rhythm and metre focus on the relative proportions between durations or inter-onset intervals. Absolute time values certainly also play strong roles in such theories, as the production and perception of rhythmic figures and metric types depend on event density and tempo (Johansson 2009; London 2012). However, the structural constituents of these figurations are typically conceived of, and symbolically represented, as temporal ratios. The specific ratios constitutive of human rhythm and metre perception are widely believed to be quite constrained in terms of their mathematical complexity. Many theories contend that rhythmic categories and their metric relationships are tied to the smallest integer ratios, 1:1 and 2:1. The former (1:1) is particularly relevant for theories of metre, insofar as a human tendency to recognize and anticipate successions of categorically isochronous durations is assumed to underpin basic metric processes, such as pulse perception.[1] This assumption that metric beat requires isochrony (i.e. successive 1:1 ratios) is not confined to theories of metre in Euro-American music (e.g. Lerdahl and Jackendoff 1983) but is also prominent in comparative (Hood 1971; Savage et al. 2015) and Africanist ethnomusicology (Agawu 2006; Arom 1984; Burns 2010; Kubik 1988; Locke 1982; 2010; Nketia 1974; Waterman 1952). The psychological theory of dynamic attending (Jones and Boltz 1989; Large and Jones 1999) suggests that humans tend to entrain to isochronous periodicities which they perceive as simple and as underlying other, more complex rhythms in their environment. Biomusicologists have argued that this tendency represents an evolved predisposition that is particularly advantageous when individual participants in social gatherings synchronize their behaviours by entraining to the same beat, as in the case of music for ritual and dance (Fitch 2012; 2013; Merker et al. 2009; Ravignani et al. 2016; Ravignani and Madison 2017). The assumption of a biological predisposition for isochrony has been reinforced by advances in neuroscience, specifically the proposition that isochronous beat and metre perception may be directly controlled by mechanisms of resonance with neural oscillations (Large 2008; Large and Kolen 1994; Large and Snyder 2009; Tal et al. 2017). In summary, the perception of isochrony is widely credited as the fundamental condition of metric beat perception.

C14.P3 The psychological theory of categorical rhythm perception further bolsters these views. According to categorical perception, our minds structure infinitely nuanced, continuous sensory spaces (e.g. light, pitch, speech) by grouping segments of the respective continua into a specific number of discrete, quasi-symbolic categories (e.g. colours, tones, phonemes). The difference between percepts *within* categories is diminished (compression), whereas it is increased at the border *between* two categories (separation): The same physical difference, such as the range between two sonic frequencies, appears larger when two percepts fall into two distinct categories than when they fall into the same one; that is, the mechanism which achieves the categorical structuring of perception consists of a warping of the perceptual space. The key function of categorical perception is to reliably and fluently identify things and events and thus endow organisms with an efficient perceptual grasp on their infinitely complex environments (Goldstone and Hendrickson 2010; Harnad 1990; Repp 1984). Music psychological research, through experimental testing of the identification a nd r eproduction of simple rhythms, has suggested that rhythm perception basically works with only two fundamental categories, even and uneven, which are characterized by prototypes near the two smallest integer ratios, 1:1 and 2:1 (Clarke 1987; Fraisse 1956; 1982; Povel 1981). More complex rhythmic structures are assumed to be constructed from these basic categories, comparable to the way Western musical staff notation is able to represent the majority of complex rhythms with symbols that basically express categorical 1:1 and 2:1 relations (additionally using diacritical marks for the apparently less fundamental ratio of 3:1).

C14.P4 An important component of the theory of categorical rhythm perception is the distinction between categorical structure and performance timing. Human performers produce both intentional and unintentional timing and tempo fluctuations. These so-called microtiming or microrhythmic variations are assumed to be perceived as the deviation of a performed rhythm from the perceptual prototype of a category, and these divergences are theorized as making rhythm more expressive, interesting, and pleasurable (Clarke 1985; 1987; 1999; 2000; Clarke and Doffman 2014; Keil 1987). A perceptual prototype is the focal representation of a category which biases the perception of all category members––a phenomenon that has been addressed as perceptual attractor (Repp et al. 2012) or magnetic effect (Feldman et al. 2009). This perceptual magnet or attractor effect has been robustly demonstrated in sensorimotor synchronization ('tapping') studies. The participants' task in this experimental paradigm is to tap along with simple rhythms in best possible synchrony. The difference between the target or pacing rhythm and response, measured either during the synchronization phase or during a continuation phase that follows after the rhythm stops being played in the participant's headphone, allows researchers to evaluate the participants' mental representation of the target rhythms. Undistorted synchronization/continuation of the target rhythm indicates that the given ratio fits the prototype of a rhythmic category in the participant's perception. By contrast, consistent distortion occurs when the pacing rhythm does not directly fit any of the participant's perceptual prototypes but is affected by the attraction of a neighbouring prototype.

C14.P5 Tapping studies found a strong bias towards a prototypical 2:1 ratio for all uneven two-element rhythms (see Figure 14.1). Higher ratios, such as 3:1, were consistently lowered towards 2:1– –i .e. the relatively sharp rhythmic contrast between the two elements was reduced. By contrast, less uneven ratios such as 3:2 were enlarged in the direc-tion of 2:1, involving an increase of the rhythmic contrast. Only the fLattest end of un-even rhythms was further straightened out towards 1:1 (see e.g. Essens and Povel 1985; Jacoby and McDermott 2017; Povel 1981; Repp et al. 2005; 2011). The participant groups used in these studies included highly trained musicians; the perceptual bias towards 2:1 thus does not seem to depend on degrees of musical skill and expertise. However, all



C14.F1 **FIGURE 14.1** Upper part: Selection of small-integer ratios illustrating various two-element rhythms, given in four different formats (from left to right): small-integer ratio, percentages of the period, quotient of the long-short ratio, and quotient of short-long ratio. Lower part: Schematic representation of the perceptual categorization of the space of two-element rhythms according to the current state of research. Arrows roughly summarize the main biases found in classical tapping studies using Western listeners (e.g. Povel 1981; Essens and Povel 1985; Repp et al. 2005, 2011). The histogram shows the distribution of participants' stabilized responses in a recently developed iterative tapping paradigm (taken from Jacoby and McDermott 2017, Figure S1). Horizontal brackets schematically indicate categories suggested by this research, with prototypes at 1:1, near 2:1, and near 3:1. Adapted from Polak et al., 2018, Figure 1.

participants were from Western Europe or North America, suggesting that a Western cultural bias might play a role.

C14.P6 In conclusion, an impressively broad cluster of theories support the conclusion that the smallest integer ratios, 1:1 and 2:1, are of fundamental importance as the perceptual primitives from which more complex rhythmic and metric structures are constructed.

C14.P7 However, theories of rhythm and metre do not form a monolithic block in this respect. For instance, Justin London's metric theory allows for a degree of non-isochrony in metric pulse-trains, and proposes that this degree of non-isochrony is limited by the mathematical principle of maximal evenness, which requires that a given number of beats must be distributed in a given span of a subdivision cycle in the most evenly distributed way that is available (London 2012). Thus, three metric beats in the context of a cycle spanning seven subdivisions need to be distributed as 3:2:2 (or one of its rotations, 2:2:3 or 2:3:2) to be perceivable as a metric pulse-train; by contrast, 4:2:1 or 3:3:1 would violate this constraint on metric well-formedness. Maximally even non-isochronous beat cycles such as 2:2:3 do exist and function as main metric reference level, for instance in dance music from the Balkans (Goldberg 2017). While metric types of this kind typically appear odd, irregular, and difficult from the perspective of most Western European and

North American theorists, musicians, and listeners alike, cross-cultural experiments have demonstrated that enculturated listeners familiar with music from the Balkans, North Africa, and Turkey, among others places, do not necessarily find them more difficult to perceive than isochronous metres (Drake and El Heni 2003; Hannon et al. 2012; Kalender et al. 2013; Yates et al. 2017). Importantly, Western infants at the age of six months are equally well disposed to perceive isochronous and non-isochronous metres. This finding suggests that the bias towards isochronous metres shown by Euro-American 12-month-old infants, children, and adults, which increases in stability with age, is a result of their specific enculturation in a musical environment that privileges isochronous metre, and is not a biological disposition (Hannon and Trehub 2005a; 2005b). Studies that thus productively integrate cross-cultural and developmental perspectives are highly relevant insofar as they directly contradict the near-axiomatic assumption that the widespread usage of 1:1 and 2:1 as basic building blocks for temporal reference structures arises from a universal constraint limiting the usage of more complex ratios. Perhaps the most radical questioning of theories that assume categorical isochrony underlying pulse and metre originates from studies in Scandinavian folk-dance music, which demonstrate the simultaneous co-occurrence of non-isochronous timing patterns at both the beat and the subdivision levels (Johansson 2017; Kvifte 2007). This casts doubts on the argument that an isochronous fastest pulse is cognitively necessary in order to provide a common denominator to which all events in a rhythmic surface can be mapped. Alternatively known as 'density referent', 'fastest pulse', or 'elementary pulse' in ethnomusicology (Hood 1971; Koetting 1970; Kubik 1988; Nketia 1974) and 'metric floor' in music theory (London 2012), this concept is required for London's explanation of the well-formedness of non-isochronous beat-cycles by the principle of maximal evenness, which assumes a common greatest divisor for coordinating the maximally even distribution of uneven beats. However, no such isochronous common greatest divisor is available for metric perception when the metric floor itself is structurally non-isochronous. Non-isochronous subdivision thus represents a critical test case for the perceptual possibility of non-isochronous metre. Its existence would challenge not only Euro-American music-theoretical concepts, and not only theories of isochronous metre, but also ethnomusicological theories of African rhythm, and current pulse-based theories of non-isochronous metre. The jembe ensemble music of Mali provides many examples of non-isochronous subdivision patterns, and this music provides the empirical basis for the hypothesis being proposed here.

C14.S2 The Hypothesis of Non-isochronous Subdivision-Based Metre

C14.P8 Non-isochronous beat subdivisions occur in a broad array of genres and styles from Mali and neighbouring countries. For example, *Video Sample 1* features a trio recording of jembe-centred drum ensemble music. (The video is accessible on the handbook's accompanying website ▶.) The ensemble features two goblet-shaped jembe drums, played with bare hands, and one dundun, a cylindrical drum, beaten with a stick. The first jembe serves as the lead drum, which controls the intensity and extemporizes the musical form of the piece in performance; the second jembe's accompaniment provides time-keeping, metric density, and feel by a simple ostinato; and the dundun contributes a repertoire-specific timeline and hook pattern. The ensemble is led by Jeli Madi Kuyate, a senior percussionist retired from the state-sponsored Ballet National du Mali. Internationally acclaimed drummer Drisa Kone plays the second jembe, and their long-time ensemble co-performer Madu Jakite plays the dundun. These three professionals were apprenticed to the same master, and have performed together since the 1970s. The video features the opening 30 seconds of a recording of a piece called 'Wolosodòn' or 'Jòndòn', which means 'serfs' dance' or 'captives' dance', relating to the subaltern social strata of unfree folk in the feudal precolonial past. 'Wolosodòn' is part of the core repertoire of standard pieces for jembe music in Bamako, the capital of Mali. In what follows, I provide a brief analysis that includes information on subdivision timing ratios.

C14.P9 The lead drummer, Kuyate, opens the piece by establishing the second jembe's accompaniment pattern, a long–short ostinato with a timbral melody spanning two beats. Open tones and bass tones in alternation mark the onbeat positions, while a slap on each upbeat adds timbral accent to this metric position and thus gives anacrustic drive to the rhythm. On average, the long and the short element in each beat relate by a ratio of 57:43 (percentage of the beat duration) or 4:3. There is only minimal variation to this average, as the individual ratios fall within a very narrow range (56:44–59:41). It is a straightforward and conventional way for a lead drummer to call up a piece by taking on the accompanist's pattern. The second jembe player, Drisa Kone, therefore almost immediately (near the end of Cycle 1) takes over 'his' pattern from the lead drummer. He adopts the timbre sequence and rhythmic figure as well as Kuyate's timing profile with remarkable precision: Kone's mean subdivision ratio on the second jembe is also 57:43, and the variability in his timing throughout the excerpt is as small as Kuyate's; the standard deviation from the mean value amounts to no more than about 1%.

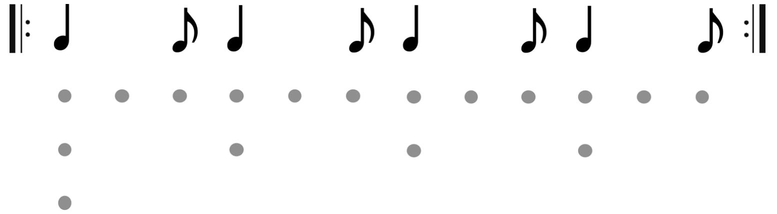
C14.P10 Immediately after the dundun's entry in Cycle 2, the ensemble synchronization appears very tight. In Cycle 3, lead drummer Kuyate starts soloing by unfolding a line of slaps, still in a lightly swung two-element rhythm very close to the accompaniment. This choice of a still super-simple rhythm speaks of an unpretentious attitude, of containment and control; many other players would have chosen some more complex rhythm here. Yet this does not mean that Kuyate refrains from sophistication. He plays all slaps in that series with his stronger, right hand and uses the left one to gently muffle the membrane in between the note onsets, thus softly dampening the harmonics and muting the decay of each slap. The effect is somewhat comparable to an electric guitarist's pumping the wah-wah pedal in time with an eighth note beat. It is a soft effect, yet of considerable appeal among jembe players; in the specialists' discourse and performance practice, it is iconic of old-school playing and associated with the liveliness of a 'breathing' or 'speaking' jembe sound. Kuyate adds to the expressivity of the phrase by flattening the swing ratio to 54:46, which he will later repeat with pinpoint exactitude when he comes back to the same motive in a slightly longer phrase, in Cycles 8 and 9. The timing thus emerges to represent a systematic treatment of the respective phrase. The local flattening of the swing ratio lets the upbeat strokes deviate only minimally from the prototype of 57:43, amounting to differences in the concerned durations of around (a hardly perceptible) 15 ms. As minuscule as this contrast appears, it adds some nuance to the anacrustic momentum of the rhythm.

C14.P11 In the first half of Cycle 4, lead drummer Kuyate lets up on his drum for a second and speaks out in honour of his late jembe master (Yamadu Dunbia, 1917–2002), who was of Woloso descent himself and had played 'Wolosodòn' as his signature piece; the other players nod their heads in consent. In the second halves of Cycles 4 and 5, respectively, Kuyate puts out a motif which for the first time in this performance manifestly realizes a 'triplet feel' or, ternary subdivision. His ternary rhythm still sounds fully consonant with the second jembe's ostinato and the dundun's hook, and this is because his triplet subdivisions also show a periodic pattern of non-isochronous subdivision, namely short–medium–long, with a ratio of about 22:35:43 on average. The lead drummer's third triplet stroke and the accompanist's shuffle second stroke receive the same percentage of the beat-span (43%), and the strokes occur with a high degree of simultaneity. In Cycles 6 and 7, Kuyate presents two turns of a phrase which features triplets similar to those of Cycles 4 and 5, which he combines with an extra stroke towards the end of each cycle suggesting a roll, i.e. a rapid ornamental figuration beyond metric perception. In Cycles 8 and 9, the lead-drummer comes back to a two-element long–short rhythm almost identical to the one played earlier in Cycle 3.

C14.S3 Listening Options Based on Categorical Isochrony

C14.P12 The timing of the beat subdivisions in Video 1 poses problems to conventional theoretical perspectives. When listened to in isolation, a two-element rhythm with a ratio of 57:43 can perhaps be heard as an expressive variation of a duplet rhythm based on an isochronous binary subdivision. However, this listening would clash with the frequent insertion of triplets; in particular, it could not account for the smoothness with which triplets appear to be embedded in the polyrhythmic surface of 'Wolosodòn'.

C14.P13 Alternatively, the accompaniment ostinato may be heard as a shuffle rhythm, in which the two sounds are perceived as mapped onto the first and third elements of an underlying isochronous ternary subdivision of the metric beat (see Figure 14.2). While this accounts for the insertion of triplets, the 57:43 performance timing of the second jembe's ostinato would still represent a massive deviation from this perspective's 2:1 (67:33) expectation. Moreover, according to categorical rhythm perception theory, the 57:43 timing, which falls right midway between 1:1 (50:50) and 2:1 (67:33) and thus can be assumed to lie near the boundary between the two categories, should induce a strong degree of perceptual ambiguity or conflict in the listener. Studies of African American styles of popular music have suggested exactly this when they described comparable



C14.F2 **FIGURE 14.2** Shuffle rhythm in Western staff notation (top tier) mapped to a metric cycle (bottom row) of four beats (second row from bottom) with ternary subdivision (third row from bottom).

subdivision timings as 'playing between the cracks' (Doleac 2013) or 'nervous' and 'hybrid' (Stewart 2000). In fact, I felt such ambiguity myself when listening to 'Wolosodòn' and comparable rhythms in Mali during my initial years of engaging with this music. Today, I feel no ambiguity or tension when listening to 'Wolosodòn'––it sounds perfectly consonant and organic to my ears. Seemingly, at some stage of my career I learned to perceive the piece differently according to how my own playing was evaluated by my masters in Mali and my students in Germany. It appears that much of this enculturation occurred during my one-year apprenticeship in Bamako in 1997–8, when I performed the role of accompanist on the second jembe several times per week at weddings, spirit possession ceremonies, and other social and ritual occasions, playing simple ostinatos, always loud and often fast, for hours.

C14.P14 The subjective listening experience set out above is consistent with more objective long-term ethnographic observations I have made in Mali. For instance, I have frequently observed that non-isochronous subdivision timing patterns were performed not only by skilled instrumentalists but also by the many young children who frequently sit close to dance celebrations and imitate the specialists by playing on toy drums. Importantly, I have never seen any performance of a piece based on non-isochronous subdivisions fall back to an isochronous version, as one might expect in situations that demanded reduced complexity. For example, there are situations where an ensemble of novice apprentices shows difficulties in ensemble synchronization or a teacher struggles to convey a specific subdivision timing pattern to European students. I witnessed plenty of such cases, yet actually never heard any Malian drummer perform 'Wolosodòn' based on anything close to a plain shuffle and evenly spaced triplets, which would be the simplest and safest, most regular thing to do from a Western isochronous metre perspective (though not necessarily the most exciting!). (Audio samples 1-A/B provided at the accompanying website demonstrate how a typical phrase for 'Wolosodòn' would actually sound when based on isochronous versus non-isochronous subdivision grids.)

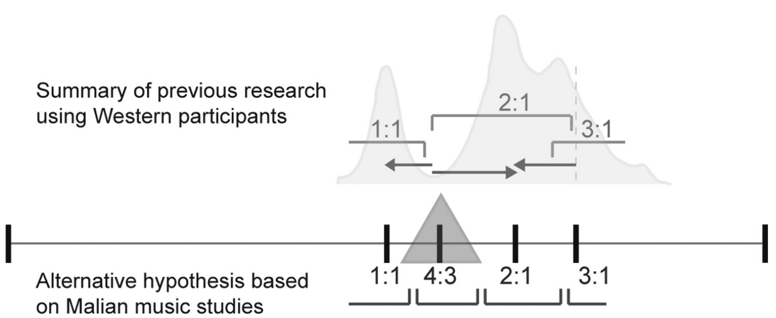
C14.P15 To conclude, it seems implausible to conceive of a performance timing pattern such as the 57:43 (4:3) ratio in the accompaniment for 'Wolosodòn' in Video sample 1 as a deviation from an isochronous reference structure, because the hypothetical isochronous prototype in this case would represent an extreme outlier to the actual performance timings. While it is not necessary for the prototype of a category to lie exactly midway in the respective segment of the perceptual space, it can be expected to lie *somewhere* in its more intensely used interior, but not at its unpopulated fringes.

C14.S4

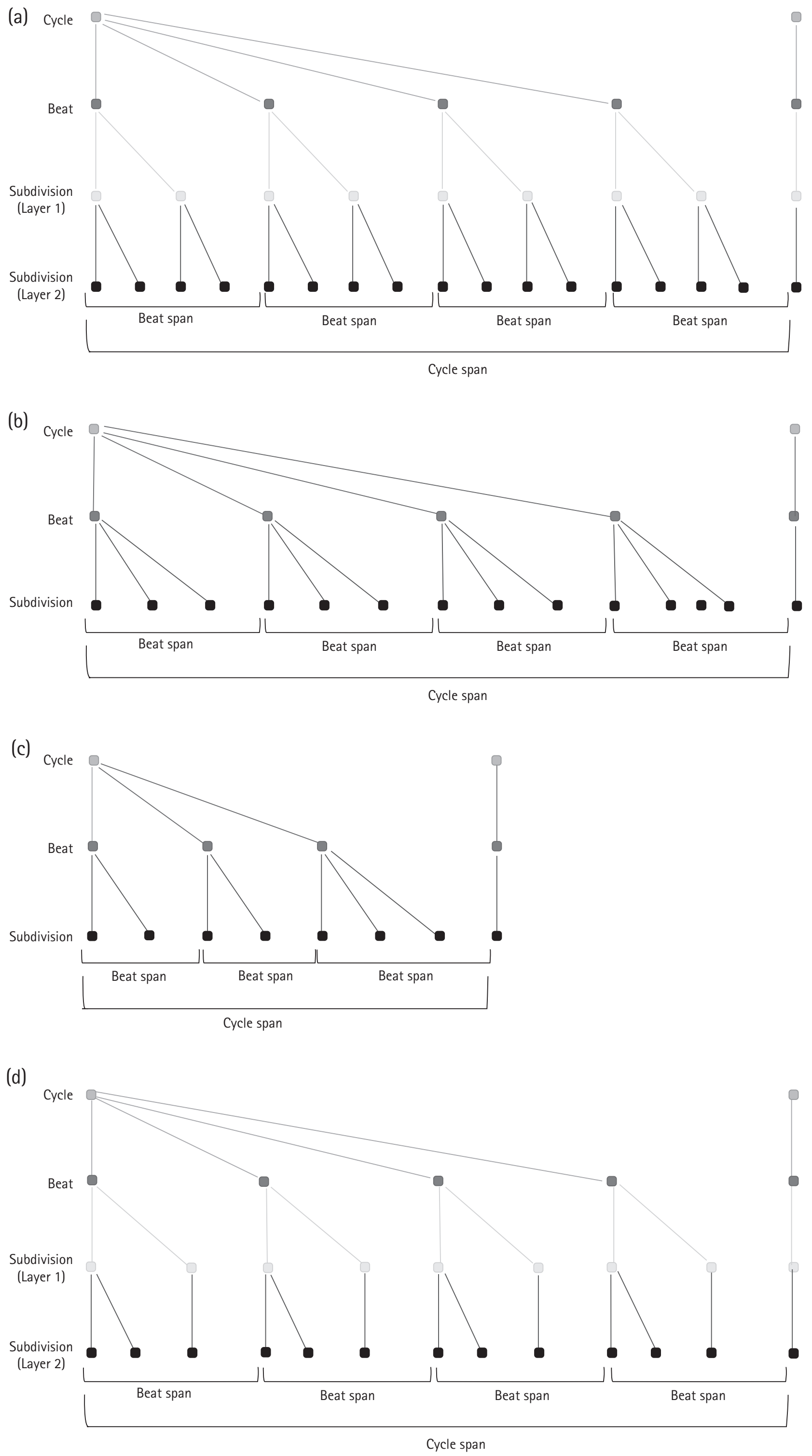
An Alternative Model Allowing for Categorical Non-isochrony

C14.P16 In light of these problems with listenings based on categorical isochrony, I propose the alternative hypothesis: that a complex ratio such as 57:43 (4:3), falling between the categories of 2:1 and 1:1, can constitute a distinct rhythmic category of its own. I further hypothesize that non-isochronous beat subdivisions related by such complex ratios, if consistently organized in recurrent patterns, can serve as metric temporal reference structures. Figure 14.3 shows how this hypothetical separate category would fall in a range of ratios where Western participants display a significant gap indicative of perceptual ambiguity at the border between the 1:1 and 2:1 prototypes. The ratios in this range have been conceived of as irregular and thus difficult and problematic, if not explicitly unmusical, in European and Euro-American theories of music since antiquity.[2]

C14.P17 A metric type based on a rhythmic prototype such as 4:3 at the subdivision level would challenge some fundamental assumptions widely held in metric theory. Figure 14.4 illustrates this novelty by comparing hierarchic tree representations of four different metric types. Figures 14.4a and 14.4b represent two common types of isochronous metre which are both based on a four-beat cycle. The type in 14.4a is qualified by two layers of binary beat subdivision (4/4 in Western staff notation), whereas the type in 14.4b has one layer of ternary subdivision (12/8). A listening of ‘Wolosodòn’ (Video 1) based on categorical isochrony, as sceptically discussed above, would suggest the latter metric type (12/8). In these two metric types, pulse-trains at both the beat and the subdivision levels consist of isochronous elements throughout. Consequently, the pattern of bifurcation in the hierarchical structure is strictly periodic; each pulsation at the same



C14.F3 **FIGURE 14.3** Upper tier: Schematic representation of the perceptual categorization of the space of two-element rhythms according to the current state of research (repeated from Figure 14.1). The lower tier indicates the alternative hypothesis of an additional category with a prototype at about 4:3. Adapted from Polak et al. (2018: fig. 1).



C14.F4 **FIGURE 14.4** Schematic illustrations of hierarchic trees of selected metric types. A. Isochronous 4-beat metric cycle with two layers of isochronous subdivision, binary and quaternary. B. Isochronous 4-beat cycle with one level of isochronous ternary subdivision. C. Non-isochronous 3-beat cycle (short–short–long) with one level of isochronous 7-element subdivision. D. Isochronous 4-beat cycle with two levels of non-isochronous binary (long–short) and non-isochronous ternary subdivision (short–medium–long).

metric level is subdivided by the same number of pulsations at the faster level. Standard accounts of metric theory suggest that these qualities represent essential preconditions for metric pickup and stable coordination.

C14.P18 By contrast, the metric types in Figure 14.4c and 14.4d include non-isochronous pulse-streams. Figure 4c outlines a non-isochronous three-beat cycle with a seven-element subdivision, typically notated as 7/8. This metric type is popular in music from the Balkans among other places, and was used as a prime example in the aforementioned studies of non-isochronous beat cycles (Goldberg 2017; Hannon et al. 2012). Finally, Figure 14.4d illustrates my hypothesis of non-isochronous metre in music from Mali in the example of a metric cycle of four isochronous beats with two levels of non-isochronous subdivision, one binary (long–short), and the other ternary (short–medium–long). This is how I hear 'Wolosodòn' (Video Sample 1), for instance.

C14.P19 In the two non-isochronous metric types (C and D), the structure of hierarchic coordination of pulse-trains varies in the course of the cycle. In type C, the first and second beats are bifurcated into two subdivisions, whereas the third one hosts three; in type D, the first pulse at the first subdivision level is bifurcated into two subdivisions at the second level, whereas the second pulse at the first level remains un-bifurcated. While these patterns appear simple, they are complex when compared to the strict periodicity of hierarchical coordination in isochronous metres. This complexity notwithstanding, the layers in the non-isochronous metric hierarchies (C and D) are as fully nested into each other as they are in the isochronous types (A and B).

C14.S5 Empirical Evidence

C14.P20 Arguably, the hypothesis of non-isochronous subdivision based metre illustrated in Figure 14.4d could elegantly explain the performance practice exemplified in Video Sample 1. However, the hypothesis contradicts the assumptions of strict isochrony and periodic bifurcation as fundamental preconditions of metre perception. I have therefore engaged in a series of five empirical research projects to provide evidence that would enable an evaluation of the hypothesis. This section offers concise summaries of the key findings of these studies. The order is chronological, yet at the same time displays a developing trajectory of methodologies, from performance-timing analysis to controlled laboratory experiments, from qualitatively grounded and exploratory to quantitative and hypothesis-testing approaches, and from individual to collaborative research workflows.

C14.S6 Study 1: Performance Timings of Jembe Drumming from Mali

C14.P21 Study 1 comprised an empirical performance-timing analysis based on a corpus of multi-track live ensemble recordings, an approach applied for the very first time to music from Mali (or indeed anywhere else in Africa). Over the course of fieldwork conducted in 2006 and 2007, I hired five different ensembles of experienced jembe and dundun players for open-air studio sessions both in Bamako and in two villages in the rural area to the south of the capital. Using a portable digital multi-track machine, we recorded about 180 takes of over 20 pieces of repertoire. A clip-on microphone attached to each drum created a separate audio track of each ensemble member's playing, which involved only a little acoustical crosstalk from the neighbouring instruments and thus allowed precise identification of the onset timings of the drum-strokes constituting the composite ensemble polyrhythms.

C14.P22 In all analysed performances, the beat-span turned out to be isochronous. Three cardinalities of beat subdivision were found in the repertoire (binary, ternary, and quaternary), and each of these subdivision types occurred with stable non-isochronous timing patterns in most of the pieces. The relation between subdivision timing pattern and repertoire emerged very clearly: for most pieces, the pattern of subdivision timing proved invariant, as if it were 'written' into the composition. The in-depth analysis of several recordings of a piece called 'Manjanin', which features a pattern of non-isochronous ternary beat subdivision (short–medium–long), demonstrated that such timing patterns can occur with an amazing degree of consistency. It proved stable across five parameters, namely:

C14.P23 1. different recordings by different rural and urban ensembles;
C14.P24 2. different recordings of the same ensembles;
C14.P25 3. different instruments (jembe versus dundun) involving different playing techniques and motor skills;
C14.P26 4. different musical roles (lead, timeline and accompaniment) involving different phrase types and rhythmic structures;
C14.P27 5. a wide range of tempos. (Polak 2010)

C14.S7 Study 2: Performance Timings of Other Styles of Drumming from Mali

C14.P28 The second project took up the methodology developed in Study 1 and expanded the scope from jembe music to two other traditions of ensemble drumming––the distinct drum ensembles, repertoires, and styles of two ethnolinguistic groups from central and western Mali (Bamana and Khasonka, respectively). In the two respective corpuses of recordings made in 2012, about half the pieces consistently showed non-isochronous subdivision timings, and the patterns and the degree of consistency with which they were performed turned out to be very similar to those found in jembe music. Moreover, detailed analyses of two pieces suggested that non-isochronous timing patterns can occur simultaneously in two nested layers of beat subdivision. One of those two pieces nests a binary long–short pattern into a ternary short–medium–long subdivision, very much like the jembe piece 'Wolosodòn' exemplified in Video 1 and modelled in Figure 14.2. The nesting of both levels of subdivision turned out to be highly systematic and almost perfectly accurate, meaning that the second binary and the third ternary subdivision onsets consistently occur nearly simultaneously. The other piece analysed in detail entails a first layer of ternary subdivision timed according to a long–short–short pattern and a second, quaternary layer patterned short–short–long–long. Here, too, the second level of subdivision is constructed through the further bifurcation of only one element at the first level––the long one (Polak and London 2014). In other words, the quality of non-isochrony in some pieces of Malian drum ensemble music is recursive across metric levels.

C14.S8

Study 3: Timing Variability and Ensemble Synchronization in Jembe Drumming

C14.P29 The third project was a data-intensive, computational repeat study of 15 recordings selected from the corpus made in the context of Study 1. In contrast to Studies 1 and 2, which relied on analysing the onset timings of a limited number of typical phrases, in Study 3 we extracted the onset timing for each drum stroke of all players in each of the 15 recordings in the corpus, amounting to about 40,000 time-points, each representing the onset of an individual drum stroke. This allowed us to confirm on statistical grounds the key findings of Studies 1 and 2, namely the near-perfect isochrony of the beat-span in all pieces and the high degree of consistency and stability in the subdivision timing patterns for each individual piece. The variability of the timings in the two non-isochronous pieces in the corpus ('Wolosodòn' and 'Manjanin') proved not to be significantly higher than in the third, isochronous piece that we had included for comparison. Moreover, the analysis of microrhythmic asynchronies amongst the onsets of different ensemble members in the same metric positions indicated that the quality of ensemble synchronization was extremely tight in all three analysed pieces. Importantly, we did not find a significant difference between the isochronous and non-isochronous pieces in this respect (Polak et al. 2016).

C14.S9

Study 4: A Listener Test of Subdivision Timing Patterns in Jembe Music

C14.P30 The fourth project involves experimental listener tests. We selected two typical phrases from recordings of the jembe piece 'Manjanin' (cf. Studies 1 and 3), and created realistically sounding versions of these phrases based on manipulated subdivision timing patterns, including the original one (short–medium–long) as well as isochronous and inverted ones (long–medium–short).

C14.P31 We presented hundreds of pairings of two (identical or different) manipulations, and asked drummers and dancers in Bamako, who had much experience of the piece, (1) whether the two versions in a pair were, first, the same or different, and (2) which version was the better representation of the piece. There were no differences between the drummer and the dancer groups, and both responded identically. Participants reliably recognized almost all manipulations as same or different, but performed quite poorly at discrimination between versions based on the patterns short–medium–long and short–long–long. In the preference task, the version based on the original subdivision timing pattern (short–medium–long) together with the perceptually identical one (short–long–long) gained the highest score, whereas other manipulations were ranked increasingly lower as their difference from the original became more pronounced. For example, the version based on an isochronous subdivision earned considerably lower ratings than the original, and the version based on a reversed sequence of non-isochronous elements (long–medium–short) scored substantially less. In summary, our groups of enculturated participants displayed an aesthetic ideal of preference for a subdivision pattern modelled after the style-specific performance practice (Neuhoff et al. 2017).

C14.S10 Study 5: A cross-cultural listener test of context-free simple rhythms

C14.P32 Study 5 used the experimental paradigm of finger-tapping, presenting simple rhythms without melodic or other context to participants whose task was to tap along to the given rhythms on a little percussion instrument in best possible synchrony. We tested jembe drummers in Mali, musicians (mostly percussionists specializing in Western art music) in Germany, and folk musicians as well as musicians trained in Western art music in Bulgaria. At a slow tempo, where the pacing rhythms could be expected to be perceived as representing the metric beat level, we replicated key findings of previous research (see Figure 14.1). All participant groups reliably reproduced the 1:1 ratio but, in the case of uneven rhythms, showed a strong bias toward the 2:1 ratio; they softened a 3:1 pacing stimulus and sharpened a 3:2 stimulus, involving a distortion in the direction of 2:1 in both cases. However, the Bulgarian folk musicians responded to the 3:2 stimulus with a slightly smaller degree of distortion than the other groups, which correlates with the fact that 3:2 rhythms feature prominently in some genres of Bulgarian folk-dance music at tempos such as the one used in the stimuli.

C14.P33 At a fast tempo, which affords perception of the pacing rhythms as subdivisions of an isochronous beat, we found that all tested groups exactly reproduced a 1:1 stimulus and performed quite well on a 2:1 rhythm, but strongly diverged in their response to a 58:42 (approximately 4:3) stimulus. The German and both Bulgarian groups massively distorted this complex ratio towards 2:1, whereas the Malians reproduced it with near-perfect fidelity. This suggests that the Malian musicians—but not the Bulgarian and

German musicians—have a perceptual rhythmic category whose prototype lies in the vicinity of 4:3 (Polak et al. 2018).

C14.S11

Summary and discussion

C14.P34 This chapter has evaluated the hypothesis that in the context of drum ensemble music from Mali, non-isochronous beat subdivision patterns constitute a structural aspect *of* rhythm and metre rather than representing an expressive timing deviation *from* these temporal reference structures, as established theories of rhythm and metre in music suggest. I have presented various kinds of empirical evidence. First, performance timing analyses of various styles of dance drumming from Mali suggested that the performance of isochronous and non-isochronous subdivision timing patterns alike is characterized by qualities of consistency, stability and intersubjective coherence (Studies 1–3). This is inconsistent with the assumption that 1:1 and 2:1 represent the only available perceptual prototypes. The latter assumption would predict that the non-isochronous patterns in question, which fall about midway 1:1 and 2:1, will induce perceptual ambiguity, structural instability, and increased degrees of variability, flexibility, and contingency in the performance timings. Our performance timing analyses systematically belie this prediction. Secondly, we found that patterns of non-isochronous subdivision can occur recursively across two smoothly nested layers of subdivision, where the second layer is constructed from the bifurcation of exactly one element in the first one––the longest one (Study 2). This suggests that the pattern of uneven subdivision timing in one layer is used as a perceptual reference framework for the timing of the other. A third type of evidence came from two psychological experiments that tested how musicians in Mali perceive non-isochronous beat subdivision patterns. Study 4 suggested that the same rhythmic figures based on different subdivision timing patterns involve structurally different percepts, and found a clear aesthetic preference for the original patterns that are used in the specific repertoire's performance practice. However, while the original performance timing patterns consist of three different durational elements (e.g. short–medium–long), the experiment suggested that the medium category is hardly perceptible, and the subdivision structure thus can be constructed from only two durational classes in the listeners' perception (short–long–long). In other words, whereas subdivision timing patterns in general *are* perceptually and aesthetically salient, not *all* aspects of the timing patterns that can be measured in performances contribute to this relevance; for instance, the medium category of the short–medium–long pattern that can be found in many performances does not. Study 5 demonstrated that Malian musicians have a separate perceptual prototype for categorical rhythm perception at approximately 4:3, i.e. exactly midway between 1:1 and 2:1. The findings of Studies 4 and 5 directly contradict important counter-arguments against the hypothesis, namely, that subdivision timing patterns based on complex ratios are either perceptually irrelevant or substantially detrimental to the perception of rhythmic and metric structure due to universal cognitive constraints.

C14.P35 To summarize, there is diverse and robust evidence in support of the hypothesis that uneven subdivision patterns can constitute rhythmic and metric reference structures. Demonstrably, these patterns do not appear irregular in the perception and evaluation of enculturated listeners. Let me end the chapter by considering some of the implications of this finding for our broader understanding of how our perceptual capacities are shaped by the cultural environment in which we grow up and dwell. Study 5 (Polak et al. 2018) revealed two important qualifications regarding the finding that a somewhat complex ratio such as 4:3 can constitute a perceptual prototype for categorical rhythm perception. First, only musicians in Mali, who prominently use ostinato rhythms based on the same ratio in their style- and repertoire-specific performance practice, appear to have this category; other musicians, who have been socialized in musical cultures that do not prominently use the respective ratio, do not show the category, regardless of the musicians' expertise or the sophistication of their musical culture. Secondly, the Malian group displayed the category only in response to stimuli that were presented in the fast tempo typical of the beat subdivisions that feature the 4:3 ratio in their performance practice, and not in response to stimuli presented at a slower tempo that is typical of beat rates rather than of subdivision rates. Taken together, those two correlations between style-specific performance practice and perceptual prototypes suggest a strong role of the music-cultural environment in framing links between performance and perception prototypes. Evidently, the Malian musicians' perceptual capacity for non-isochronous subdivision-based metre is not a cognitive universal; our research suggests that instead they have developed this specific capacity in their music-cultural environment.

C14.P36 This finding aligns with recent propositions that the temporal reference framework within which rhythmic structure is constructed, and from which expressive deviations are perceived, is constituted not primarily by symbolic systems (e.g. a score) nor by universal cognitive constraints, but rather by statistical inference from actual performances of repertoires and styles frequently practised and perceived in one's music-cultural environment (Honing 2013; Leech-Wilkinson 2009; Pearce 2018; van der Weij 2020; van der Weij et al. 2017). More generally, this finding is also consistent with views from the ecological theory of perception on perceptual learning (Gibson 1963; 1969; Gibson and Gibson 1955; Goldstone 1998; Goldstone and Hendrickson 2010; Goldstone et al. 2010; Goldstone et al. 2015), as well as with the concept of 'perceptual narrowing', which describes processes of environment-dependent unlearning of generic perceptual capacities.

C14.P37 An exemplary case is speech perception. While very young infants can distinguish speech sounds which are not necessarily used in their mother tongue, the capacity for categorical phoneme perception by older infants, children, and adults increasingly focuses on those phonemes which are used in the mother tongue, to the cognitive detriment of other phonemes (Maurer and Werker 2014; Werker 1995). Erin Hannon and Sandra Trehub have found equally fluent perception of isochronous and non-isochronous beat cycles by very young Western infants, yet a perceptual privileging of isochronous beats is observable from the age of one year and tends to increasingly stabilize with age (Hannon and Trehub 2005a; 2005b). Adults' perceptual capacity to fluently process non-isochronous metre seems to depend on its being used in musical performance and listening practices (Hannon et al. 2012), and it becomes impoverished in the context of musical cultures which do not frequently use non-isochronous pulse-streams. Importantly, this demonstrates that the perceptual bias towards isochrony found in Western listener groups is due to their *specific enculturation* rather than a universal cognitive predisposition (Hannon 2010), as much as the Malian participants' special perceptual capacity for non-isochronous subdivision is the result of an increasing ability to perceptually differentiate the diverse stimuli that *their* music-cultural environment has to offer. This is inconsistent with the nativist assumption that a bias towards isochrony is culturally universal because of a biological constraint on human cognition. The wide spread of this assumption may instead indicate a Western cultural bias in scholarly and scientific accounts of rhythm and metre.

C14.S12 Acknowledgements

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C14.S13 Accompanying media files

C14.P39 Video sample 1. Trio performance of Woloso. Jeli Madi Kuyate: first jembe (stereo position: centre); Madu Jakite: dundun (left; out of sight); Drisa Kone: second jembe (right).

Recorded in Bamako, January 2006, by the author. The recording is primed by two artificial clicks giving the beat tempo before the first jembe starts on Beat 3 of Cycle 1.

C14.P40 Audio sample 1-A and 1-B. Synthesized renditions of a typical phrase for 'Wolosodòn', modeled after the triplety phrase played in Cycles 4 and 5 of Video sample 1. The two versions were constructed by Nori Jacoby from single-note instrument sounds played and recorded by the author; both are quantized to a metric grid, which entails that they do not contain timing variations within the ensemble parts nor asynchronies amongst ensemble parts. They thus allow for a fair comparison of the subdivision timings, which are non-isochronous (23:35:42) in 1-A and isochronous (33% per element) in 1-B.

Notes

1. The concepts of 'beat' and 'pulse' largely overlap. I term 'pulse' any stream of felt metric pulsations, independently of which layer in the metric hierarchy this pulse would represent. By contrast, I reserve the concept of beat for metric pulse-streams that constitute the middle level in a hierarchy of three metric layers (cycle, beat, subdivision), whereas the beat subdivision represents the lowest/fastest layer in that hierarchy.
2. I am grateful to David Cohen (pers. comm., 18 Sept. 2018) for providing me with information on Aristoxenus of Tarentum addressing the ratios falling between 2:1 and 1:1 as 'irrational' or 'arrhythmic' in his fragment *Elementa rhythmica* (4th century BC).

C14.S14
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