Perception and Evaluation of Timing Patterns in Drum Ensemble Music from Mali

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Polak's (2010) chronometric analyses of Malian jembe music suggested that the characteristic "feel" of individual pieces rests upon nonisochronous subdivisions of the beat. Each feel is marked by a specific pattern of two or three different subdivisional pulses—these being either short, medium, or long. London (2010) called the possibility of more than two different pulse classes into question on psychological and theoretical grounds. To shed light on this issue, 23 professional Malian percussionists and dancers were presented with timing-manipulated phrases from a piece of Malian drumming music called "Manjanin." In a pairwise comparison experiment, participants were asked: (1) if the items of each pair were same or different, and (2) if different, which of the two was the better example of the characteristic rhythm of Manjanin. While most contrastive pairs were well distinguished and produced clear preference ratings, participants were unable to distinguish short-medium-long patterns from short-long-long patterns, and both were preferred to all other manipulations. This supports London's claim that, perceptually, there are only two pulse classes. We discuss further implications of these findings for music theory, involving beat subdivision, tempo effects, microtiming, and expressive variation, as well as methodological issues.

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Psychologically oriented theories of musical meter (Lerdahl & Jackendoff, 1983; London, 2012) aspire to articulate universal principles of musical structure. Accordingly, "well-formed" rhythmic and metric structures, while they may be determined by specific cultural practices, are also constrained by a number of psychological mechanisms, such as rate limits for temporal information, Gestalt laws of grouping, the limitations of working memory, the need for categorical perception, and others. While the concept of the beat (or tactus) enjoys an uncontested status as a universal feature of metrical music in the theory of meter, both the upper and lower ends of the temporal envelope for meter are subject to discussion and research (London, 2012, pp. 27-39).

The upper end concerns the maximal extension of successive events in time, while still allowing them to be perceptually integrated into a stable pattern. Only very little research has been conducted on this subject until now. Theory of meter, therefore, refers to concepts and findings in general psychology and applies these, on a trial basis, to music.

The lower end, or temporal region, of meter concerns events at the level of the shortest metrical time intervals. A fair number of studies have been conducted on this topic, many of them devoted to expressive timing in different genres of music. An important, and recurrent, paradigm in the field is based on the idea of categorical isochronicity of the shortest metrical time units (Clarke, 1987; Fraisse, 1963; London, 2004; Povel, 1981)—an idea nurtured by the notational conventions of Western music as well as by ethnomusicological, in particular Africanist concepts of metric pulse (Arom, 1984; Koetting, 1970; Kubik, 1988) and the corresponding, grid-based notational designs and practices.

Yet there is a range of music that is apparently not based on an isochronous substrate of beat subdivisions, but instead displays complex ratios for the division(s) of the beat, often identified as the source of the specific "feel" (or swing) of that music. These include the Viennese waltz (Bengtsson, 1975; Bengtsson & Gabrielsson, 1983), Brazilian samba (Gerischer, 2006; Haugen & Godøy, 2014), Scandinavian springar (Haugen, 2014; Kvifte, 2007; Johansson, 2009), some jazz styles (Benadon, 2006; Collier & Collier, 2002; Ellis, 1991; Friberg & Sundström, 2002; Honing & De Haas, 2008; Prögler, 1995), music from the Maghreb (Elsner, 1990; Jankowsky, 2013), from Central Asia (During, 1997), or—as in this case—from Mali (Polak, 2010; Polak & London, 2014).

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The hypotheses to be tested in the present study derive from Polak's (2010) chronometric analyses of traditional jembe pieces from the Bamako region in Mali, which maintain that rhythmic feels, or swing timing patterns, are a constitutive feature of these compositions, and that their specific aesthetic quality is achieved by the intentional use of nonisochronous—ternary or quaternary—subdivisions of the beat.

Polak further holds the view that these pulses are not distortions or expressive timing deviations from an isochronous pattern of subdivisions, but rather direct expressions of the metrical framework itself, allocating the attentional energy of the listener analogously (and implying that distortions of the meter are instantly detected). Hence, following London (2012) and Kvifte (2007), a specific collocation of pulse classes is called a metric timing pattern (MTP).

Polak's argument relies on chronometric measurements at the millisecond level of various ensemble performances. Given the consistent presence of particular timing ratios—ratios that are preserved even under dramatic tempo changes (up to 150% over the course of a piece)—he argues that in some contexts there are three distinct subdivisional pulse classes. With reference to their relative durations, they may be referred to as short, medium, or long. A pulse that may take on different categories is called flexible. Each MTP is marked by a specific collocation of these pulse classes, such as short-flexible-long (SFL), with the variants short-medium-long (SML) and short-long-long (SLL). Importantly, according to Polak, such MTPs are part of the identity of given pieces of jembe music.

In the following discussion, we will refer to the *pulse positions* (pp1, pp2, pp3) within each ternary beat as distinct from the relative duration of the subdivisional *pulse classes* (S)hort, (M)edium, or (L)ong.

Polak analyzed various recordings of "Manjanin," a well-known piece from the jembe repertoire of Bamako, and found both SML and SLL timing patterns. For example, measured mean proportions (in percent of the normalized beat duration) include 25:33:42 and 27:33:40 for SML and 25:36:39 and 28:36:36 for SLL (cf., Polak, 2010, chapters 4.3 to 4.6). Some performances begin with SML patterns at a relatively slow tempo, maintain that SML pattern during medium and fast tempos, but in the fastest passage, at the very end of a performance, minimize the distinction between medium and long, turning SML into SLL in a manner analogous to the flattening out of the swing ratio in jazz performances where the tempo is increased (Friberg & Sundström, 2002). In all of Polak's data, pp1 displays the shortest and pp3 the longest of the three pulse classes; and the duration of the pulse class at pp2 was always greater than pp1 and less than or equal to pp3.

In a commentary on Polak's article, London (2010), following Fraisse (1963), argued that perceptually—thus from the psychological point of view—there can be only two distinct categories of pulse classes. Given the absolute values for the durations of S vs. M vs. L elements, especially at moderate to rapid tempos, the differences in duration between these elements would be at or below JND thresholds.[1] London thus argued that the M must be regarded as an expressively timed variant of either the S or L pulse class. Therefore, the SML pattern in the performance of Manjanin, as described by Polak, perceptually represents an expressively timed variation of either SSL or SLL. Polak was unsure about this in 2010, which is why he introduced the above-mentioned F category ("flexible") as a wildcard.

On a more general level, then, the issue concerns the perception and cognition of small durational differences between units at the lowest, apparently nonisochronously organized metrical level of a piece of music, and as a result the correspondence between production (or surface structures) and perception/cognition in the described context.

There are no experimental studies available regarding the perceptibility of small IOI perturbations under these specific conditions. Research, among others, by Hibi (1983) and Hirsh et al. (1990) featured isochronous sequences of a unitary time-marker only. It revealed that, for an IOI of 100 to 250 ms (which is the relevant window for our study), subjects can perceive displacements of a pulse down to 7.5-12% of the IOI. The differences between short and medium pulse classes and between medium and long in Manjanin lie well above this threshold in all tempos. Friberg and Sundberg (1995), using an adjustment task, arrived at a JND of 6 ms for perturbations of the fourth tone in an otherwise isochronous sequence of six tones, for tone IOIs shorter than 250 ms.[2] Nothing is known, however, regarding the effective functioning of the obtained values in real music and performance or in nonisochronous metrical settings.

Regarding the listener, however, an important intervening factor in this context may be categorical perception. Arguably, then, the surface differences discovered by Polak (or at least some of them) may not pertain to perception, since the relevant subdivisions might

[1] London (2010) does not specify the assumed ms-values of these thresholds.

[2] For a comprehensive account of this research field see the introduction and discussion in Friberg and Sundberg (1995).

perceptually equate to one and the same pulse class, or category.

RESEARCH QUESTIONS AND HYPOTHESES

The aim of the present study, therefore, was to probe the perceptibility of typical performance timing patterns of Manjanin and their evaluation by expert listeners: If specific timing patterns are intentional productions and meaningful aspects of drum compositions in the reference area, then encultured persons must be able to distinguish them from deviating patterns.

The questions to be inferred from this may be specified as follows: Do expert listeners perceive the posited differences between short, medium, and long subdivisional pulses? Do they judge the perceived differences in such a way that some configurations will be classified as representing Manjanin better than others? Specifically, do they recognize the three class model (SML) as different from the two class model (SLL)? And if so, do they prefer one of these over the other?

The hypotheses corresponding to these questions are derived from the measurements of Polak (2010), changing the perspective from production to perception and predicting the latter through direct deductions from the surface data. They are, therefore, to be taken as experimental hypotheses. And since Polak's data rests on real music, a central concern of our approach was the use of equivalent, ecologically valid stimuli that would work "in the field" (see below for details).

The investigation is organized in two sections. In the first section (Hypothesis 1) we examine the shortness of the first pulse as a constitutive factor of Manjanin. It comprises two steps, the first one addressing its perceptibility, the second one its assessment.

H1: Shortness of pp1 is constitutive of the characteristic rhythm of Manjanin.
H1.a: Experts perceive shortness of pp1.
H1.b: Experts assess shortness of pp1, and only pp1, as better Manjanin than timing patterns without this feature.

The second section (Hypothesis 2) addresses the priority of the SML pattern. H2 is divided into two partial hypotheses, each of which comprises the same two steps as H1.

H2: SML is the best timing pattern for the rhythm of Manjanin.
H2.1a: Experts can discriminate a medium pp2 from a long pp2 (SML from SLL).
H2.1b: Experts assess a medium pp2 as "better Manjanin" than a long pp2 (SML over SLL).
H2.2a: Experts can discriminate a medium pp2 from a short pp2 (SML from SSL).
H2.2b: Experts assess a medium pp2 as "better Manjanin" than a short pp2 (SML over SSL).

Method

We employed a forced choice design, comprising a same-different discrimination and a preference task on pairs of timing-manipulated phrases of Manjanin. Timing-manipulation means that in the present case the onsets of drum-strokes are shifted from the original time point to other time points, to the effect that a given stroke sounds a certain amount of time earlier or later than in the original. One challenge for our experiment was to adapt this classic design to a field setting, which involved participants who were wholly unfamiliar with a typical research laboratory environment. Thus the design of our stimuli, the level of contrast employed amongst stimuli, the duration of our trials, and our response modes were all tailored to engage our participants' musical abilities and judgment to the fullest extent possible.

PARTICIPANTS

Professional Malian percussionists (13 men, age range 30-65 years) and professional dancers (10 women, age range: 35-60 years) were recruited from the Bamako music scenes to take part in the experiment.[3] Participants were compensated with 15,000 CFA francs each, corresponding to approximately $25 (€23). All participants were carefully instructed in the local language Bambara (and, if understood, in French) about the task they were asked to perform in order to ensure that the task and procedures were not misunderstood in any way.

STIMULI

Stimulus construction was based on multitrack recordings of Manjanin collected by author Polak in Bamako, Mali in 2006 and 2007. Two typical phrases were selected for the production of stimuli, the first from a duet ensemble in medium tempo (beat IOI = 414 ms/145 BPM), the second from a quartet in medium fast tempo (beat IOI = 349 ms/172 BPM).

Table 1 shows the rhythmic pattern of the duet phrase in the style of "TUBS" notation ("Time Unit Box System"), where each box represents an individual

[3] In the Malian music tradition under study here, percussionists are exclusively male and dancers mostly female.

TABLE 1. *Test Phrase Duet in TUBS Notation*

Metric cycle	1.1	1.2	1.3	2.1	2.2	2.3	3.1	3.2	3.3	4.1	4.2	4.3
Lead jembe	x		x	x	x	x	x	x	x	x	x	x
Dundun	x		x			x			x		x	

TABLE 2. *Test Phrase Quartet in TUBS Notation*

Metric cycle	1.1	1.2	1.3	2.1	2.2	2.3	3.1	3.2	3.3	4.1	4.2	4.3
Lead jembe	x	(x)	x	x		x	(x)	x	x	(x)	x	(x)
Dundun 1	(x)		x			x			x		x	
Jembe 2	x		x	x		x	x		x	x		x
Dundun 2	x					x	x					x

Note. Bracketed events are sounded in cycle 1, but not in cycle 2 of the 2-cycle phrase.

subdivisional pulse unit; Table 1 thus represents a complete four-beat measure with a ternary subdivision of each beat. An x within a box indicates the presence of a drum stroke at that location. (The tone colors of the different drums and the different strokes executed on them are not represented in this notation.)

In the present case, the lead jembe performs a rhythmically dense pattern typical for duet settings. The dundun, a stick-beaten cylindrical bass-drum, plays an asymmetric timeline pattern constitutive of Manjanin. The duration of the phrase in medium tempo is about 1.7 s.

Table 2 shows the rhythmic pattern of the quartet phrase, which extends over two metric cycles. Here, the lead jembe embellishes the timeline's basic structure. Dundun 1 varies the timeline by leaving out the stroke on the downbeat (Pulse 1.1.) of the second cycle. Jembe 2 and dundun 2 add short and simple ostinatos for accompaniment. The duration of the phrase in medium fast tempo is about 2.6 s.

Note that in both phrases one location is unsounded, but the patterns are otherwise metrically "saturated," with every beat and subdivision pulse position articulated by an instrument in the ensemble.

Stimuli were prepared using the Cubase audio/MIDI editing environment. In order to achieve an ecologically valid stimulus design, we utilized the original sound track for the lead jembe and manipulated it by dragging the onsets of the drum strokes within the envelope display of Cubase to the desired points in time (see testing matrices below). The accompanying instruments were recreated using MIDI-triggered sampled drum sounds.

Special care was taken to maintain the original, minute asynchronies between the onsets of different instruments in the same metric positions.[4] In order to dress cut-off sounds, and to bridge pauses that resulted from pulling apart two sounds, numerous tiny fades, reverbs, and other processes and effects were applied, resulting in a highly natural sound pattern.

Testing matrices. Each of the two phrases was manipulated with respect to timing variations that were organized in two matrices, one for each hypothesis. Table 3 presents the systematics and the percentage values for the H1 timing manipulations (short pp1 is constitutive).

The duration of pp1 was altered in increments equal to 6% of the total beat duration. The "SLLmedium" pattern (pp1 at 27%) was close to the average duration of pp1 was found in Polak (2010). Starting from this value for pp1, we obtained, by one descending incremental step, the value of 21%. The latter denotes the lower end of the empirical timing range for pp1. By one incremental step in ascending direction, on the other hand, we obtained isochronicity of all three pulses. The addition of another ascending incremental step turned pp1 into a long pulse. Subsequently, pp2 and pp3, which

[4] The mean asynchronies between instruments amount to about 2% of the normalized beat duration (6-12 ms, depending on the tempo) across the recorded live performance (for detailed analyses of this issue see Polak, Jacoby, & London, 2016). The differences between the "subdivisional classes" S, M, and L in the manipulated stimuli come to 7% of beat IOI (24 ms) at minimum and are thus more than twice as big as the mean asynchronies. We set the lead jembe on the exact time points as defined by the testing matrix and kept the accompanying instruments at proportional distances $\leq$ 10 ms (duet) and $\leq$ 8 ms (quartet), corresponding to their respective position in the original recording. In some cases the interval had to be reduced as against the original interval, in order to avoid overlap with a succeeding sound. Note that the timing patterns as defined by the matrices are articulated by the accompanying instruments as well as by the lead jembe, but with shifts within the said values.

TABLE 3. *Testing Matrix H1 in Percent per Beat and Corresponding Milliseconds for Medium and Medium Fast Tempos*

Variation	Timing pattern	pp1	pp2	pp3	Test sum
A	SLLstrong	**21.0%**	**39.5%**	**39.5%**	**100%**
		87 ms	163 ms	164 ms	414 ms
		73 ms	138 ms	138 ms	349 ms
B	SLLmedium	**27.0%**	**36.5%**	**36.5%**	**100%**
		112 ms	151 ms	151 ms	414 ms
		94 ms	127 ms	127 ms	349 ms
C	Isochronous	**33.3%**	**33.3%**	**33.3%**	**100%**
		138 ms	138 ms	138 ms	414 ms
		116 ms	116 ms	116 ms	348 ms
D	LSSmedium	**39.0%**	**30.5%**	**30.5%**	**100%**
		162 ms	126 ms	126 ms	414 ms
		136 ms	106 ms	106 ms	348 ms
Z	SSL	**26%**	**26%**	**48%**	**100%**
		108 ms	108 ms	199 ms	414 ms
		91 ms	91 ms	167 ms	349 ms

Note: medium tempo = 414 ms per beat; medium fast tempo = 349 ms per beat.

TABLE 4. *Testing Matrix H2 in Percent per Beat and Corresponding Milliseconds for Medium and Medium Fast Tempos*

Variation	Timing pattern	pp1	pp2	pp3	Test sum
A	SSL	**26%**	**26%**	**48%**	**100%**
		108 ms	108 ms	199 ms	415 ms
		91 ms	91 ms	168 ms	350 ms
B	SML	**26%**	**33%**	**41%**	**100%**
		108 ms	137 ms	170 ms	415 ms
		91 ms	115 ms	143 ms	349 ms
C	SLL	**26%**	**37%**	**37%**	**100%**
		108 ms	153 ms	153 ms	414 ms
		91 ms	129 ms	129 ms	349 ms
D	SLM	**26%**	**41%**	**33%**	**100%**
		108 ms	170 ms	137 ms	415 ms
		91 ms	143 ms	115 ms	349 ms
E	SLS	**26%**	**48%**	**26%**	**100%**
		108 ms	199 ms	108 ms	415 ms
		91 ms	168 ms	91 ms	350 ms

Note: medium tempo = 415 ms per beat; medium fast tempo = 349 ms per beat.

must be of equal length, assumed *short* categorical value. LSSmedium was thus an inversion of the original SLL timing pattern.

As a fifth pattern to take part in the tests for H1, we adopted SSL from the H2 set (see Table 4, pattern A), because it deprives pp1 of its exclusive status as a short pulse. SSL does not correspond to the systematics of the matrix for H1 and is, therefore, offset from the other patterns and named Z in Table 3.

Table 4 presents the patterns used to test H2 (i.e., SML is distinguished from SLL and SSL, and SML is the best timing). Here, pp1 remains constant at 26%, while pp2 varies from S to L and pp3 covaries from L to S.

Note that timing patterns like LSS (H1) or SLS (H2) are not directly related to the hypotheses. They were included for two reasons: First, for want of preceding studies, we had to think of the possibility that the hypotheses are too narrowly shaped. Therefore, the testing matrices were designed in such a way that the timing patterns would systematically deviate from the original performance timing to the point of reversal of the original pattern. If, for instance, Isochronous is not differentiated from or not preferred to SLL, while both Isochronous and SLL (or only SLL) are well differentiated from and well preferred to LSS, this would allow us, while disproving H1, to inductively describe the perception much more accurately than without such data.

Second, such testing matrices would allow us to describe the perceptual disposition of expert listeners—provided it exists in the data—in a linear form (as through the statement that an increased distance to the original timing decreases the aesthetic quality of the pattern).

Once constructed, the phrases were looped so that each stimulus presented 4 iterations of each pattern in the case of the duet phrase (total stimulus duration approximately 7 s) and 3 iterations in the case of the quartet phrase (total stimulus duration approximately 8 s); this created stimuli much like the repeated cycles one would hear in a live performance of Manjanin. In order to avoid any confusion regarding tempo or beat location, each stimulus was preceded by a click track of four beats equivalent to one metric cycle. All items ended with a quick fade out.

Pairings. To create the stimulus pairs, each timing pattern was paired with itself and with all other patterns of the same hypothesis set, and presented in both orders (e.g., A:B and B:A), for a total of 25 stimuli per set. As stimuli were presented in both duet and quartet versions, this yielded a total of 50 stimuli per hypothesis set. The two patterns of a pair were played in direct succession per trial. The stimulus pairs as presented to the respondents thus had the following form: click sound four beats > first item (pattern) 7 or 8 s > quick fade-out > click sound four beats > second item (pattern) 7 to 8 s > quick fade out (total duration of duet pairs ca. 17 s, of quartet ca. 18 s).

DATA COLLECTION AND PROCEDURE

The order of the 100 stimulus pairs was established through random sampling from the four blocks of

TABLE 5. *Test Questions and Possible Answers (English Translation)*

Task	Question	Possible Answer
Discrimination of two patterns	1. Are the two examples of jembe-rhythm, which you just heard, fully identical or could you perceive a difference between them?* Consider even very small differences.	a. The two examples are fully identical. b. I can perceive a difference between the two examples.
Assessment of the same two patterns (if having been discriminated in the first step)	2. You have carefully considered the first sample and the second one, and the difference between them. We are now interested in your personal opinion. Among the two samples, which one did you like better? Which one was the better Manjanin, the real Manjanin?**	a. The first example is the real / is better Manjanin. b. The second example is the real / is better Manjanin. c. Neither example is better Manjanin.

Note. Original formulations are provided in the footnotes. *In Bambara: “I bòra ka nin jembe fòlisenw fila lamèn. Est-ce que u fila bèè tunye kelen ye kosèbè, wala danfara fitinnin b’u nyògòn ce?” **In Bambara: “O tuma, I ye lakòlòsili kè Manjanin misali fòlò ani filanan ni nyògòn ce. Sisan, an mago be min na o ye e yèrè hakili na ye. E be se k’a fò an ye wa, min jara i ye Manjanin misali fila ni nyogon cè? Folisen fila ni nyògòn cè, jumèn ye Manjanin yèrè-yèrè ye?”

H1/H2 duet and quartet stimuli, employing an arbitrary alternation rate between blocks so as to allocate more of the (faster) quartet pairs in the second half of the series (and to thus support an active listening disposition on part of the participants). All participants were exposed to the same succession of stimuli.

Data collection took place in Bamako in December 2012 on six consecutive days. Experiments were conducted by authors Neuhoff and Polak in parallel sessions, each assisted by a local person who spoke both French and Bambara.

Stimuli were played via closed studio headphones (transmission range 5-35,000 Hz) while participant responses were written directly into an Excel file by the experimenter. The duration of an individual single session was approximately 2.5 hr, not including breaks, which were taken on demand or proposed by the examiners upon signs of fatigue. After about half the time, respondents changed to the respective other examiner (those who had worked with Polak, continued with Neuhoff, and vice versa).

For each stimulus pair participants had to answer two questions as depicted in Table 5.

In case participants did not state any difference, they were asked if the pattern was “good/real Manjanin,” or “poor Manjanin.”

Results

For all conditions, no relevant effects of group (percussionists vs. dancers) were found, nor was there any relevant effect of order of presentation (A:B vs. B:A).

For effects of group, evaluation task, ANOVAs for a single factor were run for each timing pattern, separately for the duet and quartet condition. For H1 duet, there was one significant effect ($p = .02$) for SLLm, and all other patterns were *ns* (p ranged from .36 to .95). For H1 quartet, there were no significant effects (p ranged from .09 to .94). For H2 duet, there were no significant effects (p ranged from .06 to .80). For H2 quartet, there were no significant effects (p ranged from .32 to .86).

Order of presentation (A:B vs. B:A) was analyzed using paired t-tests: discrimination task H1 $t(19) = 0.47$, $p = .65$, H2 $t(19) = 0.77$, $p = .45$; evaluation task H1 $t(19) = 0.68$, $p = .50$; H2 duet $t(9) = 0.51$, $p = .62$; quartet $t(9) = 2.54$, $p = .03$, however, the effect size for the latter is low (Cohen‘s $d = -.16$).

Age was not taken into account as a potentially influencing variable. Given that all participants were professionals and more than thirty years old, the repertoire-specific cognitive structures were considered fully developed and not subject to relevant modification through further experience. Moreover, the age range of the participants was limited to 35 years at the maximum, while age statements in the West African settinges are vague and error-prone to a high degree.

Results from each stimulus set are presented in turn.

H1.A: EXPERTS PERCEIVE SHORTNESS OF PP1

Figure 1 displays the discrimination results of the ten pairings of Hypothesis set 1 for both duet and quartet conditions. Table 6 shows, for each pair of timing patterns, the corresponding p values of the binominal test of the two-tailed statistical significance of deviations from the (expected) random distribution of 50%:50% between the two answer options.

Findings. In the duet condition, eight discrimination judgments were significantly beyond chance ($p < .01$); of these, seven were above chance (bars 1 to 7 with 80% or more correct alarms) and one below (bar 10, 18% correct alarms and 82% misses). Two stimulus pairs, namely SLLmedium: Isochronous and Isochronous: LSS (bars 8 and 9), led to nonsignificant ($p > .01$) deviations from chance level, with discrimination rates of 66% and

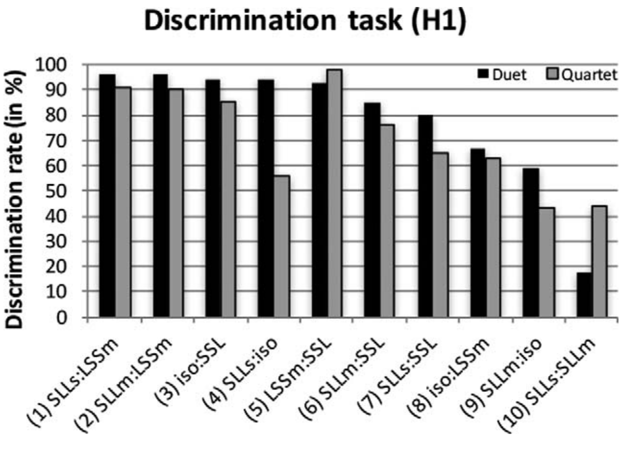

FIGURE 1. *Discriminability timing patterns in percent for Hypothesis 1 (H1). Pairings are ordered in descending rate in the duet condition.*

TABLE 6. *Discrimination Task, H1, Exact Binominal Test of the Two-tailed Statistical Significance (p values) of Deviations from the Expected Distribution of 50%*

Pair	Duet	Quartet
1	.000	.000
2	.000	.000
3	.000	.000
4	.000	.551
5	.000	.000
6	.000	.001
7	.000	.054
8	.036	.096
9	.461	.291
10	.000	.533

Note: 50% for each pair of timing patterns ($n = 46$).

59% respectively. Note that all three pairings with chance level discrimination or below involve comparisons between "neighboring" timing patterns where the accumulated difference across the three pulse positions is least. Each of the pairs comprising nonneighboring timing patterns, however, or SSL (pattern Z), allowed for an easy detection of the difference.

Importantly, the difference between a *very* short pp1 (pattern A, SLLstrong) and a short pp1 (pattern B, SLLmedium) was not signaled in most of the judgments. If, however, either of the two was paired with one of the other patterns, the difference detection rate was significantly higher (chi-squared test of the difference between the discrimination of A:B and B:C, $\chi^2(1, N = 94) = 16.66, p < .001$, although the difference of the accumulated difference between A:B and B:C was virtually nil). H1.a was therefore corroborated by the duet data.

In the quartet condition, results were similar by tendency but less pronounced and less significant. Notably, the discriminability between the SLLstrong and isochronous pattern (bar 4) drops to chance level (56% correct alarms, which is near the rates for SLLmedium: Isochronous), while discriminability between the two SLL patterns, which was poor in the duet condition (18%), rose to chance level (44% correct alarms). This suggests that timing pattern perceptibility interacts with, or depends on, (a) the tempo, (b) relevant thresholds, and/or (c) features of the manifest rhythmic phrase.

In summary, Hypothesis 1.1a was strongly corroborated by the duet data in medium tempo. Patterns SLL were, both in the strong and medium form, discriminable from all other patterns, while they were virtually indistinguishable from each other. And discriminability was best, if SLL was matched with its inversion LSS. These results tended to be true for the medium fast quartet condition, too, but were less pronounced.

H1.B: EXPERTS ASSESS SHORTNESS OF PP1, AND ONLY PP1, AS BETTER MANJANIN THAN TIMING PATTERNS WITHOUT THIS FEATURE

With regard to the evaluation task, the following scoring procedure was employed. As all stimulus pairs were presented, for every pair a score of 1 was given to the "better" pattern; if no preference was registered, then each pattern received a score of .5. Given the number of basic patterns in each stimulus set (5), there were four pairs for each stimulus. As one sums the ratings for all four pairs, preference scores ranged from 0 (a pattern was never preferred) to 4 (a pattern was always preferred). Fractional scores were also calculated for multiple stimulus presentations, so that if a participant gave a rating of 1 on one trial, and .5 on a subsequent trial, his/her score for that stimulus would be the average (.75). Figure 2 shows the means across all participants for the H1 stimuli for both duet and quartet conditions, and Table 7 lists the corresponding t-test data.

Findings. Both SLL patterns were clearly rated as better than all other patterns in both the duet and the quartet versions, and all differences between them and the other patterns were significant at the .01 level (except for the quartet difference between SLLs and Isochronous). Differences between the two SLL varieties, however, were small and not significant. Separate one-factorial ANOVAs with Bonferroni correction yielded the same significances as did the t-tests. The LSS pattern was almost always discarded, and this in turn gave rise to the middling preference ratings for the isochronous and SSL patterns, given the manner in

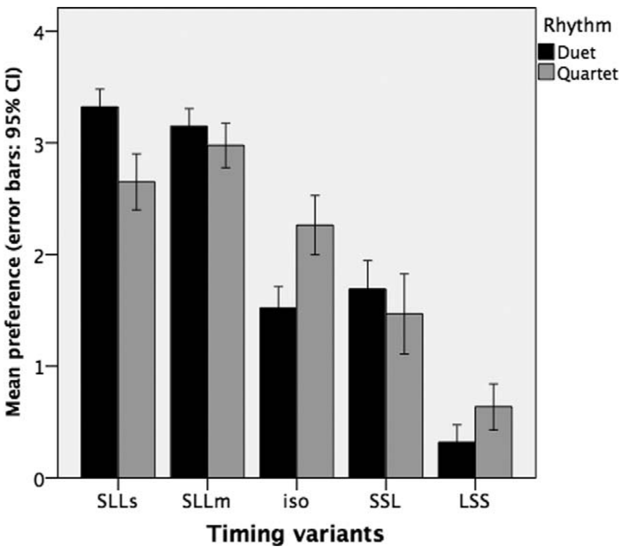

FIGURE 2. *Evaluation of H1 timing patterns, mean scores across subjects.*

TABLE 7. *t-tests (two-tailed) and Mean Scores of H1 Timing Patterns*

	Duet			Quartet		
Pair	*t*	*df*	*p*	*t*	*df*	*p*
SLLs - SLLm	1.52	22	.143	-2.12	22	.045
SLLs - Iso	16.64	22	.000	1.84	22	.079
SLLs - SSL	9.47	22	.000	4.92	22	.000
SLLs - LSS	22.94	22	.000	12.10	22	.000
SLLm - Iso	13.66	22	.000	4.96	22	.000
SLLm - SSL	8.62	22	.000	6.54	22	.000
SLLm - LSS	23.49	22	.000	13.88	22	.000
Iso - SSL	−.86	22	.401	2.97	22	.007
Iso - LSS	8.54	22	.000	10.20	22	.000
SSL - LSS	9.85	22	.000	3.84	22	.001

which the data were scored. Yet, the better rating of the isochronous pattern in the faster quartet condition suggests that timing pattern evaluation, too, interacts with or depends on (a) the tempo, and/or (b) features of the manifest rhythmic phrase. Finally, the dismissal of SSL suggests that the medium pulse (pp2) must not be short. Hypothesis 1.b, therefore, was also confirmed by the data: a short pp1 yielded the best rating from among all the timing patterns presented.

Taken together, the discrimination and evaluation data strongly support Hypothesis 1 as a whole: shortness of pp1 was constitutive of the characteristic rhythm of Manjanin. Moreover, the scores map that an increased distance to the original timing decreased the aesthetic quality of the pattern.

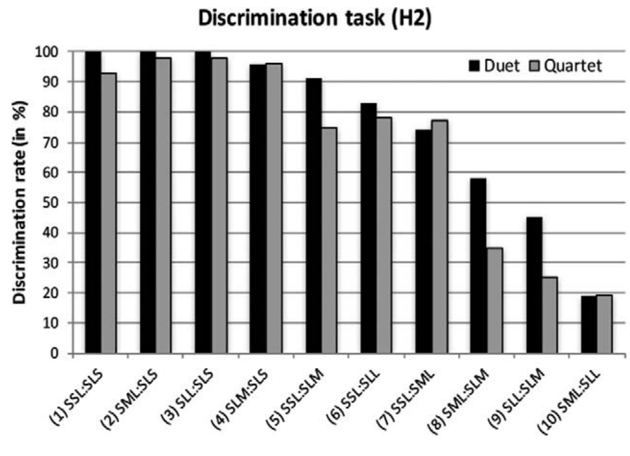

FIGURE 3. *Discriminability of timing patterns in percent for Hypothesis 2 (H2). Pairings are ordered according in descending rate in the duet condition.*

TABLE 8. *Discrimination Task, H2, Exact Binominal Test of the Two-tailed Statistical Significance (p values) of Deviations from the Expected Distribution of 50%*

Pair	Duet	Quartet
1	.000	.000
2	.000	.000
3	.000	.000
4	.000	.000
5	.000	.001
6	.000	.000
7	.002	.001
8	.360	.066
9	.644	.001
10	.000	.000

Note: 50% for each pair of timing patterns ($n = 46$).

H2: SML IS THE BEST TIMING PATTERN FOR THE RHYTHM OF MANJANIN

Discrimination. Figure 3 displays the discrimination results of the ten pairings of hypothesis set 2 for both duet and quartet conditions. Table 8 shows for each pair of timing patterns the corresponding p values of the binominal test.

Findings. All stimuli paired with the SLS pattern were marked by a perfect or near perfect discrimination in both the duet and quartet conditions. The pronounced reversal of pp2: pp3 durations of the original SML-pattern (turning M:L into L:S) thus provokes the strongest reaction by the expert listeners.

Stimuli whose pp2 also involved a short element (bars 5 to 7 in Figure 3) were also significantly discriminated above chance level, with percentages between 70 and

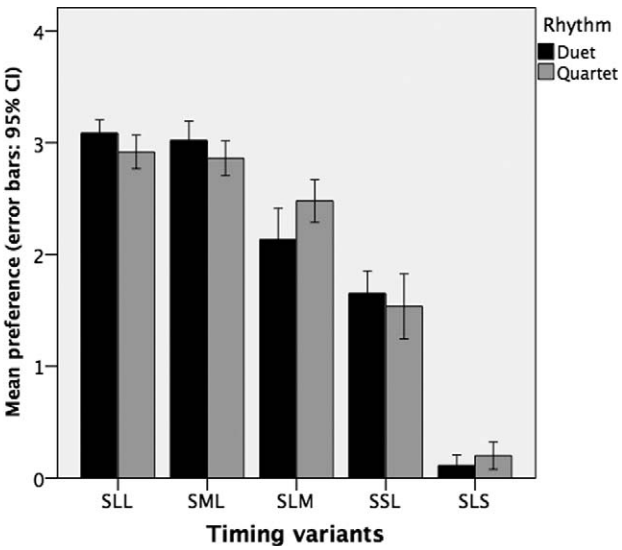

FIGURE 4. *Evaluation of H2 timing patterns, mean scores across subjects.*

80%, and sometimes higher. H2.2a, therefore, was corroborated: Experts *do* discriminate a medium (and a long) pp2 from a short pp2.

Discrimination degraded, on the other hand, for stimulus pairs whose pp2 and pp3 were both comprised of M and L durations (bars 8, 9, and 10), and especially so in the quartet condition. The poorest discrimination was found in the crucial pairing SML:SLL (bar 10, 19% correct alarms and 81% misses). Hypothesis 2.1a, therefore, must be rejected: In the vast majority of judgments a medium pp2 were not discriminated from a long pp2 (SML from SLL).

Even so, participants better discriminated SLL from SLM, as well as SML from SLM, at the slower tempo in the duet condition. This suggests that the discriminability of L from M is position sensitive within the pattern at this tempo: while S can be distinguished from M and L at every position within the pattern, L and M are only distinguished at pp3, but not at pp2.

Evaluation. Figure 4 shows the results of the preference task for the Hypothesis 2 stimulus pairings; the same scoring procedure was used here as with the stimuli for Hypothesis 1. Separate one-factorial ANOVAs with Bonferroni correction yielded the same significances as did the *t*-tests. Table 9 lists the corresponding *t*-test data.

Findings. Pairwise *t*-tests found differences between all stimulus patterns to be statistically significant ($p < .01$), except for the differences between SLL and SML, which are tiny and not significant. The similarity between the ratings for SLL and SML patterns comes as no real surprise since, as Figure 3 had shown, in more than 80% of the SML:SLL pairings no difference had been detected. And in the 19% of judgments where respondents had stated a difference, ratings were evenly distributed between the two patterns.

Hence, different means for SML and SLL could have been obtained only from their diverging assessment in the comparisons with other patterns. This, however, was not the case: SML and SLL were always and clearly the better rated patterns, while not being differentiated from one other. H2.1b (SML assessed better than SLL), then, is disproved by the data.

On the other hand, SML was clearly favored over SSL (Table 10). Virtually all of those who discriminated the patterns did name a preference, and more than 90% of them called SML the better Manjanin (H2.2b corroborated).

The fact, then, that M is not discerned from L, but is discerned from S, and that both M and L performed in exactly the same way across comparisons with all other patterns, means that M is perceptually equivalent to L at pp2.

TABLE 9. *t-tests (two-tailed) and Mean Scores of H2 Timing Patterns*

	Duet			Quartet		
Pair	*t*	*df*	*p*	*t*	*df*	*p*
SSL - SML	−9.19	22	.000	−7.09	22	.000
SSL - SLL	−10.85	22	.000	−7.61	22	.000
SSL - SLM	−2.44	22	.023	−4.25	22	.000
SSL - SLS	15.42	22	.000	8.66	22	.000
SML - SLL	−.92	22	.367	−.58	22	.565
SML - SLM	4.59	22	.000	3.41	22	.002
SML - SLS	28.01	22	.000	23.66	22	.000
SLL - SLM	5.39	22	.000	3.87	22	.001
SLL - SLS	46.51	22	.000	23.84	22	.000
SLM - SLS	12.39	22	.000	22.66	22	.000

TABLE 10. *Discrimination and Evaluation of SML vs. SSL*

	A	B	
	Difference detection SML: SSL (%) (for significances see Table 8, Pair 7)	Statements "better Manjanin" SML vs. SSL (% of column A values)	
Phrase		SML is better	SSL is better
Duett	74	91	9
Quartet	77	93.5	6.5

Discussion

In this experiment, Malian expert dancers and drummers were presented with systematic timing variants at the subdivisional level of characteristic rhythms used in Manjanin, a well-known piece from the repertoire of Malian percussion music, based on a four-beat time cycle with ternary subdivision of each beat.

In a series of forced-choice discrimination and evaluation tasks, our participants were well able to distinguish, at the subdivisional level, most orderings of two- and three-element patterns (two-element patterns being composed of short and long elements, and three-element patterns being composed of a short, a medium, and a long element). The few contexts where patterns were not well distinguished involved either variants of the same basic pattern (Short-Long-Long strong vs. Short-Long-Long medium in the H1 test set), or patterns that exchanged Long vs. Medium elements in pp2 (subdivisional pulse position 2) or pp3 (in the H2 test set). Discriminability between Medium (M) and Long (L) was especially poor for M vs. L in pp2.

In light of our discrimination data, our preference data provide sound support for H1: the shortness of pp1 is constitutive of the characteristic rhythm of Manjanin. However, our results provide only partial support for the various claims of H2: experts can discriminate a medium pp2 from a short pp2 (SML from SSL), and they clearly take SML for the better Manjanin.

On the other hand, they do not, in the vast majority of cases, discriminate a medium pp2 from a long pp2 (SML from SLL). This supports the claim that L and M are heard as members of the same perceptual category at pp2. Accordingly, the evaluations of the H2 stimuli showed that SML and SLL are equally well suited to constitute the characteristic feel/swing of Manjanin and are better at doing so than any other pattern.

In the pairwise comparisons the M and the L timings at pp2 were tested for discriminability as members of two different, consecutively presented patterns (namely SML and SLL). The absolute difference between M (S*M*L) and L (S*L*L) amounts to 16 ms in the duet and 14 ms in the quartet condition.[5] The difference in duration between M and L *within* the SML pattern (S*ML*), however, is twice as big: it amounts to 33 ms in the duet and 28 ms in the quartet condition. Can we claim on that grounds that the difference between M and L in SML is not perceived?

Yes, we can. For, if the difference between M and L within the SML pattern was the cause of a distinct swing or "feel" then the difference to SLL, which lacks that feature, must make itself felt in perception. This, however, was not so.

SLM falls between SLL/SML and SSL in terms of assessment. This suggests that while the shortness of pp1 is characteristic of the Manjanin rhythm, so too is the "length" of pp3. Accordingly, neither SSL nor SLM are to be found in the surface structures of performances by professional artists.

Our results, then, confirm that distinct nonisochronous subpulse classes that subdivide the isochronous beat are at work in the perception and cognition of the Manjanin rhythm. And they show that a specific pattern of these, namely short-long-long (SLL), is constitutive of its metrical perception and assessment as "real or good Manjanin."[6] This supports London's claim (2010) that, perceptually, there are only two metric pulse classes, not three. The short-medium-long pattern (SML), as identified by Polak (2010) by means of chronometrical analyses of the surface structures of Manjanin performances, pertains only to rhythm production. The metric structure, then, appears perceptually less fine-grained than the performance data suggested.

If the SML production pattern cannot be understood as an intentional, perceptually motivated shaping of the beat subdivisions, how then might the M category at pp2 in the surface structure be explained?

At present we can conceive of two explanatory approaches to answer this question: one relates to motor aspects of musical sound production, the other one to concepts of subdivision.

Regarding the motor approach, it is important to see that the M timing does not constitute a deficient realization of L. Performers, therefore, enjoy some flexibility in the execution of the second pulse, and it is possible that they (unconsciously) make use of this margin to adapt the motor processes to certain recurrent problems in the performance task.

One such problem could be the constant rapid change from short to long pulses, which may favor the emergence of a transitional stroke. And it would seem plausible that, in ternary subdivision, this transitional stroke

[5] Note that given the identical definition of the beat, the L in SML is longer than the L in SLL, namely by the amount the M in SML is shorter than the L in SLL.

[6] Note that short, medium, and long are relational concepts (but do not involve specific durational values). If it applies that the productional M and L pulse classes are perceptually not differentiated in Manjanin then the perceptual pattern must be described as SLL not SMM (the medium class is pertinent only on the given condition of another two classes, namely a short one and a long one).

emerges on the middle pulse of the three, resulting in an intra-beat transition, while a permanently produced SLM pattern would rather result in a smoother inter-beat transition.

With regard to subdivision, analyses of related repertoires by Polak and London (2014) revealed that West African drumming often employs a particular subdivisional concept, keeping (in the case of ternary subdivision) one of the three pulses short, while one of the two L positions is disposed to the interpolation of another subdivision (in fast tempos as an ornament, in slower tempos metrically bifurcative), and prolonged for that purpose.

Although we had not designed our study to test tempo effects, possible effects of tempo on the discriminability and evaluation of metrical timing patterns repeatedly cropped up in the data. And though we can say that we strongly suspect them to be pertinent here, the differences between the comparisons in medium and medium fast tempo may be accounted for by other factors, too—notably the differences in the rhythmic figures and ensemble size linked to the two tempo levels. Tempo being a crucial parameter for the aesthetic quality of music, future research should address this point thoroughly and systematically.

Are "short" and "long" finally to be taken for categories, or could they be regarded as expressive timing variations of a single category?[7] Our investigation does not allow to make any truly positive claims. But it sheds some light on the pertinence and implications of both concepts (categorical rhythm perception and expressive timing) to the repertoire under study.

Clearly, expert listeners can and do discern the SLL pattern from an isochronous rendering of Manjanin phrases, and they do consider the former to be the better, the real Manjanin. What is more, performers amazed us through their highly stable maintenance of the SLL pattern and the small degree of random variation around the average values. Undoubtly, the pattern is culturally wanted.

Up to this point, the S may still be taken as an expressive variation of a single pulse class. It is that very "expressive" shortening of the first subdivisional pulse that gives Manjanin its specific "feel." And if this shortening is perceived by expert listeners—and it is, as we proved—then it takes on metric quality by allocating their attentional energy and disposing their expectancy accordingly.

On the other hand, Polak (2010) furnished evidence that other jembe ensemble pieces employ other configurations of S and L (and, maybe, M) in order to create other "rhythmic feels." If we take these for more and other cases of expressive variation, then the very same principle of deflecting a unitary pulse would be called on to explain a variety of distinct musico-aesthetic phenomena. And the question arises if the cognitive costs for the performers to produce such different musico-aesthetic phenomena are lower when they (a) have to regularly achieve sufficient deviation from a categorically unitary pulse or (b) can draw on the reality of two or more distinct subdivisional categories and their different collocation?

Perhaps the most striking argument, however, supporting the categorical interpretation of S and L comes from the above mentioned analyses of related Malian repertoires by Polak and London (2014): It is, in particular, always and only the L pulses that may be further subdivided through the interpolation of another stroke on one of the drums. And the duration of the L pulses is, indeed, controlled in such a way, as to allow for that interpolation. The S pulses, on the other hand, never once undergo further subdivision.

It is obvious that the issues addressed in this paper involve the problem of differential threshold values, or just noticeable differences (JND). Are M and L (and SLLstrong vs. SLLmedium), in a significant majority of cases, not discerned because the durational difference between them is located near or below the pertinent JND?

While our study was not designed to yield precise data on that question, it would seem natural to check how our findings relate to the results of abstract threshold determinations in music psychology.

On the one hand, our manipulations of the subdivisional time spans in Manjanin suggested that (in this music) the perception of differences between timings of rhythmic elements starts somewhere between 16 and 24 ms (16 ms being the difference between a medium and a long pp2 in the duet condition, which was hard to detect, and 24 ms the difference between a short and a medium pp2 in the quartet condition, which was well detected above chance level).

This suggests a higher threshold (three times as big) than the 6 ms constant absolute JND for IOIs between 100 and 250 ms as identified by Friberg and Sundberg (1995)—the latter having been established under distinctly different conditions, of course (see the introduction)—and also higher than the values obtained by Hibi

[7] Expressive variation concerns differences *within categories* ("kinds of blue," "kinds of long") as produced both on the intra-performer level (deviations from the proper means), on the inter-performer level (differences between the means of different performers), or as deviations from some otherwise established norm (e.g., the values of a prescriptive score).

(1983) and Hirsh, Monahan, Grant, and Singh (1990), amounting to about 12 ms at an IOI of 150 ms.[8]

Things take on yet another, more drastic look, however, if we accept that the difference between M and L *within* the SML pattern is not being perceived. That difference amounts to no less than 33 ms in the duet condition (and 28 ms in the quartet). Accordingly, the JND had to be estimated as > 33 ms.

It appears, therefore, that in the context of the present music the differential threshold values as they have been determined for the pertinent IOI window in abstract settings, do not suffice to bring about perceptable, aesthetically productive differences. Instead, (considerably) higher values than those must be assumed. This seems plausible in that the real music comprises many more sources of auditory information (timbre, intensity, articulation, etc.) and thus constitutes a far more complex stimulus than the controlled tones and beeps from programmable electronic devices. It remains to be seen to what extent these observations hold true for other musics as well. Eventually, the issue is about ecological validity of laboratory data.

Furthermore it seems likely that the perceptability is position and task sensitive. A difference of 24 ms is perceptable in one context (at pp2 in SSL versus SML), while a difference of 33 ms is *not* in another (between pp2 and pp3 within SML). And while the M timing was hard to detect at pp2 (81% misses) it was perceived at chance level at pp3. The lack of position effects, then, as found to be pertinent in the abstract experimental settings (Friberg & Sundberg, 1995) seems not hold true here.

In sum, we conclude that differential thresholds in real music are strongly context dependent. And it seems worthwhile to take into view the specific characteristics and their implications in a given music.

In the present case the given characteristics imply that the scope for expressive variation *within categories* is very small: A transgression of the pertinant threshold would almost inevitably involve a change of the category. And a lower deviation from the threshold would indicate that the concerned "expression" is not perceptible.

And indeed, on the assumption of normal distribution of category realizations (supported by Polak's, 2010, chronometric analyses), the variation produced by the performers is, for the most part, so tiny that it seems doubtful that individual players of Manjanin would be recognizable by virtue of their characteristic "within category" variation of the metrical timing pattern alone.

Instead, we are inclined to see that the production and perception of timing patterns in such dense, polyrhythmically complex, and medium to very fast percussion ensemble pieces are located at, and exploit, a high, nearly borderline degree of refinement concerning the nonisochronous subdivision of the beat. Any further degree of sophistication with regard to metric timing would not be easily transformed into an aesthetic result, but would rather deprive the music of the minimum measure of rhythmic elasticity and flexibility it needs (or, at worst, lead to unwanted effects). Hence, the scope for individual thumbprints on the metric level is very thin—perhaps too thin to be functional here. Moreover, there are many other aspects that are much better suited to apperceptive differentiation among players, such as choice and variation of patterns, ornamentation, timbral qualities, and bodily gestures. Conceivably, observable nuances in timing and occasional stronger deviations from the right duration—which do occur—might rather be functions of such other modes of shaping the music.

The metric significance of the music then—the "right" feel discerned by experienced listeners—is essentially brought about by the drum stroke patterns, their specific nonisochronous timing in performance, and their perception as SLL. Timing nuances within the perceptual categories, on the other hand, may not constitute an independent dimension of significance in this music.

Limitations and Outlook

We would like to indicate the exploratory nature of the present study. While the issue of a possible nonisochronous timing of beat subdivisions may be viewed as settled today (see the introduction), the perception of such structures has so far not been investigated empirically. In fact, the mechanisms and principles by which perception works at this level of auditory processing, are largely unknown—and notably so in the case of real music. We thus opened up the door to a new form of research: a crossing point between experimental psychology and the field concept of ethnomusicology.

In doing so, the present psychological study has shown that chronometric analyses of music surfaces (and other forms of music analysis as well) may reveal

[8] Friberg and Sundberg (1995, p. 2526) point out the incomparability of the values obtained through the adjustment method and the forced-choice method, the former being systematically smaller than the latter. Drawing on theoretical and empirical work by Cardozo, Wier, and Fraisse, they conveniently adjust the adjustement values to the forced choice values by doubling them (resulting in an estimated value of 12 ms for the constant absolute JND, too). The form of adjustement does not imply any proposition regarding the "true" values.

structures in musical pattern production, which may not have a counterpart in perception. The music conceived of as a totality of production/performance and perception/reception behaviors appears in a different and more illuminating light if submitted to analysis under *both* perspectives. We would therefore urge the general consideration of a complementary design for these kinds of repertoire studies: empirical analyses of rhythmic production and surface structures, plus related psychological, especially experimental analyses of auditory perception.

Author Note

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Interested readers are welcome to contact Hans Neuhoff via e-mail for a download link to the complete stimulus set.

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