Temporal structure and synchronization in the *Tōgaku* ensemble of Japanese court music (*Gagaku*)

Sayumi Kamata & Martin Clayton

INTRODUCTION

In this paper we present the first empirical analysis of rhythm, meter, and synchronization to be carried out using a recorded corpus of instrumental *gagaku* music. We present an account of metrical-formal structure, tempo change, interaction (including the role of preparatory arm movements), and interpersonal entrainment (including the synchronization of rhythmic events). We draw on existing observations and theorizations of *gagaku* music, particularly including observations of phenomena which can be described as aspects of performance practice; that is, they do not form part of the notation or formal description of the repertoire but can be observed and form part of musicians' practical knowledge. In this respect, we complement existing accounts with new interview material. The first aim of this paper is to use empirical analysis of a recorded corpus to shed light on these aspects of *gagaku* music by providing precise descriptions of what occurs (at least in these specific performances). The second aim is to use these descriptions to argue that *gagaku* embodies a number of phenomena that are not explained by existing theorizations of meter. Thus, we argue, in order to develop more a comprehensive and less culture-bound metrical theory, *gagaku* and other traditional Japanese music genres need to be taken into account.

[2] There are three levels of understanding of present-day melodies of *gagaku*: the music as performed, an oral mnemonic system known as *shōga* 唱歌 (literally

Analytical Approaches to World Musics, Vol. 12, No. 1. Published January 2025.

meaning "singing song"),[1] and traditional tablatures (Terauchi 1996:9). Previous studies have examined the music primarily based on *shōga*, tablature, and performers' explanations of how they perform the music. *Shōga* is an indispensable means for grasping the melodic details and the flow of the music as a whole, since a musician's learning process begins with *shōga* on one of the wind instruments. Throughout the last half-century, *shōga* has attracted a wider interest not only as a syllabic notation system but as a practical experience in the multiple processes of transmission, playing, and listening (Yokomichi and Gamō 1978, Fujita 1986, Hughes 2000). The tablature is regarded as a supplementary tool to facilitate memorization and comprises symbols indicating the fingering, strings or frets to be used, and/or characters indicating the *shōga* syllables. It does not indicate subtle rhythmic nuances, and it is therefore impossible to play the actual melody from this symbolic notation without an understanding of the performance practices embodied in *shōga*. In ethnographic interviews, performers emphasize both *shōga* and the importance of the ensemble experience of being aware of the other parts (Shōno 1987). While several studies have examined changes in ensemble tempo from audio recordings (Gamō 1973; Terauchi 2002, 2008), detailed research has yet to be conducted on the actual sounds and movements practiced by individual parts during an ensemble. There is, therefore, much opportunity to analyze the performance practice of *gagaku*.

[3] This paper argues that an empirical research approach to the actual sounds and actions of ensemble playing enable us to explore the previously unexamined details of

1. The term '*shōga*' refers to a practice of expressing rhythmic and melodic details by singing mnemonic syllables without the use of instruments. The syllables can be regarded, in this context, as a kind of oral notation. In contemporary *gagaku*, these syllables are one of the components of the written musical notation, along with other symbols.

rhythmic practice. We aim to achieve a balance between this quantitative analysis and the musicians' own explanations, by presenting both data from audiovisual recordings, as well as interviews with performers through ethnomusicological approaches. After introducing some basic information about the genre and time organization, we present the results of the interviews and empirical analysis and put them into dialogue with each other.

REPERTOIRE AND INSTRUMENTS

[4] The term *gagaku* 雅楽 (literally, 'elegant/refined music', translated by Nelson as "proper music" (2008)) signifies the entire body of classical music and dance that has been performed in the Japanese imperial court. This paper deals specifically with *tōgaku* 唐楽 (literally, "music of the [Chinese] Tang [dynasty]"), a subset of instrumental ensemble music that comprises a large proportion of the *gagaku* repertoire. *Gagaku* comprises three categories: *kuniburi-no-utamai* 国風歌舞 (accompanied vocal music of indigenous origin); *kangen* 管絃 and *bugaku* 舞楽 (instrumental music and accompanied dance deriving from the Asian continent); *saibara* 催馬楽 and *rōei* 朗詠 (accompanied vocal music originating at the Japanese court in the 9th and 10th centuries). *Tōgaku* belongs to the '*kangen* and *bugaku*' category.

[5] The subject of analysis here is a set of *tōgaku* ensemble recordings performed by a small group of eight players, one for each instrument, and semi-structured interviews with the performers. Complete audiovisual recordings, accompanying annotations, and interview transcripts are published separately (Clayton et al. 2023). The recorded material includes (1) 'Ichikotsuchō no Chōshi 壱越調調子', the introductory piece

for playing in the *Ichikotsuchō* mode (which is roughly analogous to a mixolydian mode on D), and the *tōgaku* suite 'Shunnōden 春鶯囀', literally 'The Warbler Sings in the Spring'. In its full form, Shunnōden consists of six movements—(2) Yūsei 遊声, (3) Jo 序, (4) Sattō 颯踏, (5) Juha 入破, (6) Tesshō 鳥声 and (7) Kisshō 急声—and falls into the most prestigious *taikyoku* 大曲 category, with complex compositions in terms of movement structure.

[6] The instruments in *gagaku* can be grouped into three classes: winds, strings, and percussion—traditionally referred to as *fukimono* (blown things), *hikimono* (plucked things), and *uchimono* (struck things), respectively. The instruments of the *tōgaku* ensemble are illustrated in Figure 1: in the present recording we have one player of each, although the standard instrumentation includes nine woodwinds (three *hichiriki,* three *ryūteki* and three *shō*), four string instruments (two *koto* and two *biwa*) and three percussion instruments (one *shōko*, one *kakko*, and one *taiko*).[2] Basic descriptions of the instruments can be found in Table 1. (For more detailed descriptions of the instruments and their playing styles, see Terauchi 2011, Kapuscinski and Rose 2010–2020).

2. The decision to record an ensemble with one player per part was made for practical reasons. This means that we cannot explore, for instance, the relationships between leaders and others within each instrument group (e.g., different *hichiriki* players). Of course, the empirical study of a specific performance cannot be generalized to all instances of *gagaku* performance, and this is an example of a variable which could make a significant difference.

Section	*Instrument (left to right)*	*Description*
Wind (fukimono 吹物*)*	Ryūteki 龍笛	transverse bamboo flute
	Hichiriki 篳篥	short double-reed pipe
	Shō 笙	free-reed mouth organ
String (hikimono 弾物*)*	Koto (Sō, Gakusō) 箏 (楽箏)	13-stringed long zither
	Biwa 琵琶	four-stringed lute
Percussion (uchimono 打物*)*	Shōko 鉦鼓	dish-shaped gong
	Taiko 太鼓	large suspended drum
	Kakko 鞨鼓	small barrel drum

Table 1. Instruments of the *tōgaku* ensemble

[7] The specific roles within the ensemble are summarized by Endō (2013, 79–82, translations from Japanese): the wind instruments are responsible for the melody, among which the *hichiriki* provides the "framework of the melody", the *ryūteki* has "generally more detailed melodic movements", and the *shō* has "the main role of enveloping [the *hichiriki* and *ryūteki*] with its unique chords called *aitake* 合竹".[3] The stringed instruments play the role of "tracing the melody while clearly indicating the beats", with the *biwa* showing "the first beat" with its arpeggio-based technique and the *koto* showing "mainly the second beat" with its patterns based on broken chords. The three percussion instruments "set the tempo and rhythm of the piece by creating a series of rhythmic patterns." In particular, the *kakko*, with its gradually accelerating

3. Such descriptions are common among Japanese performers and researchers. In terms of the historical origins of the melodies, Marrett (1985), using the example of a *tōgaku* piece Seigaiha, demonstrated that the *shō* is actually playing the original structural melody, over which the *ryūteki* and *hichiriki* are playing later ornaments.

rolling patterns,[4] and the *taiko*, which is struck at the end of the rhythmic patterns, play the role of "controlling the music as a whole." The roles of different instruments are discussed in more detail below under 'Interview data'.

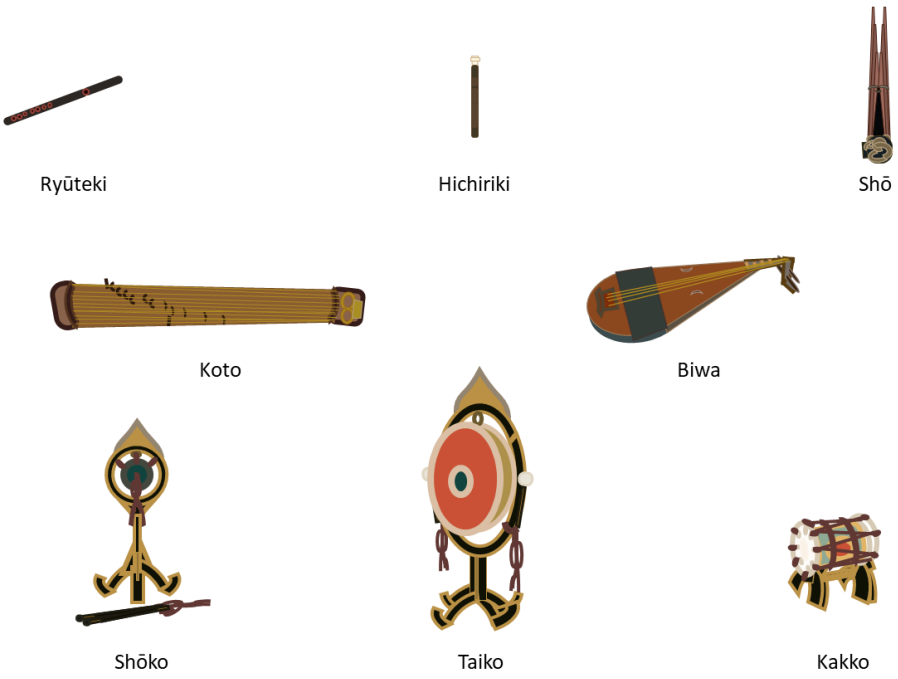

Figure 1. Layout of instruments (drawn by Sayumi Kamata).

METRICAL AND FORMAL STRUCTURE

[8] In this paper, we concentrate on sections (4) Sattō and (5) Juha, which are the two movements organized according to explicit metrical-formal structures. The metrical-formal structures of *tōgaku* pieces, such as these two movements, comprise hierarchically organized multi-level schemes in which fixed numbers of (in this case)

4. "*Kakko* is a double-headed cylindrical drum playing one of three basic patterns with two long, thin sticks. The solid single stroke *sei* is played with the right stick. Two kinds of gradually accelerating rolling patterns—*rai*, with one stick on either side, and the double roll *mororai*—are combined into larger patterns that span the rhythmic cycle." (Terauchi 2011, 31).

4-beat measures or bars (*kobyōshi* 小拍子, literally 'small' *hyōshi*)[5] are combined to form long cycles (*hyōshi* 拍子), and fixed numbers of these cycles make up a movement's formal structure (see Nelson 2008, 55–58). The term *hyōshi* warrants attention here. While it is also prevalent as a Japanese translation of 'meter' in the Western sense, in the *gagaku* context from which it originates the meaning is broader. In sources specifically dealing with instrumental *gagaku* pieces, for instance, Nelson notes that "*Hyōshi* is a term with a broad range of meanings including 'beat', 'meter', and 'rhythm'" (2008, 58), while Terauchi points out that "The *taiko* stroke is called *hyōshi*, a term also indicating the measurement of a rhythmic cycle" (2011, 21). Gamō explains at greater length: "The term '*hyōshi*' has a variety of meanings in *gagaku*, but broadly speaking, they all relate to rhythm. It is important to note that this is not just a rhythm, but a rhythm linked to the act of 'beating.' [...] The '*hyōshi*' has also been adopted into [the translation of] Western musical terminology, but as a musical term it has fallen into disrepute among intellectuals, as it confuses the terms 'beat' and 'measure'." ([1978] 2000, 242–243, translated from Japanese). The term *hyōshi* thus refers to different things in different contexts and should not be confused: in *gagaku*, this one term can be applied to time organization at different levels (from beat up to form) and implies that this organization is effected through the act of 'beating'.

[9] Sattō, one of the pieces analyzed here, is described as '*haya-ya-hyōshi hyōshi-jūroku* 早八拍子 拍子十六': 8 bars of 4 beats each make up one rhythmic cycle, which is repeated 16 times. The other piece, Juha, is '*haya-mu-hyōshi hyōshi-jūroku* 早六拍子 拍子十六': 6 bars of 4 beats each make up one rhythmic cycle, which is repeated 16

5. For the translation of *kobyōshi* as measure see Gamo (1989:18). This effectively interprets the local pattern as metrical, while recognizing the overarching cyclical organization.

times. Both Sattō and Juha adhere to an ABCB structure: the start of the C section is a significant moment known as *hanjō* 半帖 (literally, the half-way point of the piece). The whole ABCB structure can be repeated, in which case the beginning of A is replaced by a phrase called *kandō* 換頭: the present recordings do not include this repetition, comprising in each case a single round of the ABCB form. The *taiko* drum is struck with strict regularity at the end of every cycle, and this is anticipated as the moment when all instruments converge. It should be noted, however, that the melodic phrase cycle and the rhythmic cycle do not begin or end together (see Terauchi 2018, 22–23). For instance, the melodic phrase in Juha begins at the second bar of the rhythmic or percussion cycle: that is, if we count the 6-bar cycle as 123456 according to the melodic phrase led by the winds, the same material is counted as 234561 for the percussion according to the rhythmic pattern structure, which includes many non-sounding moments. Figure 2 illustrates these characteristics in the context of the first two cycles of Juha; our recording of this extract can be viewed as Video Example 1.

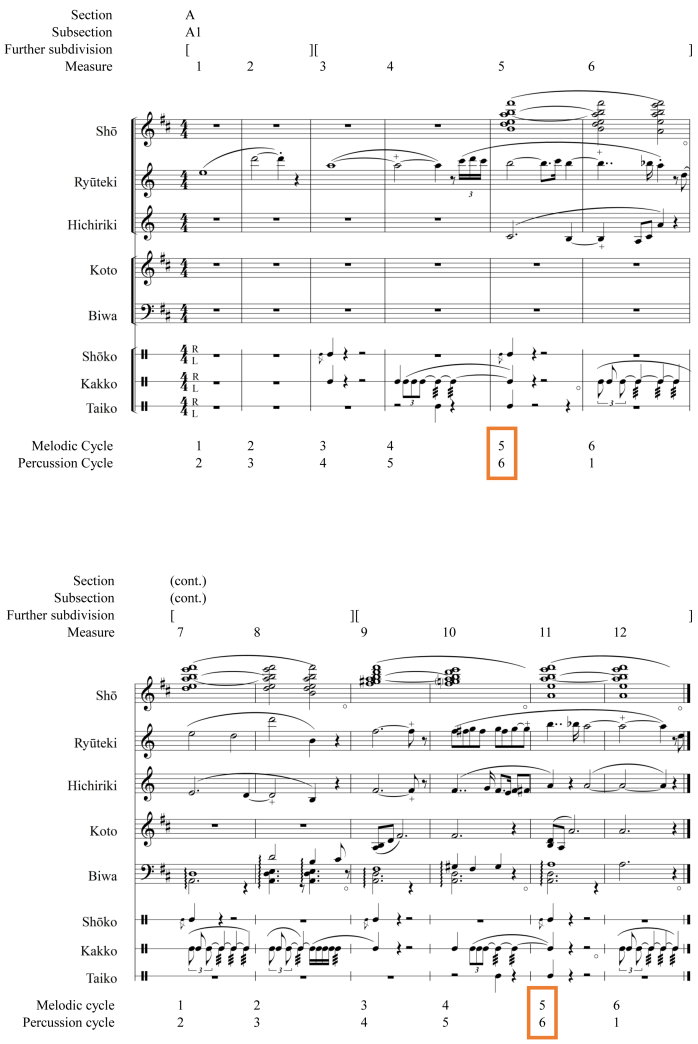

Figure 2. Transcription of the first two rhythmic cycles of Juha. The notation follows that of Shiba (1971, 311), except that the time signature at the beginning has been changed from 2/2 to 4/4[6], and that some parts that are not played at the beginning in Video Example 1 have been omitted. The annotation of section and subsection boundaries is also based on Shiba (ibid., 43–44), according to which this extract corresponds to the first half of section A in ABCB, subsection a1, which can be further divided internally into groups of 2, 4, 2, and 4 measures. The main *taiko* strokes, which are considered convergence points, are highlighted by squares.

6. This is the same choice as in other studies (Nelson 2008, Terauchi 2011), where the 'haya' model of 'four-beat-unit repetition' is notated in 4/4 time signatures. This is consistent with the musicians' statement in the interview that they always count '1, 2, 3, 4' in their minds while playing, and on the slow tempo (the 2/2 'beat' would extend up to 5 secs).

[10] Metrical grids and sectional divisions are illustrated here for both Sattō (Figures 3 and 4) and Juha (Figures 5 and 6). As noted above, while there is no ambiguity as to the focal point of the cycle (the main *taiko* stroke), there are two options for the numbering of measures: the *taiko* does not fall on measure 'one' in either, but rather on the last measure when viewed in the percussion count. Hereafter, the measure counts will follow the melodic cycle.

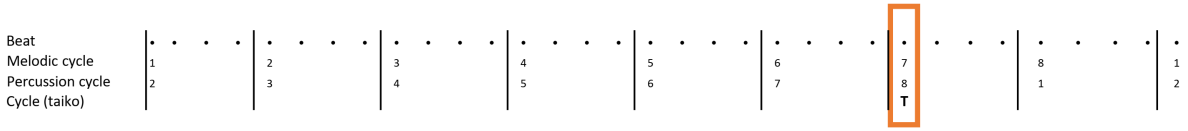

Figure 3. Metrical structure (measures and cycle) in Sattō.

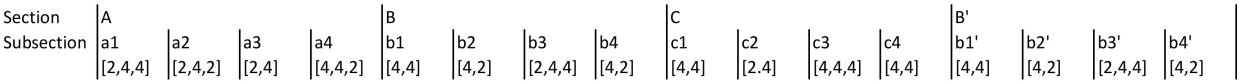

Figure 4. Sectional divisions in Sattō. The annotations of section and subsection boundaries are based on Shiba, also a *gagaku* performer (1971, 42–43). [ ]=number of bars for further subdivisions based on musical formulae of the *ryūteki* melodies, e.g., "a1[2,4,4]" means that subsection a1, which consists of 10 bars, can be divided into 2 bars, 4 bars and 4 bars.

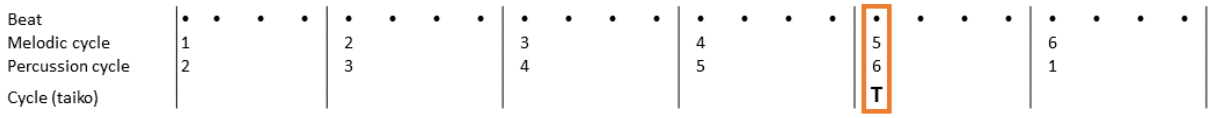

Figure 5. Metrical structure (measures and cycle) in Juha.

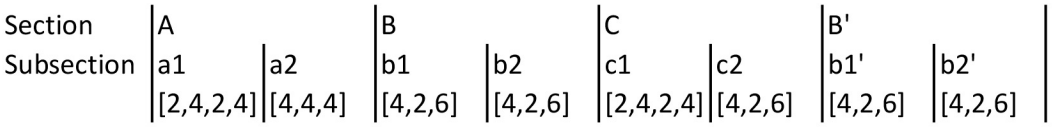

Figure 6. Sectional divisions in Juha. The annotations of section and subsection boundaries are based on Shiba (1971, 43–44).

ISSUES IN TIME ORGANIZATION

[11] Previous studies of contemporary *gagaku* performance have highlighted three prominent characteristics relating to its time organization as performance practices: (a) the gradual acceleration observed as a piece progresses; (b) a markedly drawn-out interval between the last beat (i.e., the fourth beat) and the first beat of the next measure (to put it another way, a somewhat extended fourth beat); and (c) the loose synchronization between the timing of each instrument. The main observations noted are as follows:

a) Continual tempo change is well known to be "one of the characteristics of *gagaku*" (Shōno 1987, 28). Acceleration is not deliberately led by one part or player, but is said to occur "naturally, of its own accord" (Shōno, 30) from a "stylized 'conversation' among the instruments" (Terauchi 2011, 31–2). This can also be discussed in relation to the structural concept known in contemporary usage as *jo-ha-kyū* 序破急. *Jo-ha-kyū* is a compound term referring to the three contrasting music styles '*jo*', '*ha*' and '*kyū*', and the way in which different pieces can be combined to create a coherent compositional progression in *bugaku*. It was extended in the context of other performing arts to convey a wider meaning encompassing the progression or gradual increase in speed. Prior research explains that *jo* means "prelude or beginning", *ha* means "scattering or breaking apart", i.e., "developing in complexity", and *kyū* means "fast" but "here indicates 'a finale that speeds up before coming to a final slow cadence'" (Tokita and Hughes 2008, 26–27).

b) The last beat of the measure is described as "greatly extended in order to give more impact to the first beat" of the next (Garfias 1975, 73). Nelson writes that

"certain beats, especially the final beats in even bars, tend to be drawn out, as the finger-changes of the *shō* are articulated carefully during breaks in the flute and *hichiriki* melodies, and the *biwa* plays the arpeggio which often precedes the first beat of the following bar." (Nelson 2008, 58)

c) A guidebook for school music teachers, produced in collaboration between professional performers, researchers and educators, visualizes this loose synchrony with the help of wave patterns, suggesting an interesting sense in which asynchrony is affirmed as an intentional characteristic rather than a negative looseness (Figure 7). The authors describe the relationship between percussion instruments thus: "The way in which the three percussion instruments are matched depends on a unique sense of rhythm, such as when the *shōko* enters after hearing the sound of the *taiko*, and daring not to align the heads [of the beats] exactly. [...] the percussion instruments listen to each other and strike with subtle timing, so it may sound off, but they dare to 'match' it that way, so observe carefully." (The Society for Connecting Education and Research of Japanese Music, eds. 2019, 35–38, translated from Japanese). The idea of a musical wave could be interpreted in different ways: rather than a large wave crest breaking, what is intended here may be more an image of waves continuously lapping on the shore; thus it is also an image of continuity. In the image reproduced here, note that the new wave seems to be intertwined with the old. As will become clear, however, this image is not one that came up in our interviews with the musicians. It is difficult to know how widely shared this image is.

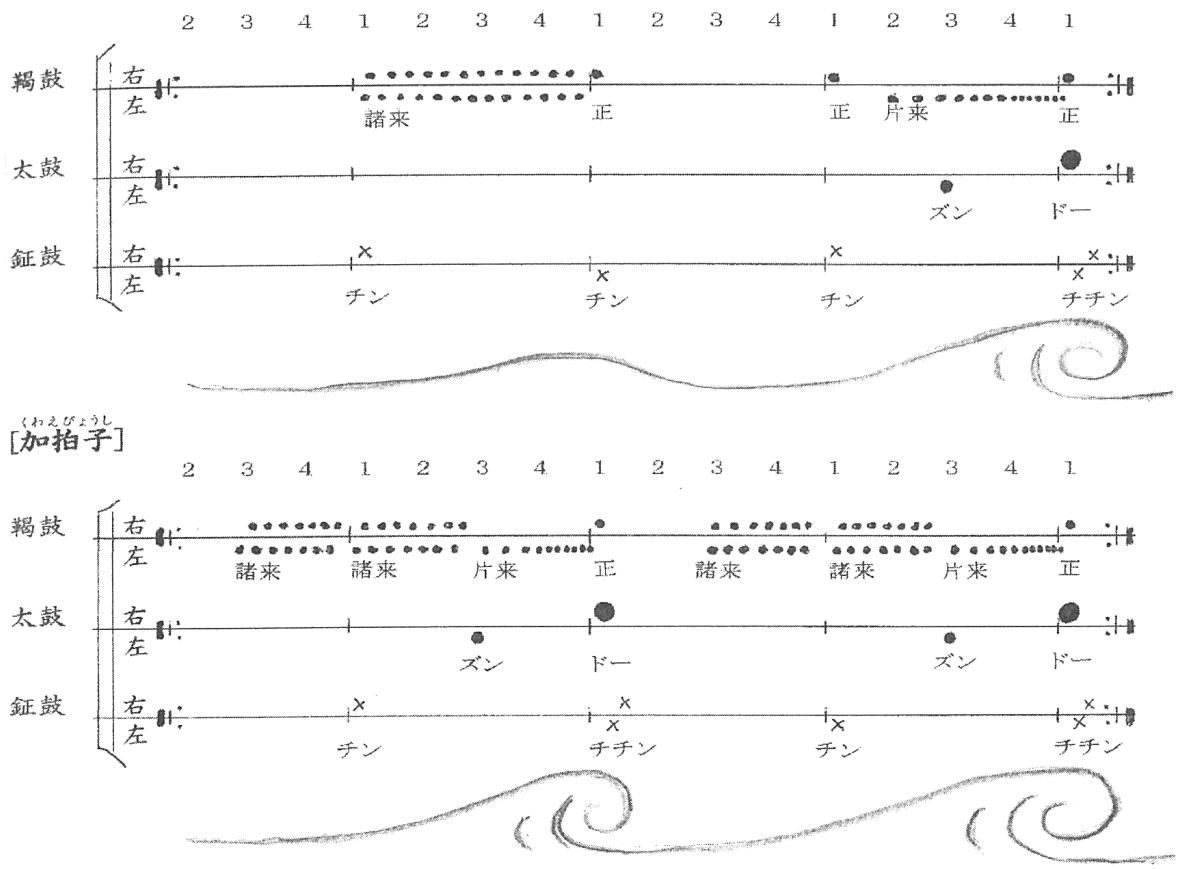

Figure 7. "Hyōjō Etenraku Uchimono no rizumu [Percussion rhythms used in Etenraku in Hyōjō mode]", prepared by Hitomi Nakamura (*gagaku* performer), In *Shōga de manabu nihon ongaku* edited by the Society for Connecting Education and Research of Japanese Music (Tokyo: Ongakunotomosha, 2019), p.37, musical examples 1–3. The upper row shows the first half of the pattern, and the lower row shows the second half. Each row consists of three lines: *kakko* (top), *taiko* (middle) and *shōko* (bottom), with the right-hand strokes shown at the top of each line and the left-hand strokes at the bottom. This image is reproduced with the publisher's permission.

[12] We can thus identify a number of issues relating to the time organization of metrical movements of *tōgaku* which merit further discussion and empirical investigation, which we address here drawing on interviews and audiovisual data, and which have implications both for our understanding of *gagaku* itself and for metrical theory more widely. Firstly, the complex temporal structures over long durations invite discussion of what they may contribute to the theorization of meter. There are

no direct comparators between this system and other musical traditions considered in depth in the theoretical literature, but we can consider rough parallels with gong cycles in gamelan music and long *tāla* cycles in Hindustani music. In gamelan music, different instruments typically articulate different levels of the temporal structure, the largest gong sounding to mark the longest percussion cycle. Long Hindustani *tāla* cycles were the subject of discussion by Clayton (2020), who coined the term 'long-form meters' and argued that extended, multi-layer patterns with a clear moment (called *sam*) at which different parts are felt to come together by experienced, enculturated practitioners and listeners, can be regarded as 'metrical' even if their extent is far longer than the duration of a few seconds usually assumed for a metrical cycle. We make no *a priori* assumption that the cycles of *gagaku* marked by the *taiko* are directly comparable to either gong cycles or *tāla* cycles, nevertheless, in each case there is clear identification of a single convergence point and the cycle durations thereby denoted are of a similar order (tens of seconds, in some cases over a minute). Secondly, we can start to explore acceleration patterns empirically, as a first step towards understanding how this phenomenon emerges from the complex interplay between parts. Thirdly, we can analyze the variability of beat lengths, particularly the extension of the fourth beat. This topic relates to a growing body of literature in rhythmic and metric theory concerning non-isochronous (unequal) time intervals, which can be observed in different kinds of music at various levels from fast beat subdivisions (Polak and London 2014) through beats (London's 'NI meter', 2012) to beat groups (Clayton 2020). Calculation of beat lengths in the present example is complicated by the loose synchronization of different instruments, which can make it difficult to accurately estimate beat positions. Nonetheless we can hope to draw some conclusions about the nature of beat variability in *gagaku* on the basis of these

recordings. While the loose synchronization complicates the calculation of beat lengths, it is one of the most distinctive and aesthetically relevant aspects of *gagaku* rhythm. Thus, finally, we can use these recordings to explore the loose synchronization of instrumental parts and thus the phenomenon of entrainment in this genre. By way of further contextualization we refer to Clayton et al.'s studies of entrainment across diverse musical genres (2020). In this paper an intriguing feature of the corpus studied was noted: that while in general, synchronization accuracy increases with rhythmic density—the faster one plays, the tighter the synchrony—this relationship was not observed to be the case with pairs of percussion instruments. The present study offers the possibility of exploring whether this extends also to the relatively low density percussion parts found in *gagaku*.

INTERVIEW DATA

[13] Before describing our analysis of the two metrical pieces Sattō and Juha from the suite Shunnōden, we further elaborate on some aspects of rhythm and ensemble coordination by drawing on the musicians' accounts: specifically, interviews conducted with *ryūteki* player Takuya Kōketsu, *hichiriki* player Motonori Miura and *shō* player, Junko Yatsuki, all of whom feature in these recordings.[7] The musicians' comments on how they perceive *gagaku* performance are described below, organized into four themes.

---

7. Interview transcripts are published with the audiovisual recordings: see appendix for details. Note that all these interviews were conducted before the analysis was completed in order to avoid unintentionally guiding the conversation through preconceptions. *Gagaku* performers join the ensemble in various roles depending on the occasion, so it was possible to ask questions about the parts other than the wind instruments.

The Role of each Section and Instrument

[14] All three interviewees clearly differentiate each instrument and each instrumental section, complementing the description presented in the Introduction above, noting that each has its distinct function in terms of the temporal structure of the music.

[15] Wind instruments (third row) combine to play 'big melodies' (Kōketsu 00:07:15, Miura 00:02:00). Specifically, the *hichiriki* and *ryūteki* relate most closely to each other, while at breaks in their phrases, the *shō* guides the next phrase with finger position changes (this instrument plays chords, and the changes of chord can be made one finger/pitch at a time) (Kōketsu 00:02:04, Yatsuki 00:23:28). The wind section also has its own role in terms of rhythm and meter: the *ryūteki* starts these pieces and therefore takes responsibility for setting the initial tempo, *ryūteki* and *hichiriki* then move in a closely coordinated way with the latter taking more of a lead. The *shō*'s role is rhythmically significant partly because the others closely follow the rise and fall of its volume (for example, peaking on beat 4 then falling towards beat 1) (Kōketsu 00:24:10). The wind instruments can also stretch the beat on occasions, being principally responsible for such expressive gestures (Kōketsu 00:46:15).

[16] The function of string instruments (second row) is most associated with the word 'rhythm', particularly in terms of marking specific beats (Kōketsu 00:05:41, Yatsuki 00:01:12): the *biwa* has an important role in marking beat one in each cycle (and often beat 3 in Shunnōden)[8] , while the *koto*'s patterns help to establish the

8. In marking onsets we made the decision to mark only the strongest pluck in these cases rather than try to pick out individual onsets within an arpeggio. This important detail is therefore omitted from the onset files.

timing of the other beats in the measure. On the other hand, the overarching function of the percussion instruments (first row) is described as not articulating rhythm as such, but rather marking the point that has been reached in the piece (Yatsuki 00:01:12)[9]. Within the percussion group, the *taiko*'s role in striking the main 'one' of the cycle is clearly crucial, and this is a role with special responsibility: as Miura says, "someone who beats [the drum] with a firm will, as if to indicate 'here it is' […] that kind of person with a strong sense of responsibility is suited to being the *taiko* [player]" (00:19:43). *Kakko* is suited to a senior musician who can support a broad overview of "the overall flow of the music" (Miura 00:10:25, Yatsuki 00:05:20). *Shōko*, in contrast, is regarded as the first percussion instrument that a less experienced player can take charge of in an ensemble, who must be careful not to anticipate the *taiko* (Yatsuki 00:37:25). The functions of these two groups are clearly complementary, and their comments suggest that the *kakko* in particular is not merely marking the structure but also supporting the rhythmic flow. Nonetheless this distinction between the more structural and the more rhythmic role of the two sections seems clear.

[17] Miura pointed out that today's sectional row arrangement is reasonable for performers, both in terms of sections being grouped close together and in terms of strings and percussion being visible to the wind players (00:15:01).

9. According to subsequent descriptions, the 'rhythm' here (Yatsuki actually says 'rizumu' in Japanese) refers to the detailed rhythm that determines the length or speed of each beat. The statements suggest that the percussion functions as a marker of how far the performance has progressed, not at the level of individual beats, but in the repetition of the rhythmic cycle as a whole.

Meter, Tempo and Acceleration

[18] In the context of meter, it is worth noting that while musicians count the beats, they do not require the beats and their subdivisions to be even. The musicians speak frequently of counting the beats ('1,2,3,4') of the measure, and for the higher-level patterns counting '1,2,3,4; 2,2,3,4; 3,2,3,4 etc'. There is very little mention of subdivisions, or events that occur between beat positions, although Kōketsu suggests that "If dividing it into equal [counts], *kakebuki* 掛吹 [*a prescribed upbeat motion of the *ryūteki*] starts on '4.5' of '1, 2, 3, 4', and *kakebuki* ends when everyone comes back on '1' again" (00:31:57); adding that "my teacher plays *kakebuki* as close to the back of the beat as possible, as close to the first beat as possible […] more like a 'storing [a force]' of [melodic] movement towards the first beat." This would suggest that the importance of the 'half-beat' is not so much in providing an even subdivision of the beat, but in providing an upbeat to emphasize the following beat.[10]

[19] The musicians all agree that there should be a gradual acceleration through the metrical pieces, but not too fast. The overall progression is described as a change in feel from "heavy" to "comfortable" (Miura 00:25:51) and settling down to "the right speed" (Yatsuki 00:36:11). We prompted the musicians to talk about the concept of *jo-ha-kyū* (see above) in the broadest sense, including the aesthetic principle of acceleration: its relevance was addressed at the level of multiple piece sequences. Kōketsu stated that as a piece type ideally progresses from *jo* to *kyū*, the sense of beat and *chitsujo* 秩序 (lit. discipline, order) becomes increasingly pronounced, eventually speeding up to reach a certain moment (00:28:34). Yatsuki stated that the feeling of

10. We have not analyzed these instances to estimate the position of 'beat 4.5' due to a lack of sufficient data.

'heaviness' in Sattō and Juha would be less if performed in sequence as a suite than if performed as a stand-alone piece (00:25:20). Miura also suggested that if the metrical pieces are played in succession, the speed at the beginning would be expected to change depending on the order of the pieces— when metrical pieces are played in succession, the initial tempo of a piece may be slightly faster than when played alone, due to the effect of speeding up in an earlier piece (00:23:40).

[20] In line with published accounts (Shono 1987, 30), there is a strong sense that the overall flow of the music increases in tempo "naturally/somehow/unnoticed" rather than accelerating according to the players' intentions (Yatsuki 00:10:23, Miura 00:23:40, Kōketsu 00:16:16). Experience of playing different parts and participating in ensembles is important for the mastery of this tempo change, and interestingly, all three mentioned that inexperienced players tend to rush too much. It is easy to rush after the halfway point (*hanjō*, the C in ABCB), but these professionals say they build some flow up to that point and eventually reach an appropriate and "comfortable" speed (Miura 00:25:20). The repeat of the B section is significant because the repeat (B') should feel different, and a higher tempo for the repeat makes this distinction (Kōketsu 00:18:05). While the corpus is a *kangen* instrumental performance, if it were a *bugaku* with dancers, it would customarily be performed with only winds and percussion, without the strings. In the case of *bugaku*, appropriate speed adjustment is also expressed in the details of the dance movements; that is, if the player has experience of dance they will imagine a comfortable tempo for these movements (Yatsuki 00:36:11).

[21] Miura's description of the acceleration process draws on a striking image of physical coupling between the musicians: "Can we compare it to a three-legged race?

All the players [proceed] together… if each goes too fast at first, you'll fall, but when you get your feet together, you can accelerate. I think people have that nature." (from 00:26:50). This seems to be a clear reference to the idea of interpersonal entrainment as a condition for proper control of tempo. The musicians also mention, however, specific techniques for cutting phrases short in order to deliberately adjust the tempo. ("By cutting the end of that phrase a little shorter... It's a nuance, but it's one way [of communicating that you want to speed up]." Kōketsu, 00:15:09)

Synchronization

[22] The emphasis of the musicians' descriptions is on being aware of the "flow" of the music (Yatsuki 00:23:28, Miura 00:59:26) and communicating with each other during the entire performance, rather than on the others matching the timing of a particular part. On this premise, when musicians talk of 'matching to [a particular instrument]', interpreting carefully, it seems that this does not simply mean matching to its onset timing, but rather being aware of the preliminary (melodic and physical) movements before the beat onset. Commonly mentioned in relation to a wide range of parts are changes in the volume and finger positions of the *shō* player, the arm movements of the *biwa* player, and the arm movements of the *taiko* player. However, Kōketsu states that the *biwa* only determines the starting position of the beat and cannot take the initiative to increase the tempo, suggesting a distinction between the role of 'marker' to emphasize the beat and the role of regulating tempo changes. The first beat of each bar is highlighted as a point of convergence from which coordination can be corrected if necessary.

[23] On the other hand, references were made to specific parts taking the initiative at certain points to set the beat, and to the timing being 'deliberately shifted' in

response. For example, the *kakko* and *shōko*'s timing at the beginning of the piece should be shifted slightly later than that of *ryūteki*, which plays the melody solo, and the *shōko* should be careful not to enter the first beat before the *taiko*. Miura states that there is an acceptable range of discrepancy and describes such phenomena as 'spilling over the beat (*haku ga koboreru* 拍がこぼれる)'. Yatsuki stresses the need for a deep understanding of deliberate shifting, as there is a big difference between those who intentionally shift the timing and those who just shift it accidentally. Kōketsu sees the timing of each instrument as the same, but the timing of each entry's execution (*katachi* 形, lit. form or shape) is left to each instrumentalist.

[24] References to synchronization suggest that the musician takes cues from the preliminary movements of other parts in order to obtain the favorable timing for their instrument in the flow of the music. In particular, the preparatory arm movements for the first beat of the *biwa* and *taiko*, which were mentioned frequently, are worth taking into account in our analysis. It was noted that the *biwa*'s sound is projected forward, making it difficult for wind instrument players positioned behind to hear it in some venues, yet the importance of visibility was mentioned separately from this issue. In the case of the *taiko*, the quality of movement, including the sense of "*ma-ai* 間合い" is important (Yatsuki 00:03:52). *Ma-ai* is a compound of '*ma* 間' (the time or space between two things) and '*ai* 合' (to match or fit), meaning the temporal and/or spatial distance between oneself and another when doing something, often including the nuance of judging the distance and timing appropriately. Another way of looking at the synchrony is, however, to trust that "To some extent, it is like, 'by the time I finish playing the notes that ornament the main

melody [of *hichiriki*], I'm generally going to fit with the other instruments.'" (Kōketsu 00:02:46, speaking as a *ryūteki* player).

[25] Synchrony *within* instrumental sections may be particularly important. For example, interviewees talk of the unity of the wind section: "I think that if each of us is aware that the three winds are playing a big melody together with almost the same breath, we can feel closer [to each other], and the three winds can synchronize and create a sense of groove (*gurūbu kan*)". (Miura 00:02:00). Additionally, the *ryūteki* and *hichiriki* should be particularly close, supported by the *shō*, whose player is also attentive to any inappropriate misalignment of the other two (Yatsuki 00:06:34). Similarly, the *biwa* and *koto*, and the three percussions, should be tightly linked. Both the strings, in the sense that the *biwa* indicates the first beat and the *koto* the subsequent beats, and the percussions, in the sense that the three work together to form each rhythmic pattern, must be aware of each other within the section. (Miura 00:03:05, Kōketsu 00:05:41, Yatsuki 00:37:25)

[26] It is interesting for the present analysis that Miura speaks of the importance of timing to the genre as a whole: "the most important thing is timing in the ensemble." (00:35:09). Good timing does not, however, imply simultaneity: "It is all right that there is a slight *zure* ずれ (lit. gap) by following the person who is in charge of leading […] The 'spilling over the beat' as a result of following [appropriately] the person in the leading role is something that should be allowed, yes. It's also part of the *aji* 味 (lit. flavour, taste) [of *gagaku*]." (00:44:09) Miura links this to the more general ideas of discrepancy and imbalance, and the appeal of the imperfect, such as the circle drawn freehand (00:45:46).

Leadership

[27] There is no clear leader of the ensemble, or, at least, there seems to be a distributed leadership model. For example, the *kakko* player takes the lead in introducing the piece by holding up the instrument. The *ryūteki* opens the piece, then the *hichiriki* takes more of a leading role within the wind section. The *biwa* takes responsibility for marking beat 1, the *taiko* for marking the cycle, and the *koto* for articulating the other beats. The *shō* has a crucial supporting role and is closely followed by the others. In fact, the only instrument not described as having an important leadership role is the *shōko*.[11]

[28] Miura also speaks of the importance of a "spiritual pillar" of the group, which is not solely determined by the role of the instrument in charge: "a reliable and competent player among the whole can 'take the lead (*ondo o toru* 音頭を取る)', and a flow is naturally created in which such a person leads the ensemble. This has a great influence on the whole ensemble and makes it easier for the ensemble to come together" (00:05:58). While Miura acknowledges leadership in this way, greater significance is placed on communication and collaboration across the group:

[29] "If I am, for example, the *ondo* 音頭 [*principal player when there are several players performing the same instrument, as in a normal formation of three wind instruments each] of the *hichiriki* part, I play with the awareness that I am leading [the others]. But if only one person leads, it will not be good music. It's communication after all. While communicating, while listening to the 'voices' of the other instruments, while somehow sensing the flow, or while sensing the

11. See also Terauchi 2011, 34.

atmosphere… I have to make sounds. So [even in the role of the principal player], there are a lot of parts of what I do that are dependent on others in the ensemble." (00:59:26)

[30] There is, in fact, an ideal balance between adapting to the others and 'making one's own statement': Kōketsu mentions that players of a certain level can 'communicate the intention' or 'sense each other (*sasshiau* 察し合う)' (00:13:06). On wind instruments, he says, "there are some [phrases] where the players tend to stretch out the beat comfortably, but in such cases, the players may wait for a while with each other" (00:46:15). Note that the details of this kind of awareness naturally differ depending on which of the three wind instruments the player specializes in. Yatsuki says that in the case of the *shō*, even though the part seems to be taking the initiative, for the player "it is not so much [a sense of] 'leading', but more a sense of 'carrying and guiding' so that [*hichiriki* and *ryūteki*] can perform well" (00:23:28).

[31] Miura concludes his opinion as follows:

"When I think about what good '*chōwa* 調和' (lit. match, harmony, a balanced blend) is, I realize it's not just about… matching or adapting to other people. That's how I feel when I play *gagaku*. I also have my statements, I don't just go along [with the other parts]. I think that the ultimate '*chōwa*' is when [the players are] responsible for making [their] 'statements' and doing [their] role and also listening to the other's 'voice' and becoming one." (1:06:21)

Analysis

[32] We have introduced a number of issues identified both in the literature and in interviews with performing musicians, which point to some key issues: particularly

around the process of acceleration, extended fourth beats, and loose synchronization. We now address these issues with the help of an empirical, quantitative study of a recorded corpus, interpreting our findings in the light of the foregoing discussion as well as exploring its significance for rhythmic theory more generally. In order to do so, we make use of various forms of annotation of the recordings: manual markup of the metrical and formal structures of the pieces, and timing data relating to rhythmic events (the moments at which percussion instruments are struck, strings plucked, and notes articulated or chords changed by the winds). We also make use of movement data extracted from the video recordings; as we have shown, awareness of their own and others' movements is very important for the musicians, and this data can help us to understand the organization of the music.

[33] A significant amount of numerical data was extracted from the recordings relating to both discrete rhythmic events (instrumental onsets/changes) and continuous changes (movement data; we also refer below, *ad hoc*, to dynamic curves extracted from audio tracks).[12] Visualization and analysis of this derived data was carried out in R.[13]

---

12. Full details of this process are given in Clayton et al. 2023.

13. To facilitate this analysis two packages were used which were developed specifically for the analysis of synchronization and coordination in musical ensembles. See Clayton et al. 2023 for R scripts.
• Onsetsync (Eerola & Clayton 2024). Focused primarily on analysis of onset asynchronies, and hence of sensorimotor synchronization between performers. This package also includes periodicity detection functions which can be applied to (gaussified) onset data.
• Movementsync (Eerola, Clayton & Emms 2023). Focused primarily on analysis of movement data, including the detection of periodicities (using FFT and wavelet analysis), movement coordination (cross-wavelet transforms) and leadership (Granger causality). It also handles onset asynchrony calculations, complementing the functions of onsetsync.

[34] Our analysis is presented in two sections. The first covers aspects of temporal structure: in particular, how do the beat lengths vary, and how does the ensemble accelerate in these performances? The second covers synchronization: how are the instrumental 'onsets' coordinated?

TEMPORAL STRUCTURE (METER AND TEMPO)

[35] As described above, we have a clear theoretical description of the temporal structure as it extends from beat level up to formal level. Here we are concerned mostly with what we might call the metrical levels, by which we mean the organization of 4-beat groups into measures, and the collection of (6 or 8) measures into cycles marked by *taiko* strokes. The recordings analyzed here match these theoretical descriptions and representations in notation. Our task is first to show how the abstract 'grid' described in these words maps onto the musical surface; then to explore what is meant in practice by flexible or stretched beats; and then to describe the acceleration patterns in more detail.

Metrical Structure

[36] The cycles used in Sattō and Juha can be expressed diagrammatically as in Figures 3 and 5 above. The obvious next questions, for the newcomer to the genre at least, would be: apart from the *taiko* stroke, what differences exist between measures within a cycle? How do we know where we are in the cycle?

[37] Recall in the summary of the interview data the observation that the percussion instruments "do not represent rhythm, but rather indicate where in the piece they are playing." In fact, the places in the cycle articulated by each of the percussion *and* string instruments is very consistent. This can be illustrated in a representation

plotting the relative positions of selected instrumental onsets, shown in relation to calculated isochronous beat positions for Juha (see Figure 8). The two *shōko* strokes occur (left and right hands in quick succession) on the first beat of measures 1, 3 and 5, while the *taiko* strokes fall on the 3rd beat of M4 then the first of M5. The *biwa* and *koto* play closely related patterns articulating the first beat of each measure: the *biwa* also articulates the 3rd beat of even-numbered measures, the *koto* the 2nd and/or 3rd beats. (As noted above, the *biwa* player strums the instrument, articulating an arpeggio: the individual onsets are not represented in the figure.) In addition to this, we can see that the *kakko* fills measures 1, 2, 4 & 6 with its patterns but is silent in measures 3 & 5 after the solid single stroke (*sei* 正) on the first beat (in these measures none of the percussion or string instruments articulate the 3rd beat). The net result is that each measure has its own unique combination of instrumental rhythms. Another way of putting this is that rather than the meter existing as an abstract framework within which the percussion and strings can articulate various rhythmic patterns, the rhythmic placement of each instrument's onsets combines to articulate the metrical structure.[14]

14. To nuance this slightly, the *biwa* does not always articulate beat 3 as it does in this piece, while the application of the *kakko* patterns also varies between pieces, thus the articulation of the meter through the rhythmic pattern of percussion and strings is to some extent specific to the piece being played.

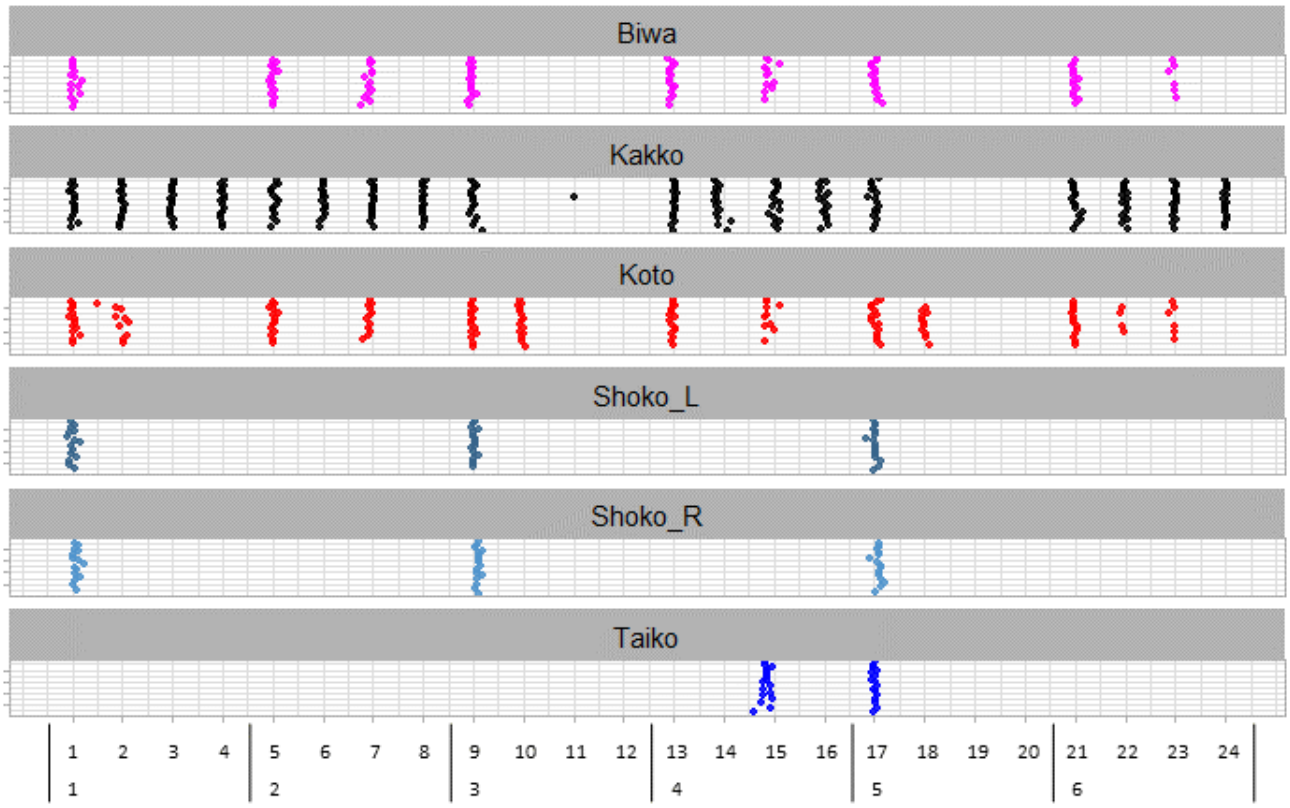

Figure 8. Metric positions of percussion and string onsets in Juha. Each cycle runs from left to right, and the piece as a whole from bottom to top within each frame. The 'beat positions' indicated by light grey vertical lines and reference numbers are estimated as follows: the first beat of each measure is estimated manually (marked by an expert listener), and the other subdivisions are calculated by dividing each cycle equally into four. Onsets selected for display are those which fall close to these nominal beat positions, and these are checked manually for accuracy. The light grey vertical lines indicating 'beat positions' are thus included for guidance only and do not imply that the music has a strictly isochronous beat. Note that the only *kakko* onsets plotted here are those that happen to fall near to beat positions; there are many others that do not. Thus, this information is useful only in illustrating which bars are filled by the *kakko* and which are not. In fact, the *kakko* plays gradually accelerating rolling patterns on the different beats, using either one or both sticks.

[38] A similar situation can be observed in the longer cycle used in Sattō (Figure 9). Here the *taiko*'s main stroke falls on the first beat of M7; the *kakko* is silent after the 1st beat in measures 3, 5 and 7; and the *shōko* plays double strokes on measures 1, 3, 5,

6 and 7 and a single stroke on M8. The *biwa* again subdivides the even measures (M2 only some of the time), and the *koto* marks the 2nd and/or 3rd beat.

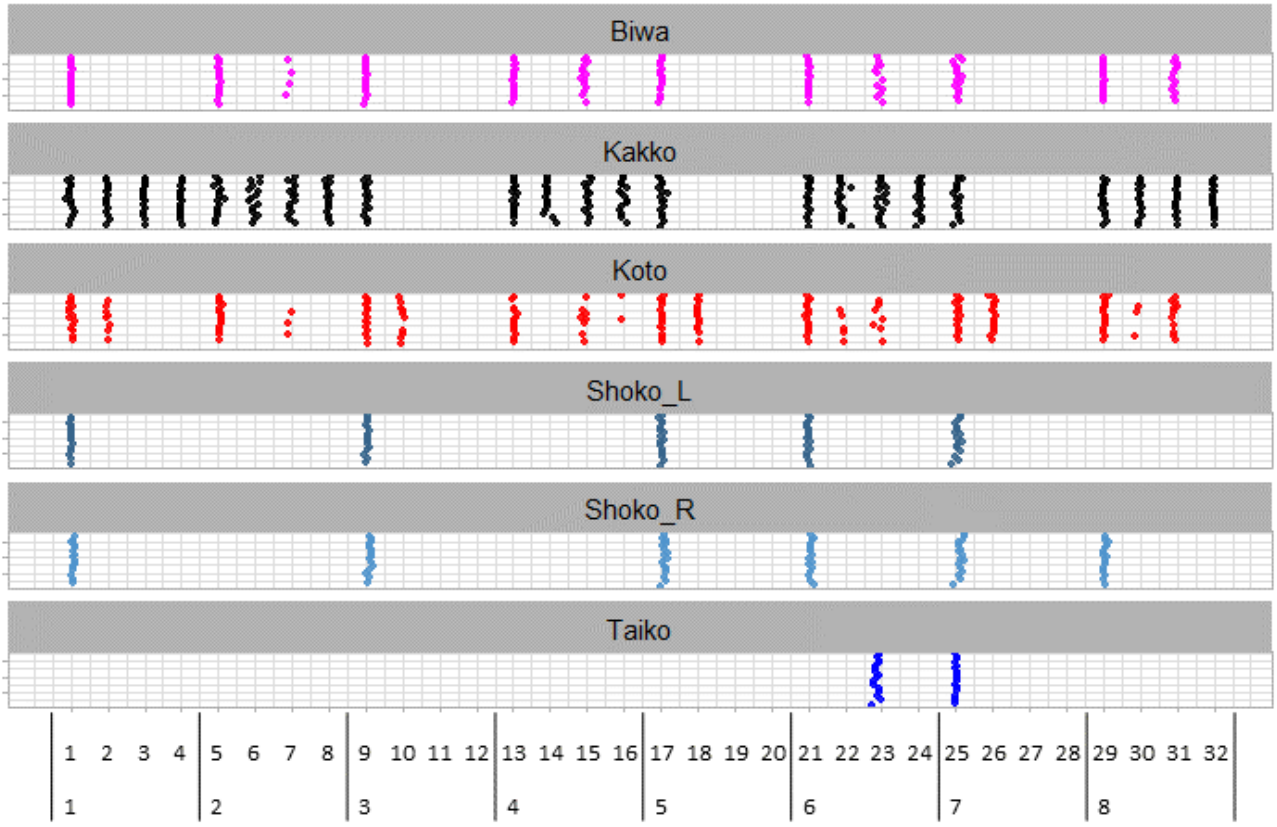

Figure 9. Metrical positions of percussion and string onsets in Sattō.

[39] Garfias writes that "Typically the first beat is stressed and a weaker but marked stress is given to the third beat. However, there is also a slight stress given to the fourth beat, in order to mark its place, but never so strong as to detract from the strength of the third beat." (1975, 73) The picture emerging here backs up Garfias' description of the importance of beats 1 and 3, in that the first beat position receives the most instrumental onsets over the cycle, followed by beat 3. However, beat 4 is not articulated by either the strings or percussion (although *kakko* strokes certainly

fall in that region): the 'marking out of the fourth beat' that Garfias notes, and its stress, is clearly achieved by some other means.

[40] Because the highest concentration of sound events (onsets) is found on beat 1, this means the highest concentration of activity *preparing for* these sound events is in fact spread over the course of beat 4 (and earlier, as we will show). As we know from interviews with the musicians, they give great importance to watching the preparatory movements of the *taiko*, *shōko* and *biwa*: instruments whose role is to mark beat 1, and to a lesser extent beat 3. To illustrate the sequence of events leading up to a *taiko* stroke we can visualize a number of key elements in a measure to see how this works (see Figure 10).

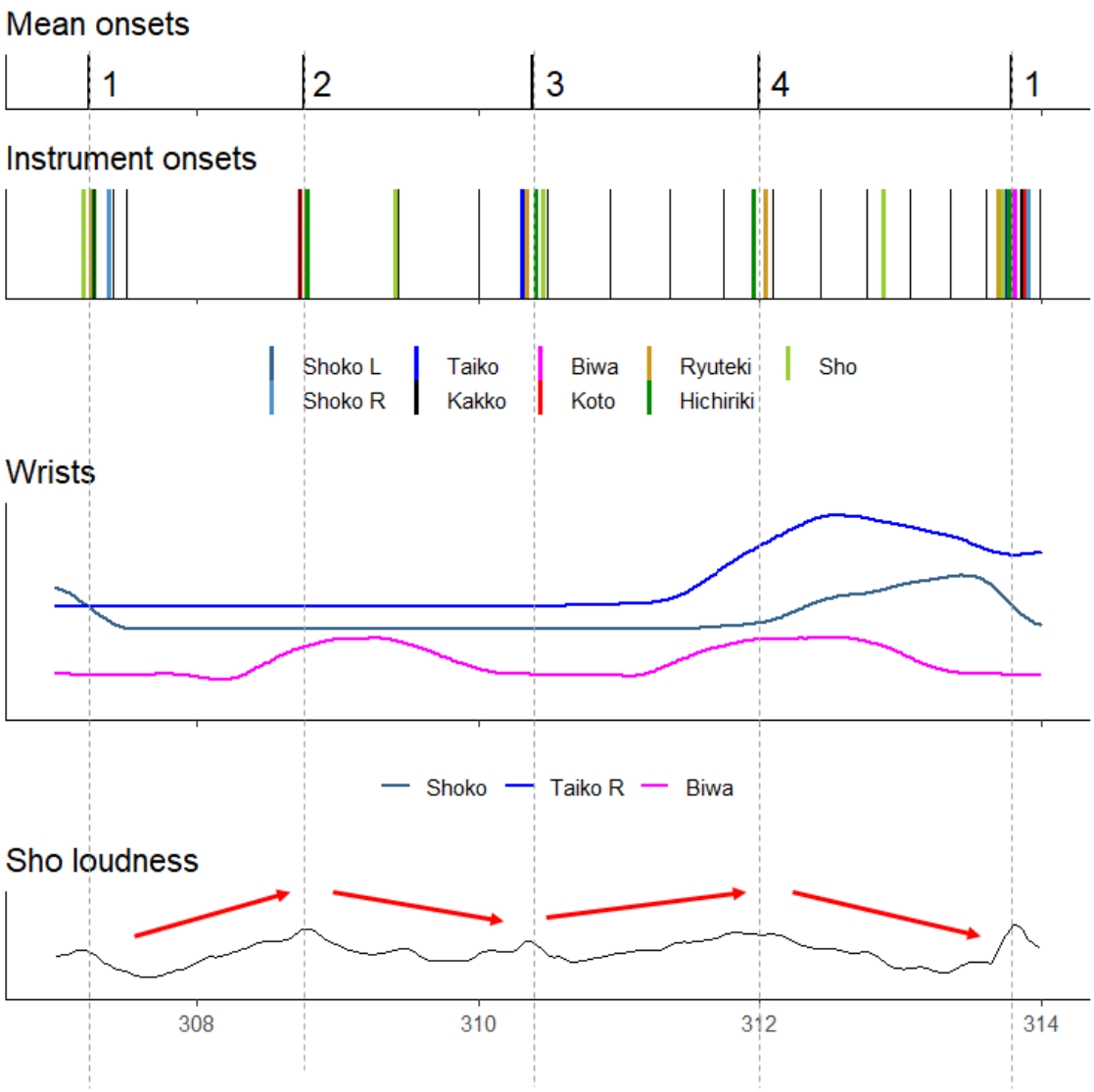

Figure 10. An example measure from Sattō (bar 38, 307–314 secs), illustrating the relationship between discrete events (onsets) and continuous processes (wrist movements, the dynamic contour of the *shō*). Units (y-axis) are not included since they are based on normalized data and are essentially arbitrary. Beat positions (top line) are based on mean onset positions; the gray dashed lines provide a beat reference for the other charts, with time reference on the bottom chart only. *Kakko* onsets are in full line width on beat one only, while for intermediate strokes thinner lines are used. Since bleed from other instruments interferes with the *shō* loudness plot, red arrows give a clearer indication of the rise and fall in this instrument's volume. Video Example 2 covers this example (5'7" to 5'15", camera 3).

[41] Figure 10 (see also Video Example 2) is taken from Sattō, a little after 5 minutes into the performance. All four beats of the measure are illustrated. The Instrument

onsets panel illustrates the clustering of discrete events around the beat positions, particularly 1. The accelerating *kakko* pattern is illustrated with thinner lines. The lower panels illustrate some of the continuous processes which were highlighted by the musicians as being significant to the time organization: the wrist movements of the *taiko*, *shōko* and *biwa* players as they prepare to mark beats 1 and 3, and the rise and fall in dynamic level of the *shō*. We can see from the movement data how the *biwa* player's right hand rises and falls as it marks beats 1 & 3. The *taiko* player's right wrist rises and falls more sharply to mark beat 1. The *shōko* player's wrist rises a little later and falls more sharply still.[15] Meanwhile, the *shō*'s sound rises and falls between beat 1 and 3, and again between 3 & 1 (peaking around beats 2 & 4). The idea of the 'ma-ai' pause in the *taiko* player's movement came up in the interviews; this may be related to the multi-phase movement (preparation followed by stroke) observed here. Note that the onset marked in the mid-point of beat 4 (in green) marks a point when the *shō* changes finger position, another factor mentioned by the musicians in interview as being significant.

[42] These observations are consistent with those of Terauchi (2011, 34), according to whom the parts (and their specific elements) that are the focus of the ensemble from beats 4–1 are as follows: *shō* (preceding finger change *teutsuri* 手移り), *biwa* (preceding notes of arpeggio), *kakko* (tremolo by the left stick [*NB. focused over beats 2–3–4–1]), and *taiko* (weak stroke of the left hand [*NB. focused over beats 3–4–1]). Nelson (2008, 58) also mentions *shō* (the finger-changes are articulated carefully

15. One reason the *shōko* player's movement seems more marked here is that there is a larger horizontal dimension in the *taiko* player's right wrist. The velocity profiles below take account of both x- and y-dimensions.

during breaks in the flute and *hichiriki* melodies) and *biwa* (the arpeggio which often precedes the first beat of the following bar) in this regard. Figure 10 stresses the importance in this process not only of discrete *events*, but also of the tracking of *continuous* processes.

[43] The top line of Figure 10 illustrates estimates of the beat positions: these are the averages of the onset times of all instruments except the *shō* (which, because of the aforementioned factor, would skew the result), and including only the left-hand stroke of the *shōko*. As can be seen from the illustration, the onsets are spread over an extended duration—as will be discussed below—and there is no reason to believe that the mean onset position is privileged as 'the' beat. Nonetheless, this is a pragmatic way of estimating a beat position in order to quantify the 'stretching' of the fourth beat. In this particular measure the beat durations are 1.52, 1.62, 1.61 and 1.79 seconds respectively (23.3, 24.8, 24.6 and 27.3% of the measure), which is consistent with the idea of the stretched fourth beat: in this case beat 4 is about 180ms longer (about 10%) than would have been expected on the basis of the previous two.[16]

[44] This effect is found across both pieces, as illustrated in Figure 11, which shows that beat 4 and, to a lesser extent, beat 2, are longer than 1 and 3. In both pieces there are a significant number of outliers affecting the proportions of beats 3 and 4. These data points relate to beat positions where one or more of the wind instruments effects its pitch change particularly early or late, demonstrating their considerable latitude in this respect (see interview data on the wind instruments stretching the beat). Average

16. Based on the mean beat positions calculated as described above.

beat proportions are summarized in Table 2.[17] It is important to keep in mind the context of what is happening in these beats, however: the preparatory movements of the *taiko*, *biwa*, and *shōko* players actually begin shortly after the third beat, which may contribute to the sense of beat 4 being stretched; this sense may be further enhanced by the *shō* player's gradual changes in finger position, and the arpeggio which slows the arrival of beat one on the *biwa* (the last note of the arpeggio being felt as falling on the beat).

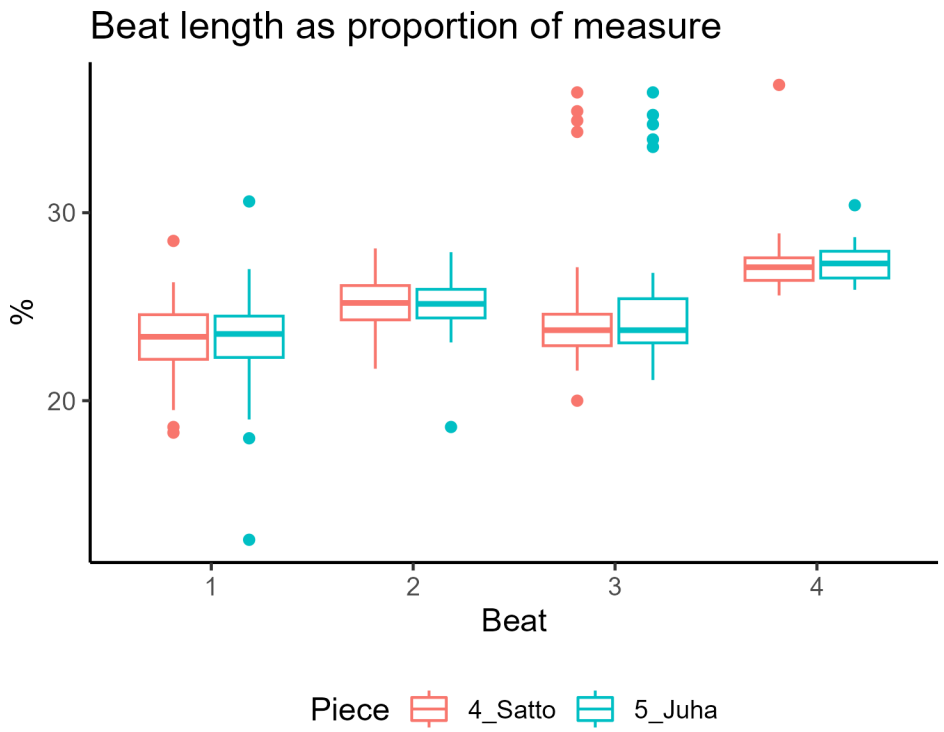

Figure 11. Beat lengths as a proportion of the measure in Sattō and Juha.

17. Note that we did not find this effect to be stronger in even bars than odd (see point b under 'Issues in time organization').

	Proportion	
Beat	Mean %	SD
1	23.2	2.1
2	25.2	1.6
3	24.9	3.6
4	26.5	3.1

Table 2. Mean beat proportions of the measure in Sattō and Juha, with standard deviations

Tempo and Absolute Durations

[45] Before considering the acceleration in detail, we summarize the data on tempo and on the ranges of beat, measure, and cycle durations (Table 3). The beat lengths are notably long, and tempo low, especially when taking into account the fact that beats are not consistently subdivided: maintaining a regular tempo in the 30–40 bpm range is challenging in the absence of such subdivision. Cycle durations, meanwhile, are typically between ½ minute and 1 minute. London has suggested that the extent of the psychological present (5–6 seconds) places a limit on the duration of metrical units (2012, 27), which would place many measures in these recordings outside the limits of meter; Clayton's suggestion that this limit can be circumvented through cultural knowledge (2020) may however also apply in this case.

	Sattō		**Juha**	
	Range	Mean	Range	Mean
Mean beat duration (**s**)	1.2–2.7	1.6	1.1–2.3	1.5
Measure duration (**s**)	4.9–10.8	6.4	4.5–9.2	5.9
Cycle duration (**s**)	41–70	51.8	28–52	35.5
Tempo (**bpm**)	22.3–48.8	38.7	26.0–53.4	42.2

Table 3. Summary data: tempo (beats per minute) and interval durations (seconds) for Sattō and Juha.

[46] Figure 12 illustrates the patterns of tempo change for the two pieces in parallel: the most obvious feature is their (rather similar) acceleration patterns. A couple of features of these curves are worth pointing out. First, the opening part of the A section does not show a clear acceleration. At this stage the *ryūteki* is opening the pieces, with the percussive (and meter-marking) elements being only gradually introduced. It is also notable that the acceleration seems to be paused at the half-way point *hanjō* (start of C), before picking up again, especially in B'. Again, the interview data is instructive here, where the significance of the mid-point in the structure in relation to acceleration is noted. It may be that the relative stability of tempo here is due to the musicians' awareness of the danger of rushing at this point. Also noted in the interviews is the idea that the repetition of the B section (B') should be distinguished by a higher tempo.

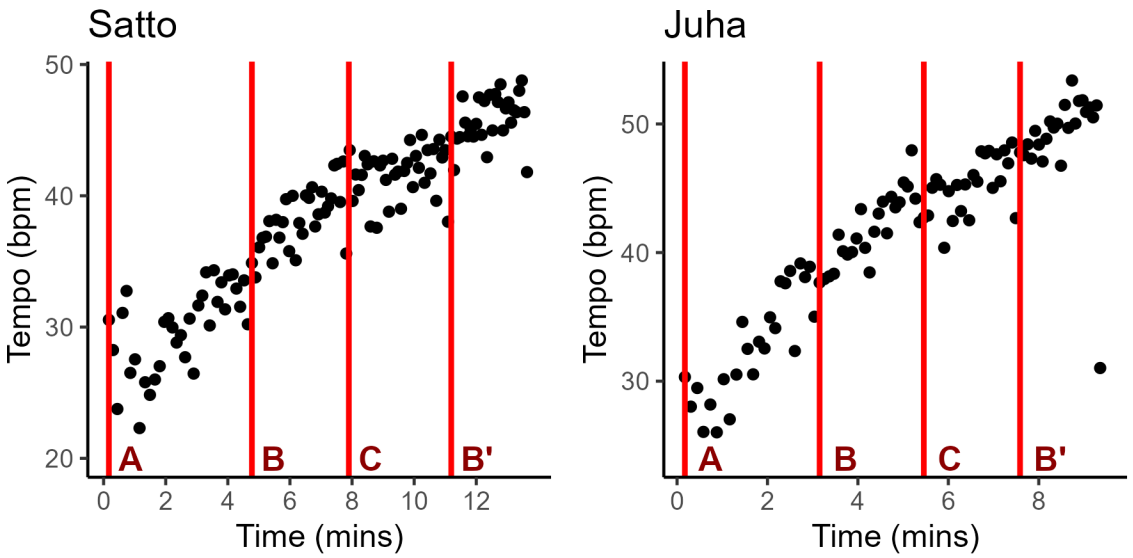

Figure 12. Tempo plots with Section divisions for Sattō and Juha (data points derived from estimates of the duration of each 4-beat cycle).

SYNCHRONIZATION

[47] Synchronization between instrumental parts can be calculated from onset timing information, using standard measures established by Rasch (1988). Those referred to in the analysis below are summarized in Table 4. 'Precision' measures evaluate how consistent the relationship between two parts is, while 'accuracy' measures explore the mean relative positions (i.e., whether an instrument is played ahead or behind another, or with respect to the group average).

PRECISION	Pairwise asynchronization	= SD of the onset time differences of simultaneous sounds of two parts (Rasch 1988, 73)
	Group asynchronization (**A**)	= RMS of all Pairwise asynchronization values (Rasch 1988, 74)
ACCURACY (RELATIVE POSITION)	Mean pairwise asynchrony	Relative position of two instruments calculated as the mean difference in their onsets, i.e., the signed asynchrony values

Table 4. Selected synchronization measures.

Tightness Of Synchronization (‘Precision’)

[48] When the synchronization of the *gagaku* ensemble is described as ‘loose’ this implies a comparison with other forms of music. In order to demonstrate that the synchronization is indeed ‘loose’, therefore, the empirical analysis of this corpus should be set in a broader context. Synchronization measures computed by Clayton et al. (2020) for a diverse range of six other musical genres allow us to do this. It is clear (see Table 5) that the synchronization in *gagaku* is, as expected, much looser than in any of these comparators. This is not surprising, since loose synchronization has already been noted as a feature of *gagaku* to be positively aestheticized (although not previously quantified); we have also seen above how various instrumental events articulating a beat may be spread over significant durations (in Figure 10 above, in which the spread of the percussion and string onsets on the final beat is about 100 ms).[18]

18. *Shoko*_R at 313.905 secs, *biwa* at 313.803 secs.

Corpus	Number of parts	A (ms)	Range of pairwise asynchronisation (ms)
Malian Jembe	4	15.6	12.6–18.8
Uruguayan Candombe	4	18.1	16.4–20.4
Cuban Son and Salsa	7	24.4	13.1–33.4
Tunisian Stambeli	2	28.0	18.7–34.7
North Indian Raga	2	29.1	18.5–54.0
European String Quartet	4	35.2	31.6–38.2
Gagaku	7	90.7	60–123

Table 5. Summary of group and pairwise asynchronization (based on Clayton et al. 2020). Nb. *Shō* is omitted from the calculation; *Shōko* L only used.

[49] Clayton et al. 2020 noted that in this diverse set of genres, synchronization between pairs of drums or percussion instruments tends to be tight (SD_{async} < 25 ms) and does not vary with rhythmic density (how fast the musicians are playing). This suggested that synchronization precision may be decoupled from rhythmic density in percussion ensembles, but left open the possibility that what was being observed was a ceiling effect: i.e., that synchronization precision is correlated with density also for drum/percussion groups, but hits a ceiling around 10–12ms. If this were the case, the authors hypothesized that if the rhythmic density is low enough, the precision would fall (the SD_{async} measure would rise) even for drum/percussion pairs. The present example demonstrates that this is indeed the case: even the percussion-only pairs have high asynchronization values. Indeed, if we plot SD_{async} against summed density for the *gagaku* examples alongside the Interpersonal Entrainment in Music Performance corpora, the *gagaku* corpus clearly stands out for both its low density and high variability (Figure 13). Note that the Gagaku data points with relatively high summed

densities—those to the right of the main group—are those including all of the *kakko* onsets; since the *kakko* plays gradually accelerating patterns with a higher density rather than articulating a regular beat subdivision, it seems it does not contribute to the synchronization of rhythmic events. The all-percussion pairs in *gagaku* are clustered between SD_{async} = 88–97ms, far from the 10–26ms range of percussion pairs from the other corpora.

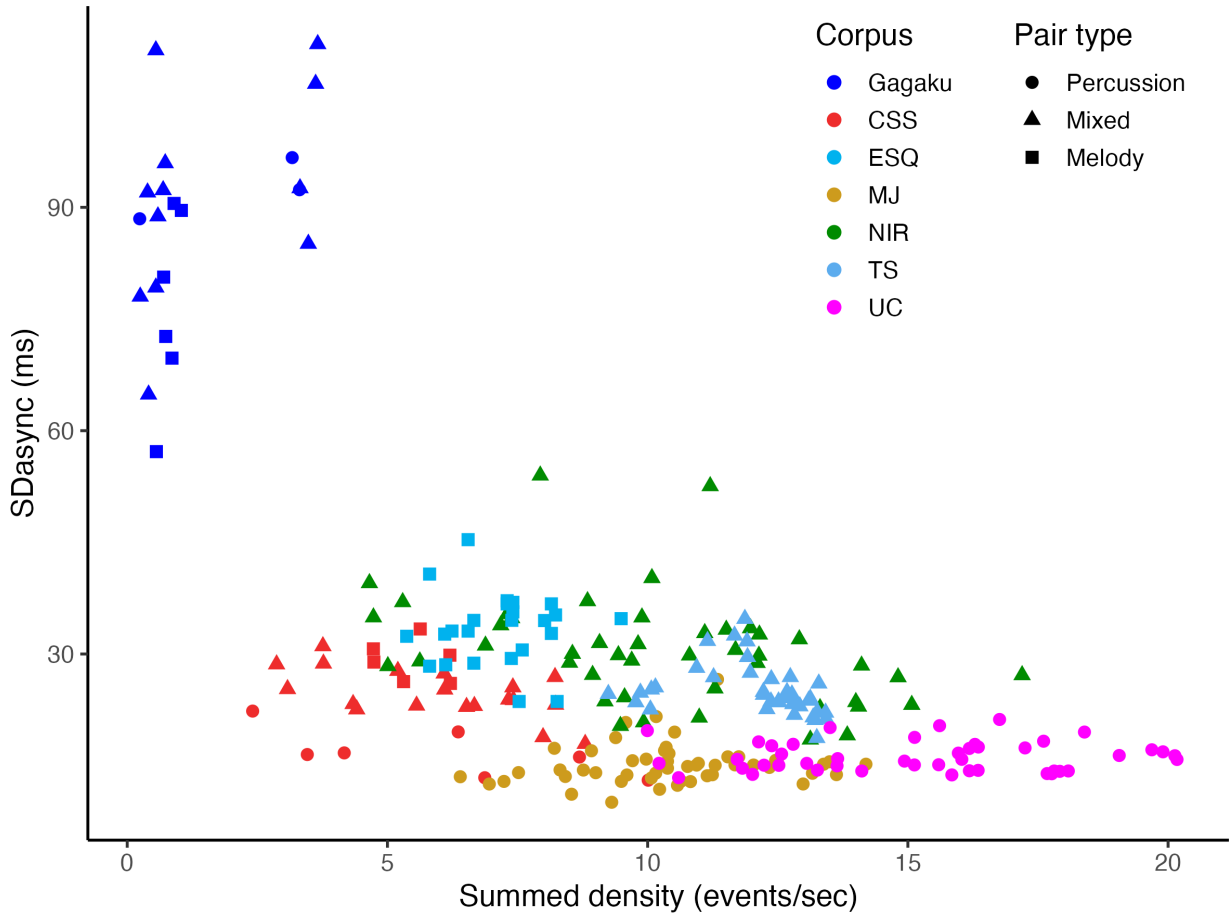

Figure 13. Asynchronisation vs. summed density for pairs within the *gagaku* ensemble plotted together with six contrasting corpora (cf. Clayton et al 2020).

[50] We may look in a little more detail at what these statistics reflect. In fast (high density) musical genres such as many Afrogenic drum ensembles, a lot of sonic cues are available to afford precise synchrony, commonly featuring sounds with sharp

onsets (sound envelopes with steep rises in energy) occurring every 100ms or so. This allows synchronization precision to reach levels as high as 10–12ms. In the present example, beats are over a second long (average c. 1.5s) and are not typically subdivided in a regular fashion. As we have seen in the previous section, musicians use cues such as the raising of players' wrists in preparation to play, and the rise and fall of the *shō*'s dynamics, to know when to play themselves. These trajectories are not intended to support the same levels of precision seen in the Afrogenic music corpora, but rather to allow for loosely synchronized coordination based on a different aesthetic: as mentioned earlier, for the musicians, good timing does not imply simultaneity. The music's character would be very different if the instruments marking beat one fell within a window of 50ms rather than up to 700ms (on the first *taiko* beat of Sattō). Were the *kakko* to articulate 4 or 8 even subdivisions of the beat, the emphasized 'deliberate shifting' (See Interviews/Synchronization), i.e. the wide tolerance, might have been diminished. This would dramatically change the effect of the music and go against the genre's aesthetic values. Interviews suggest that the unity *within sections* of the ensemble is particularly important. This is not reflected in the asynchronization figures (Table 6), although it must be admitted that the number of pairings is limited (only one pair in the case of the strings; also in case of the winds only one pair is considered here, as the data for *shō* includes many outliers due to the inclusion of pitch changes before beat one which skews the calculations). In terms of group asynchronization calculations, the string pair stand out as particularly tight, but the percussion section has a particularly high variability. This observation is consistent with the point emerging from the interview data that the strings mark rhythm and the percussion section marks not rhythm but rather form ("the place reached in the piece").

Perc. only	Strings only	Wind only	Wind-Strings	Strings-Perc.	Wind-Perc.
96.6	59.5	87.7	83.1	81.0	105.3

Table 6. Group asynchronization figures within and between instrumental sections (ms).

Relative Position ('Accuracy')

[51] The other aspect of synchronization that we can measure is accuracy, or the relative position of different instruments. Granted that onsets sound over an extended duration on a given beat position, do they fall in a fixed order? There may be time for some players to wait for others to play and then react by playing themselves: is this what happens? We can start to get an idea of this by plotting the onset positions for the first few main *taiko* strokes of Sattō. The first six such cases (Figure 14) show that the spread reduces from c. 700ms on the first cycle to about 200ms on the sixth; it also shows that there is no fixed order of events. We may observe some tendencies: the wind instruments *ryūteki* and *hichiriki* tend to mark their pitch changes or begin new phrases towards the start of the beat position. The left-hand stroke of the *shōko* falls towards the center of the beat, with the *koto* and *biwa*, and the right-hand *shōko* stroke (which follows about 110ms later, regardless of tempo) towards the end. The *taiko* falls towards the center or later. However, even in this small sample there is a lot of variability, and there appear to be no fixed rules solely based on the relationships between instrumental parts.

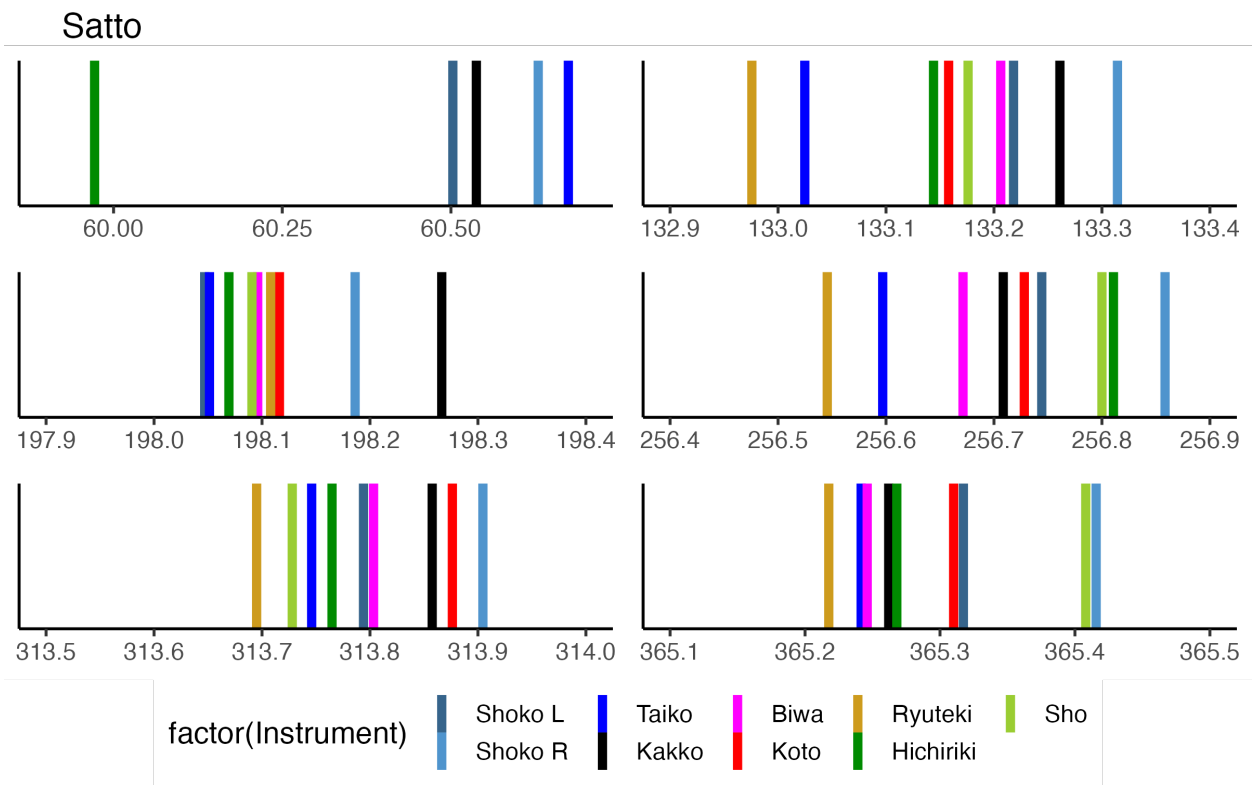

Figure 14. Onsets on the main *Taiko* beat of the first six cycles of Sattō. The time axis is in seconds.

[52] Taking the *biwa* as the reference in response to the interview transcripts, which suggest it is responsible for the placement of beat 1, we can summarize the average positions of each instrument relative to the *biwa*(Table 7). This summary suggests that on average the *taiko* plays first, followed by the *hichiriki* and *ryūteki*, *koto* (closest to the *biwa*'s position), *shōko*, *kakko* and *shō* (the right-hand stroke of the *shōko* coming last of all). The *kakko*'s relative position is somewhat earlier in Juha than in Sattō, otherwise the order is the same in the two pieces. Note the relative high variability evidenced in the SD_{async} figures, however.

	Sattō		**Juha**	
Instrument_Pair	**M_{async}**	**SD_{async}**	**M_{async}**	**SD_{async}**
Biwa-Taiko	59.7	89.6	36.9	68.7
Biwa-Hichiriki_E	44.1	93.5	33.1	80.7
Biwa-Ryūteki	44.0	86.1	30.9	73.4
Biwa-Koto	-13.4	64.8	-6.7	52.1
Biwa-Kakko_1	-13.8	90.0	-24.3	101.8
Biwa-Hichiriki	-18.7	85.6	-9.8	72.2
Biwa-Shōko_L	-21.2	87.0	-12.2	92.9
Biwa-Sho	-45.2	103.9	-35.8	67.6
Biwa-Shōko_R	-121.0	87.1	-124.5	90.9

Table 7. Mean positions of instrument onsets relative to the *biwa*. '*Hichiriki*_E' refers to our annotation of the beginning of the ornaments and pitch glides played by these instruments (E standing for 'early'); the onsets marked '*Hichiriki*' indicate the points at which a stable pitch is reached. The number in the M_{async} column is the mean of the differences between the two instrument onset times, for example the *biwa*'s onset time minus the *taiko*'s onset time (thus in the first row, the positive number indicates that the *biwa*'s position is on average after the *taiko*'s position).

[53] Where we can see greater consistency, however, is in the order of *preparatory* movements leading up to this beat. In Figure 15 we can see this for the percussion and string sections in the first six *taiko* strokes of Juha. The order is clear: *taiko*'s left wrist prepares, then the *taiko* plays (on beat 3); the *biwa*'s movement and onset fall either side of the *taiko*'s where present. Then the *taiko* player's right wrist raises, then the *shōko* player's wrists (they are raised more or less together, thus only the right is included in the illustration), and then all percussion instruments play on beat one (as noted above, the two *shōko* strokes fall about 110ms apart). Rather than the *onsets*

occurring in a fixed order, then, it appears that the *actions* are initiated in a fixed order, facilitating a pleasingly loose synchrony of the onsets.

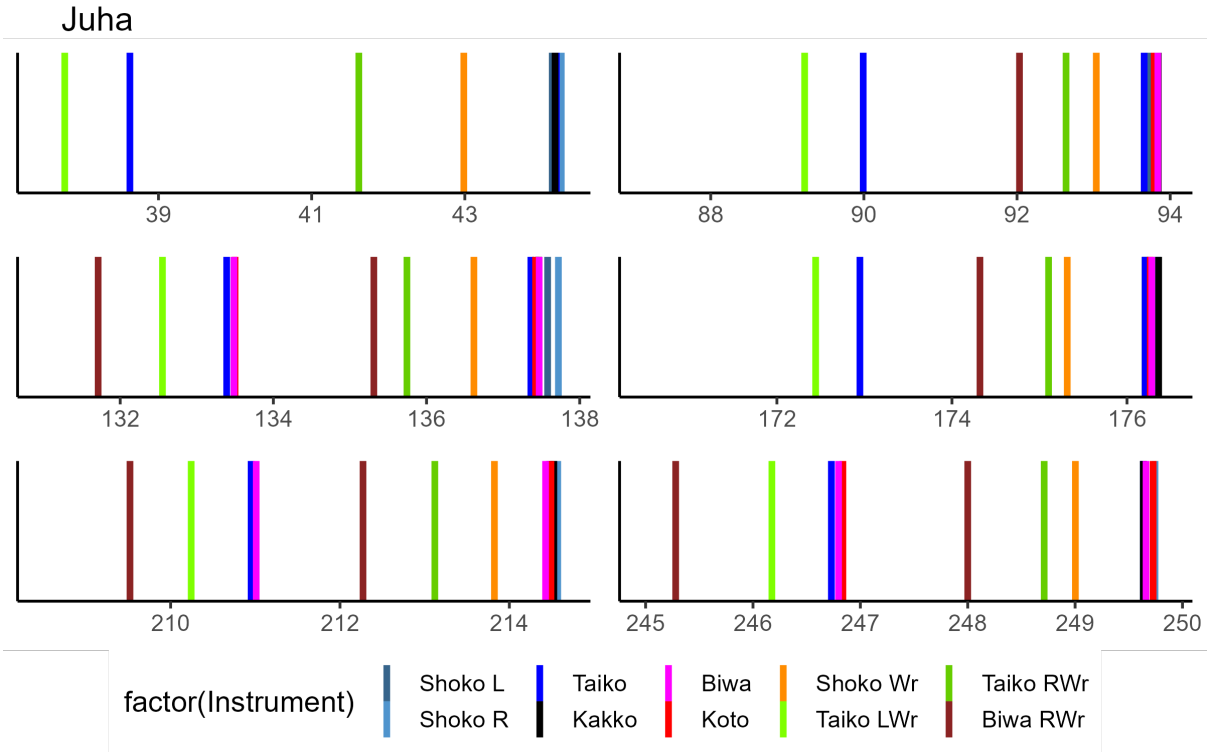

Figure 15. Onsets and preparatory movements on the main *Taiko* beat of the first six cycles of Juha. The time axis is in seconds. Preparatory movements are marked at the point the wrist reaches its highest point. The plots differ according to whether or not the *biwa* plays on beat 3. In each case, the main *taiko* stroke (and thus beat one of the cycle) lies to the right-hand side of the plot.

[54] The onset data offers a lot of possibilities for calculating pairwise asynchronies, especially considering that we have two sets of onsets for *shōko* (left and right strokes), and two for *hichiriki* (before and after the portamentos). The data show some variation between the two pieces, between sections, and between beats. We give an example of the change between sections below: in other cases, however, it is not easy to judge the significance of such differences, as they tend to co-occur with small amounts of data.

[55] Table 8 lists the various pairings, summarizing across both pieces. Only *shōko*_L is used for that instrument, and the later *hichiriki* onset is used; the *shō* is omitted as that data includes several data points from the 'half-beat' positions. We can see the spread of mean asynchronies vary from a few milliseconds (e.g. *shōko*_L to *kakko*, *koto* and *hichiriki*) to over 60 ms (e.g. *taiko* to *kakko* and *koto*). SD_{async} figures range from around 60 to over 120 ms.

Instrument pair	M_{async}	SD_{async}
Shōko_L - Taiko	42.0	94.0
Shōko_L - Kakko_1	-2.6	95.9
Shōko_L - Biwa	19.2	89.0
Shōko_L - Koto	4.4	72.0
Shōko_L - Ryūteki	65.9	93.3
Shōko_L - Hichiriki	9.0	98.3
Taiko - Kakko_1	-72.3	98.8
Taiko - Biwa	-48.8	78.8
Taiko - Koto	-60.1	62.8
Taiko - Ryūteki	7.6	87.1
Taiko - Hichiriki	-31.7	123.3
Kakko_1 - Biwa	18.1	92.6
Kakko_1 - Koto	6.9	81.3
Kakko_1 - Ryūteki	55.3	112.4
Kakko_1 - Hichiriki	6.7	107.6
Biwa - Koto	-12.2	59.2
Biwa - Ryūteki	38.3	81.3
Biwa - Hichiriki	-14.0	80.8
Koto - Ryūteki	38.5	98.6
Koto - Hichiriki	-0.3	75.1
Ryūteki - Hichiriki	-52.0	87.7

Table 8. Summary of pairwise asynchronies. M_{async} = Mean pairwise asynchrony; SD_{async} = Asynchronisation (both in milliseconds).

[56] We would expect the synchronization precision to increase through each piece as the event density increases (Clayton et al. 2020, 164–5). Figure 16 illustrates how both synchronization measures change between the major sections, using the data for all pairs including *Shōko*_L in Juha (this example is typical). We can see from the bars that both the mean difference and SD are greater in section A than in subsequent

sections. In fact, if we calculate Group asynchronization measures separately for the four major sections (combining the two pieces to increase the amount of data), we see that section A is significantly higher, particularly in Sattō, while there is no tempo-related change across the remaining three sections (see Table 9). This suggests a qualitative difference in the A section rather than a simple correlation with tempo: in particular, B' is no tighter than B despite its higher tempo. The A section includes the beginning of a piece, of course, which starts with *ryūteki* and then has percussion and strings gradually joining in; these figures illustrate that over the sections as a whole the synchronization between parts is particularly loose.

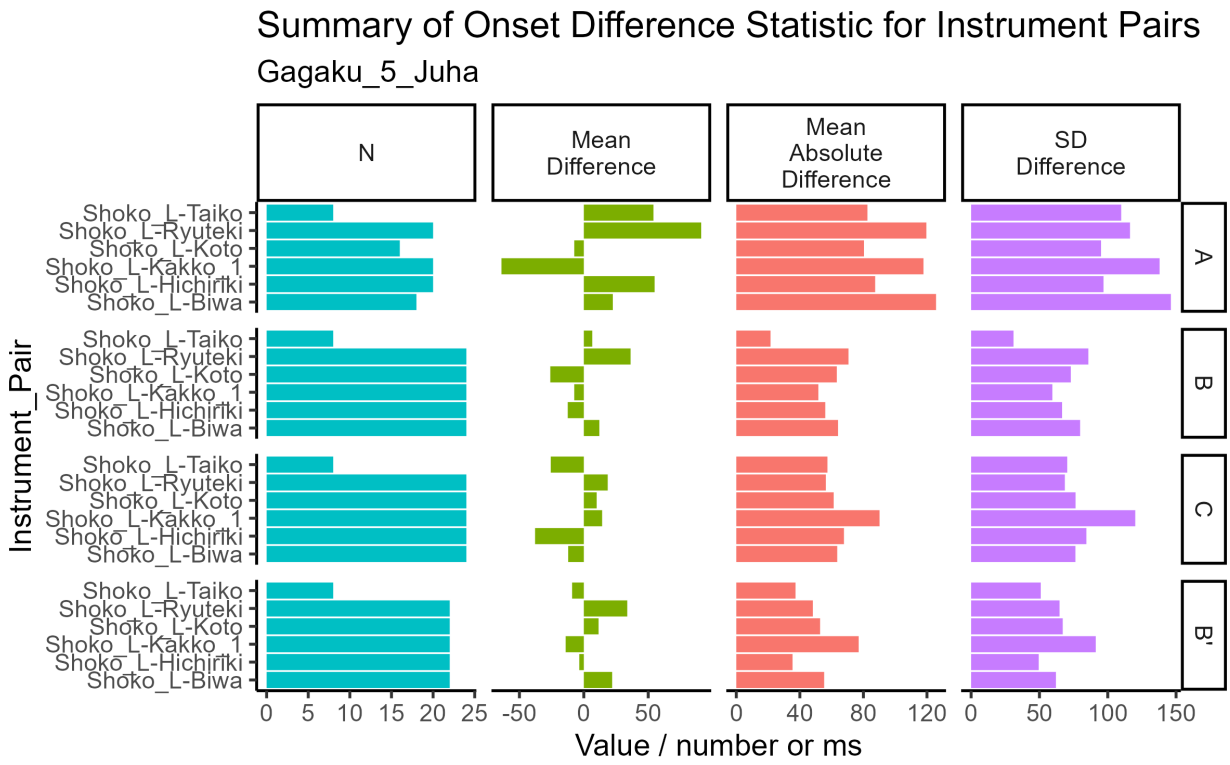

Figure 16. Summary synchronization statistics for pairs including *Shōko*_L, by Section (A, B, C, B') in Juha. As in Table 7, a positive mean difference indicates that the first-named instrument plays after the second-named instrument.

Section	A	B	C	B'
A (ms) All, including *taiko*	115.7	71.9	83.0	76.4
A (ms) Satto, omitting *taiko*	115.0	78.0	80.9	73.5
A (ms) Juha, omitting *taiko*	103.6	67.7	90.3	74.5

Table 9. Group asynchronization (A) measures by Section. The first row combines the two pieces, with all pairs including *Shoko*_L, *Taiko*, *Kakko*, *Koto*, *Biwa*, *Hichiriki* and *Ryuteki*. The rows for the two pieces separately omit the pairs including the *Taiko* due to the small number of data points involving this instrument.

DISCUSSION

[57] The aim of this paper has been to describe the temporal organization of *gagaku* instrumental music with the help of empirical analysis of a recorded corpus. Drawing on the existing academic literature, we described metrical-formal structure and three issues that were recognized as being typical or noteworthy in *gagaku*, all of which are aspects of performance practice rather than being specified explicitly in notation. Interview material allowed us to provide a performance-level account of the genre's rhythmic dimension, based on the understanding of multiple musicians. We have employed empirical analysis to explore and to illustrate the metrical and formal structure, including specific issues around variable beat lengths and acceleration patterns; and also to measure the synchronization between parts and explore what this may tell us about interaction within the ensemble. We now summarize our findings and review their significance for understanding of *gagaku* and for rhythm theory more widely.

Meter and Tempo

[58] The metrical-formal time organization of these two pieces is clearly described: 4-beat measures are combined (8 in Sattō, 6 in Juha) to form cycles; fixed numbers of

cycles make up the form, which can be repeated. The cycle is marked by a pair of taiko strokes, the second and strongest of which falls on beat one of the last measure of the cycle (according to the percussionists' count; the melodic cycle has a different starting point). Tempo ranges from 22-53 bpm, beat durations range between 1.2-2.3 secs, and cycle durations 28-70 secs. There is no ambiguity about the tactus level or the identity of beat one within the measure (musicians agree on the count of '1,2,3,4…'; the importance of the taiko stroke is similarly clear, although the cycle is counted differently with respect to the melody and percussion lines). The fixed rhythmic patterns of the percussion and string parts combine to form an unambiguous delineation of the metrical structure.

[59] At the faster end of the temporal hierarchy, there is little regular subdivision of the beat: although between the beat positions we can observe the *shō*'s finger changes, there are some additional *koto* onsets and *biwa* arpeggios leading to important beats; and most obviously, the *kakko* fills in many beats with multiple strokes; this music seems not to emphasize the value of a clear and consistent subdivision of the beat. Rather more prominent is the sense of *trajectories*—of movement and of sound—filling the beat durations and guiding the synchronization of parts on important beats. In the interviews, the musicians not only illustrated their respective images of this sense (see 'Meter, tempo and acceleration'), but also how synchronization is specifically managed (see also 'The role of each section and instrument' and 'Synchronization'). The hierarchy of measures and cycles is articulated by the rhythmic patterns of the percussion and string parts; the wind parts have more autonomy in terms of how their phrasing relates to the metrical hierarchy, as well as latitude in terms of when they articulate their pitch changes.

[60] In this context the 'stretching' of the last beat can be observed empirically, although it is worth pointing out that beat durations are hard to estimate due to the small number of onsets falling on beat 4 and in general the wide spread of onsets surrounding a beat position. Various factors, including the flexible placement of wind pitch changes (here taken to mark the position of beat 4), the long movement trajectories of *biwa* and *taiko* players, and the rise and fall of the *shō*'s volume, the *shō*'s finger changes, and the *biwa*'s arpeggios, all contribute to a sense of an extended fourth beat.

[61] The waves illustrated above (Figure 7) invite discussion of another theme—albeit a dormant one, perhaps—in rhythm theory. We can compare this illustration with Zuckerkandl's 'wave theory of meter' (1953, 169–72) and with Jones's dynamic attending theory (DAT; Barnes & Jones 2000). Zuckerkandl proposed a view of meter based on the concept of a 'metric wave', "a continuous cycle of rhythmic motion in which downbeats are represented as wave peaks" (Brower 1993a, 26, also 1993b, 40; Zuckerkandl 1953, 169–72). Brower (1993b) developed this idea further, linking this 'wave' to rhythmic tension ("An increase in tension is experienced as motion *rising to* a point of climax, while the release of tension is experienced as motion *falling away* from it." pp.33–4). According to DAT—which has influenced the metrical theory of London (2012), amongst others— a subject (listener) attending to a sequence of events experiences attentional 'rhythms' that become entrained to the stimulus sequence. This can be visualized as a kind of 'wave' in which attentional peaks align with metrically salient moments. It is tempting to pursue this comparison further, although it should be acknowledged that our interviewees did not bring up the wave image: despite its use in a teaching guidebook, it is not universally recognized by

practitioners, and therefore we exercise some caution in interpreting the importance of this image. Its greatest relevance may be simply that the image suggests the movement connecting downbeats to be a continuous process, which may be traced through continuous changes in some musical parameters. In terms of DAT, it is not so much that attention rises and falls, then, as that attention is engaged in tracking the rise and fall of these parameters. The constant reference by musicians to the 'flow' of music is evidence that they see the act of performance not as a series of discrete events, but as a continuous process.

[62] Finally, the acceleration commented on in the literature is also observed empirically. This measurement adds the observation that, in our corpus, the increase in speed picks up from the middle of the A section (when the percussion gets going), is temporarily paused at the half-way point (C), perhaps partly due to the musicians' awareness of the danger of rushing at this point, and then picks up again in the repeat of the B section.

Synchronization

[63] Empirical analysis of onset time differences (asynchronization), and their comparison with other genres that have been studied in this way, confirms that the synchronization of instrumental parts is particularly loose. This is a feature that has a positive aesthetic value, and it seems that it is afforded by the reliance on movement and sound trajectories to coordinate parts, as well as by a generally slow tempo and low rhythmic density. As highlighted in the interviews, a deep understanding of the parts beyond one's own seems essential for every musician to achieve this variety of phenomena.

[64] A consequence of this is that rhythmic events marking a beat may occur over an extended duration, even over more than half a second in some cases. Interview data suggests some specific patterns of players watching or listening out for specific cues, a process that could lead to a certain ordering of occurrence of the onsets. The timing data shows that variability is high in relation to typical mean differences, although there is some underlying consistency; there seems to be greater consistency in the order of preparatory events leading up to important beats.

Aesthetics

[65] As noted above, these musicians acknowledge the relevance of two broad Japanese concepts: *jo-ha-kyū* is mainly addressed at the level of multiple piece sequences, and supports the idea that the second of these (Juha) should start somewhat faster than the first; *ma-ai* is invoked in discussion of the *taiko* player's preparatory movements, which we show to have multiple phases. The musicians' broader aesthetic discourse is equally relevant to our study, if not more so. Amongst the values clearly articulated in the interviews are the following:

- The primary importance of timing
- Distributed leadership and the importance of paying close attention to each other
- The idea that proper control of tempo emerges naturally from entrainment (coupling) between the parts
- The positive value of 'discrepancy', the human-ness of imperfection, and the acceptability of 'spilling over' the beat

[66] These ideas, combined with the synchronization analysis summarized above, suggests something of a paradox when seen from the perspective of entrainment

studies: that *while exemplifying a very high degree of variability in synchronization (as calculated from the alignment of rhythmic events), this music in fact embodies a strong focus on ensemble coordination, alignment, and timing*. The explanation for this is that the exact alignment of events in time is almost incidental to the conception of perfect timing and ensemble coordination: in fact, 'discrepancy' is valued. On the contrary, the musicians' focus is on following the cues provided by contours of movement and dynamics, which afford coordination as well as the possibility of making fine adjustments and offering cues to help others adjust in turn.

[67] An obvious reference in the rhythm analysis literature here is Keil's idea of 'participatory discrepancy', in which context he claimed that "Music, to be personally involving and socially valuable, must be 'out of time' and 'out of tune'" (1987, 275). This is a curious juxtaposition, to be sure: Keil was writing primarily of groove-based dance music genres, which could hardly be further removed from *gagaku* in terms of either sound or social function. Nonetheless the associability of this idea with Japanese performing arts is also noted by Fujita, who cites Keil's 'participatory discrepancies' as a pioneering reference in ethnomusicological research in a section on "the 'processes' found around the sound" in the context of Noh (2010, 219-220). The evidence in support of Keil's thesis in Afrogenic music is mixed: recent studies have found that while heterochronous beat subdivisions do have an influence on judgements of musical quality, small timing asynchronies do not (Jakubowski et al 2022). In this *gagaku* case, however, the asynchronies are much larger, and are mentioned by musicians as part of the aesthetic world of the music—indeed, as reflecting its human imperfection.

Implications for Metrical Theory

[68] The term 'meter' is used in descriptions of many different types of music, evidencing an assumption that this concept is a general or universal one, rather than being culturally specific. However, attempts to theorize meter explicitly in this way have to date been patchy. Many of the academic theories of meter most commonly referred to, regardless of the genre or tradition under consideration, were formulated exclusively with Western art music in mind (e.g., Lerdahl & Jackendoff 1983, Hasty 1997, London 2012); the fact that some of these theories base their theorization on an understanding of psychology does not help, given music psychology's own cultural bias. Some authors have explicitly addressed this issue in relation to meter in other traditions (e.g., Arom in Central African music, 1991; Agawu in Northern Ewe music, 1995; Clayton in Hindustani music, 2020)—each of these studies engaging with indigenous theorization of the tradition in question, whether explicit or implicit—and the field of rhythm studies has become increasingly pluralist in recent years. Nonetheless it feels premature to write as if a culture-independent concept of meter has been established, and a danger in writing about meter in *gagaku* is of inadvertently biasing our discussions to the norms observed in Western art music and (largely) Western music psychology. Having made all of this clear, we will now broaden the discussion out to consider how our observations on *gagaku* relate to existing literature on musical meter based on other traditions. Our hope is that as metrical theory develops in less culture-specific ways, the structures and processes observed in *gagaku* and other traditional Japanese music genres will form an important part of this conversation.

[69] We hope to have demonstrated that ongoing attempts to theorize meter need to take account of a number of phenomena we have described here in the *gagaku* context.

i. Meter and form are described as a single hierarchy, seamlessly linking the two domains. From an external perspective we might ask whether the true 'meter' here is the 4-beat measure, with the cycle best described either as a hypermetrical layer or an aspect of form. Or, drawing comparison with Hindustani music, is the (*taiko*) cycle level best described as a form of 'long-form meter' (c.f. Clayton 2020)? As noted above the *taiko* cycle has both similarities with slow *tālas* and gong cycles (a strong point of emphasis marks a long time span, and a point at which different streams come together) and differences (there are two options in the *gagaku* case for how to count the 'one' in the cycle; the component parts of the whole cycle may be more heterogeneous in *tāla* than in *gagaku*). The important point here, we suggest, is not to argue over what we name different levels of temporal hierarchy, but to understand this particular system in its own terms and recognize its importance for comparative study and theorization. Another key point in this regard is the importance of considering both discrete and continuous information, and their different characteristics, in accounts of temporal structure.

ii. The absolute values of time intervals here confirm some observations from music cognition literature which have been influential in rhythmic theory. For example, an average beat duration around 1.5 secs and a range from about 1-2.3 seconds corresponds to the higher end of a 'beat' duration; at the slower

end of this range, this tests a listener's ability to perceive a regular pulse. The fact that the music does not employ clear and unambiguous beat subdivision is consistent with the idea that following the beat requires concentration (and in this case, following the continuous changes presented by movement and dynamic curves). As with slow Hindustani *tālas*, cycle durations clearly exceed the limit of a few seconds, linked to the perceptual present, which is sometimes thought to limit metrical cycle duration. As argued by Clayton 2020 in relation to Hindustani *tālas*, however, we can think of metrical structure involving both entrainment to a beat level and a higher level that lies within the perceptual present, and potentially higher levels that rely on the learning of culturally specific structures. Following the same logic the *taiko* cycles would certainly fall into the latter category, and perhaps the 4-beat cycles too at slow tempi. The high asynchronization values are consistent with the view that Clayton et al.'s findings that synchrony between drum and percussion parts do not depend on rhythmic density (2020), but in fact reflect a ceiling effect, and that given a low enough density, percussion parts can be much more loosely synchronized than any previously measured.

iii. The loose synchronization leads to the conclusion that 'beats' should be considered, rather than points in time, as extended durations. Danielsen makes this proposal in relation to neo-soul music (2018), interpreting a spread of event onsets of around 80-100ms as a 'beat bin' and suggesting that in terms of DAT, a listener's attentional focus is spread over an extended durational window rather than focused on a narrow point in time. Although this musical context is very different, and indeed the 'beat bin' can be even longer in duration in *gagaku*, a similar argument could be made here. An alternative

way of looking at this—complementary perhaps—would be to say that as the beats and measures are very long and their progression is tracked partly by following continuous information, each beat is a broadly-defined area rather than a point in time; the aesthetic value placed on the loose synchronization confirms that this is a feature of the rhythmic system.

Future Research

[70] Two of our interviewees (Miura and Yatsuki) stressed the importance of breathing and stated that this is where the characteristics of *gagaku* may be expressed. The *shō*, in particular, produces changes in volume and chords that affect the other parts, depending on the speed and volume of the breath sent out. More broadly, the very restrained movement of the musicians—which, apart from the controlled preparatory movements described above, seems to be kept to an absolute minimum—is consistent with a focus not only on listening and watching fellow musicians, but also on observing their own movements. It would therefore be valuable for future corpora to include physiological data to enable study of these aspects of performance. Expanding the study of movement to include dance would provide an invaluable additional dimension. Beyond this, of course, the recorded genre (and, in a broader sense, the various genres and sub-genres of Japanese traditional music) offer a wealth of non-metrical forms of organization as well as metrical structures. The exploration of the temporal organization and coordination for both music and dance may be expected to have much to teach us about how musical ensembles can be coordinated in time.

ACKNOWLEDGMENTS

The authors would like to thank Akira Takaoka and Simone Tarsitani for their contributions to the recording and editing of media; the Great Britain Sasakawa Foundation for funding; the Tokyo National Research Institute for Cultural Properties for the use of the recording facilities; and all of the musicians: Motonori Miura, Junko Yatsuki, Takuya Kōketsu, Yoshie Kunimoto, Shōji Takata, Yumiko Kiyota, Haruna Higashida, and Yoshiyuki Izaki. We particularly thank Motonori Miura for his assistance in organizing the recording session and for sharing his knowledge with us.

VIDEO EXAMPLES

Video Example 1. Juha, 7" to 1'49".

Video Example 2. Sattō, 5'-7" to 5'15", camera 3.

Video Example 3. Sattō, 10'42"–11'17" with OpenPose skeleton overlays. Note that movement information saved and used in this paper is derived from the best available camera view for each instrument.

REFERENCES

Agawu, Kofi. 1995. *African Rhythm. A Northern Ewe Perspective*. Cambridge: Cambridge University Press.

Arom, Simha. 1991. *African Polyphony and Polyrhythm*. Cambridge: Cambridge University Press.

Barnes, Ralph and Mari Riess Jones. 2000. "Expectancy, Attention, and Time." *Cognitive Psychology* 41(3): 254-311. https://doi.org/10.1006/cogp.2000.0738

Brower, Candace Rosemary. 1993a. "Memory and the Perception of Rhythm." *Music Theory Spectrum*, 15(1): 19–35. https://doi.org/10.2307/745907

Brower, Candace Rosemary. 1993b. *Motion in Music: A Wave Model of Rhythm*. University of Cincinnati. ProQuest Dissertations Publishing, 9329964.

Cao, Zhe, Gines Hidalgo, Tomas Simon, Shih-En Wei, and Yaser Sheikh. 2021. "OpenPose: Realtime Multi-Person 2D Pose Estimation Using Part Affinity Fields." *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 43(1): 172–186. https://doi.org/10.1109/TPAMI.2019.2929257

Clayton, Martin. 2000. *Time in Indian Music: Rhythm, Metre and Form in North Indian Rāg Performance*. Oxford: Oxford University Press

Clayton, Martin. 2020. "Theory and Practice of Long-Form Non-Isochronous Meters: The Case of the North Indian Rūpak Tāl." *Music Theory Online* 26(1): 2. https://doi.org/10.30535/mto.26.1.2

Clayton, Martin, Kelly Jakubowski, Tuomas Eerola, Peter E. Keller, Antonio Camurri, Gualtiero Volpe, and Paolo Alborno. 2020. "Interpersonal Entrainment in Music Performance: Theory, Method and Model." *Music Perception* 38(2): 136–194. https://doi.org/10.1525/MP.2020.38.2.136

Clayton, Martin, Jin Li, Alison R. Clarke, Marion Weinzierl, Laura Leante, and Simone Tarsitani. 2021. *Hindustani Raga and Singer Classification Using Pose Estimation*, OSF. https://doi.org/10.17605/OSF.IO/T5BWA

Clayton, Martin, Sayumi Kamata, Akira Takaoka, & Simone Tarsitani. 2023. *Gagaku*. OSF. https://doi.org/10.17605/OSF.IO/WA5H6

Danielsen, Anne. 2018. "Pulse as Dynamic Attending: Analysing Beat Bin Metre in Neo Soul Grooves." In Scotto, C., Smith, K.M., and Brackett, J. (Eds.). *The Routledge Companion to Popular Music Analysis: Expanding Approaches* (1st ed.). Routledge. https://doi.org/10.4324/9781315544700

Eerola, Tuomas, and Martin Clayton. 2024. "onsetsync: An R Package for Onset Synchrony Analysis". *The Journal of Open Source Software*, 9(93), Article 5395. https://doi.org/10.21105/joss.05395

Eerola, Tuomas, Martin Clayton and Paul Emms, 2023. *movementsync*. https://CRAN.R-project.org/package=movementsync

Endō, Tōru. 2013. *Gagaku o shiru jiten.* Tōkyōdō-shuppan.

Fujita, Takanori. 2010. Nō no nori to jibyōshi: rizumu no minzoku ongakugaku. Hinoki-shoten.

Fujita, Takanori. 1986. "Kuchishoga: The Vocal Rendition of Instrumental Expression in the Oral and Literate Tradition of Japanese Music: With Emphasis on the Nokari." In Tokumaru, Yoshihiko and Osamu Yamaguchi, ed. *The Oral and the Literate in Music*, 239–51. Tokyo: Academia Music.

Gamō, Mitsuko. 1973. "Tōgaku no tenpo [The Tempo in Tōgaku]." In Koizumi, Fumio, Asahi Hoshi and Osamu Yamaguchi, ed. *Nihon ongaku to sono shūhen*, 143–155. Ongakunotomosha.

Gamō, Satoaki. 2000. "Gagaku ga hokano geinō ongaku ni oyoboshita eikyō ni tsuite." In *Nihon koten ongaku tankyū,* 210–275. Shuppan-geijutsusha. (Reprint of article first published in *Gagakukai* 54: 86–150, 1978.)

Gamō, Satoaki. 1989. *Gagaku gaisetsu*. In Ono, Ryōya, ed. *Gagaku jiten*, 6–26. Tokyo: Ongakunotomosha.

Garfias, Robert. 1975. *Music of a Thousand Autumns: The Togaku Style of Japanese Court Music*. Berkeley and Los Angeles: University of California Press.

Hasty, Christopher F. 1997. *Meter as Rhythm*. New York and Oxford: Oxford University Press, 1997

Hughes, David W. 2000. "No Nonsense: The Logic and Power of Acoustic-Iconic Mnemonic Systems." *British Journal of Ethnomusicology* 9(2): 93–120. https://doi.org/10.1080/09681220008567302

Jakubowski, Kelly, Rainer Polak, Martín Rocamora, Luis Jure, and Nori Jacoby. 2022. "Aesthetics of Musical Timing: Culture and Expertise Affect Preferences for Isochrony but not Synchrony." *Cognition* 227 (C):105205. https://doi.org/10.1016/j.cognition.2022.105205

Kapuscinski, Jaroslaw and Francois Rose. 2010–2020. *Introduction to Gagaku.* https://gagaku.stanford.edu/en/

Keil, Charles. 1987. "Participatory Discrepancies and the Power of Music." *Cultural Anthropology* 2(3): 275–83. http://www.jstor.org/stable/656427

Lerdahl, Fred and Ray Jackendoff. 1983. *A Generative Theory of Tonal Music*. Cambridge, MA: MIT Press.

London, Justin, 2012. *Hearing in Time: Psychological Aspects of Musical Meter*. New York: Oxford University Press. Second Edition.

Marett, Allan, 1985. "Tōgaku: Where Have the Tang Melodies Gone, and Where Have the New Melodies Come From?" *Ethnomusicology* 29(3): 409–31. https://doi.org/10.2307/851797

Nelson, Steven G. 2008. "Court and Religious Music (2): Music of Gagaku and Shōmyō." In *The Ashgate Research Companion to Japanese Music*, edited by Alison McQueen Tokita and David W. Hughes, 49–76. Aldershot, UK: Ashgate. https://doi.org/10.4324/9781315172354

Ono, Ryōya, ed. 1989. *Gagaku jiten.* Tokyo: Ongakunotomosha.

Polak, Rainer and Justin London, 2014. "Timing and Meter in Mande Drumming from Mali." *Music Theory Online* 20(1). https://mtosmt.org/issues/mto.14.20.1/mto.14.20.1.polak-london.html

Rasch, R. A. 1988. "Timing and Synchronization in Ensemble Performance." In J. A. Sloboda (Ed.), *Generative Processes in Music: The Psychology of Performance, Improvisation, and Composition*, 70-90. Oxford, UK: Clarendon Press.

Shiba, Sukehiro. 1971. Gosen-fu ni yoru gagaku sofu: maki san kangenkyoku nobegaku, taikyoku hen. Kawai gakufu.

Shōno, Susumu. 1987. "The Role of Listening in Gagaku." *Contemporary Music Review* 1(2): 19–43. https://doi.org/10.1080/07494468400640231

Terauchi, Naoko. 2011. "Surface and Deep Structure in the Tôgaku ensemble of Japanese Court Music (Gagaku)." In. Tenzer, Michael, and John Roeder, eds. *Analytical and Cross-Cultural Studies in World Music*. Oxford University Press. https://doi.org/10.1093/acprof:oso/9780195384581.003.0001

Terauchi, Naoko. 2008. "1940 nendai zenhan no gagaku rokuon ni okeru tōgaku no tenpo: kokusai bunka sinkoukai seisaku rekōdo 'Nihon Ongakushū' o megutte [Tempo and phrasing of the gagaku in 1940s: focusing on the 78-rpm Records 'The Album of Japanese Music' produced by Kokusai Bunka Shinkokai]." *Journal of Intercultural Studies* 30: 1–29. https://doi.org/10.24546/81000857

Terauchi, Naoko. 2002. "20 seiki ni okeru gagaku no tenpo to furēzing no henyō: Gaisubāgu rokuon to hōgaku chōsa gakari no gosenfu. [Changes of gagaku in the 20th century : tempo and phrasing in the recording by F. Gaisberg and the transcription by Hogaku Chosa Gakari]" *Journal of Intercultural Studies* 17: 85–111. https://doi.org/10.24546/81001247

Terauchi, Naoko. 1996. Gagaku no rizumu kōzō: Heian jidai sue ni okeru tōgaku kyoku ni tsuite. Daiichi-shōbō.

The Society for Connecting Education and Research of Japanese Music, eds. 2019. *Shōga de manabu nihon ongaku.* Tokyo: Ongakunotomosha.

Tokita, Alison McQueen and David W. Hughes. 2008. "Context and Change in Japanese Music." In *The Ashgate Research Companion to Japanese Music*, edited by Alison McQueen Tokita and David W. Hughes, 1–33. Aldershot, UK: Ashgate. https://doi.org/10.4324/9781315172354

Yokomichi, Mario and Satoaki Gamō, eds. 1978. *Kuchishōga taikei: nihon gakki no sorumizēshon.* Tokyo: CBS/Sony.

Zuckerkandl, Victor. 1953. *Sound and Symbol*, trans. W. R. Trask. Princeton, NJ: Princeton University Press.

APPENDIX: DATA COLLECTION

The Gagaku data collection is published in Clayton et al. 2023, where detailed information can be found about the recording setup and annotation methods. In brief, it comprises full performances of the *togaku* suite Shunnōden, plus an introductory piece, by an eight-piece ensemble. Each instrument was recorded through its own microphone, ensuring a reasonable level of sound separation, and the use of five video cameras ensures that it is possible to extract movement data for each player. The material relevant to the analysis presented in this article is as follows:

Items:

Section 4: Sattō, duration 14'14"

Section 5: Juha, 9'50"

Audio files:

Eight solo files for each item plus one stereo pair.

Video files:

Five video views for each item (see Figure 1 above for camera positions). Note that camera 1, which has the best view of several instruments, covers only the first half of Sattō (to 7'24").

Annotation files:

Annotation: section and subsection start and end points (following the nomenclature of Shiba's transcription of this suite referred to above; note that although we made use of this transcription we do not reproduce it here or in the published corpus).

Metre: times for each downbeat (beat one of each measure), annotated manually.

Onsets Edited: timings of rhythmically significant events such as instrument strikes or plucks, or wind pitch changes, derived using a combination of computational algorithms and manual annotation.

Onsets Selected: tables in which selected onsets are assigned to specific metrical positions. These 'onsets' also include moments at which the *taiko*, *shōko* and *biwa* players' wrists reach their highest point.

Pose: 2D movement data for each player, derived using the 'Pose estimation for raga' interface for OpenPose (Cao 2021, Clarke and Weinzierl 2022). See Video Example 3.

Interview transcripts:

Semi-structured interviews were conducted with the three musicians who played wind instruments on the recordings. Since gagaku musicians take various roles in the ensemble depending on the occasion,[19] it was possible to ask them questions about the other parts of the instrument besides the wind instruments. The dates and subjects were as follows:

- 30th May 2022 - *Ryūteki* player, Takuya Kōketsu
- 31st May 2022 - *Hichiriki* player, Motonori Miura
- 14th June 2022 - *Shō* player, Junko Yatsuki

The interviews addressed the role of each instrument in the ensemble, details of the pieces recorded and performance techniques, and their awareness of tempo,

19. To be precise, they specialize in one of three winds and one of two strings, and experience all percussion instruments.

acceleration and synchronization during the performance. Complete transcripts of interviews with three of the musicians are saved in Japanese with English translation.

Permissions

The performers on the recordings are as follows: Motonori Miura (*Hichiriki*), Junko Yatsuki (*Shō*), Takuya Kōketsu (*Ryūteki*), Yoshie Kunimoto (*Koto*), Shōji Takata (*Biwa*), Yumiko Kiyota (*Shōko*), Haruna Higashida (*Taiko*), Yoshiyuki Izaki (*Kakko*). All eight performers are professional musicians from the Geidai Gagaku Ensemble, brought together at Miura's initiative. Each of them is active in domestic and overseas performances as a member of the professional ensembles such as Tokyo Gakuso (established in 1975), and several are also teaching younger students as lecturers at Tokyo University of the Arts. The musicians' permission was obtained to share the recordings for non-profit research and educational use only. For the interviews, permission was granted for publication of transcripts before they were conducted, and each interviewee was asked to read through them and highlight any errors or personal data issues before publication.