The Byar: An Ethnographic and Empirical Study of a Balinese Musical Moment

Andy McGraw with Christine Kohnen

Introduction

The repertoire of the Balinese *gamelan gong kebyar* ensemble (see Tenzer 2000 and the glossary provided in Appendix A) is marked by virtuosic, unmetered tutti passages, referred to as *kebyar*, that often introduce pieces or function as transitions within compositions. The kebyar itself often begins with a sudden, fortissimo *byar*, a single, tutti chord that is performed by the majority of the ensemble.[1] The sheer virtuosity and power of this famous repertoire is encapsulated in the expert execution of a byar, in which twenty to thirty musicians, without the aid of notation, a conductor, or beat entrainment, synchronize to produce a shockingly precise and loud eruption of sound.

During several fieldwork sessions in Bali over the past decade, McGraw has occasionally heard expert performers and composers claim that they could identify regional ensembles simply by hearing them perform a single byar. Several informants suggested that the relative temporal alignment of instrumental onsets was the primary distinguishing characteristic of a byar. This would be the equivalent to being able to identify symphony orchestras by hearing, for example, only the first sforzando chord of Beethoven's *Eroica* Symphony.

This paper concerns the expression and recognition of group identity as conveyed through performance and listening. Is the temporal structuring of an ensemble's byar indicative of their musical identity? What is the minimal temporal scale of the expression of such identity? If such differences are not empirically evident or statistically significant, what implications does this have for Balinese conceptions of musical identity? What does this approach reveal about Balinese and non-Balinese listening habits and abilities and how they overlap or diverge? Because these questions are extremely complex we have limited our investigation to the smallest building block of the kebyar repertoire: the musical moment of the byar.

In this paper we first analyze the empirical differences between a total of 45 byars performed by six ensembles to determine if they exhibit predictable ensemble-specific tendencies, as implied by the claim above. We identify some tendencies that suggest ensemble-specific interpretation of the byar while noting a high level of variation within ensembles. The second section of the paper concerns Balinese respondents' cognition and perception of the byar as gauged through a survey and listening experiment. A survey

1. *Taruna Jaya*, a composition which evolved between the early 1930s to the 1950s and was primarily composed by Pan Wandres and I Gede Manik in Jagaraga, is a classic example. See *Music of the Gamelan Gong Kebyar* (1996).

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indicated that 94% of respondents believe that regional ensembles display distinguishable differences in the performance of their byars. A majority attributed these differences to "technique" or "feeling." Following the survey, a listening test was administered in which respondents attempted to match synthesized recordings of byars with their respective ensembles. Respondents for the listening test were selected from three populations: Balinese musicians, non-Balinese students of gamelan and non-Balinese with no experience of gamelan.[2]

Prior to training (hearing the audio examples without prior identification), Balinese respondents correctly associated synthesized byars with their respective ensembles 21% of the time. After training, Balinese respondents were able to correctly identify ensembles 40% of the time, non-Balinese with gamelan experience 25% of the time, and non-Balinese with no gamelan experience 23% of the time. Prior to training, Balinese subjects were not able to reliably identify ensembles by temporal information alone, but did demonstrate modest ability after training, performing considerably better than non-Balinese subjects. This suggests that the relative alignment of instrumental onsets is insufficient information to enable Balinese listeners to reliably associate byars with their respective ensembles, contradicting the claim made by some native experts. When and if such identification is indeed possible, we speculate that is likely the combined result of temporal, intonational, timbral, and compositional information.

THE BYAR

Any byar includes both variable and invariable voices. When executing a byar all metallophone instruments perform, in unison, one of the five pitches available on the Balinese gamelan gong kebyar. These ensembles are tuned to the *selisir* mode of the *pélog* tuning system, typically notated in standard Western notation as C♯ (pitch 1 or ding), D (pitch 2 or dong), E (pitch 3 or deng), G♯ (pitch 5 or dung), A (pitch 6 or dang), although actual pitches—both starting pitches and intervals—are highly variable by ensemble (cf. McPhee 1966). Invariable voices include the *ceng-ceng* cymbals, the *kendang wadon* (the lower of the paired barrel drums), *gong agung* (the lower of the paired large gongs) and the *reyong* horizontal pot gongs. Although pitched, the reyong always performs a chord including the 1st, 3rd, 4th, 6th, 7th, 9th, 10th and 12th pots, associated with pitches (low to high) 3 (E), 6 (A), 1 (C♯), 3 (E), 5 (G♯), 1 (C♯), 2 (D), 5 (G♯), creating a tone cluster including all of the tones of the selisir mode. In some cases, half of the *gangsa* metallophones perform a harmonic variation known as an *empat* in which the base tone is doubled four keys above, resulting in an interval close to a fifth. Figure 1 provides a transcription of a byar on pitch 1 (ding, C♯). Each of the samples analyzed in the present paper, and used as the basis for the listening task, were pitch 1 (ding,

2. This experiment was determined to be IRB-exempt. Non-Balinese (primarily Americans) with gamelan experience were drawn from various ensembles in North America and students studying in Bali. Non-Balinese without gamelan experience were students in two introductory music courses at the University of Richmond. One hundred twenty-three subjects were included in this experiment. One hundred five subjects participated in the experiment under group conditions.

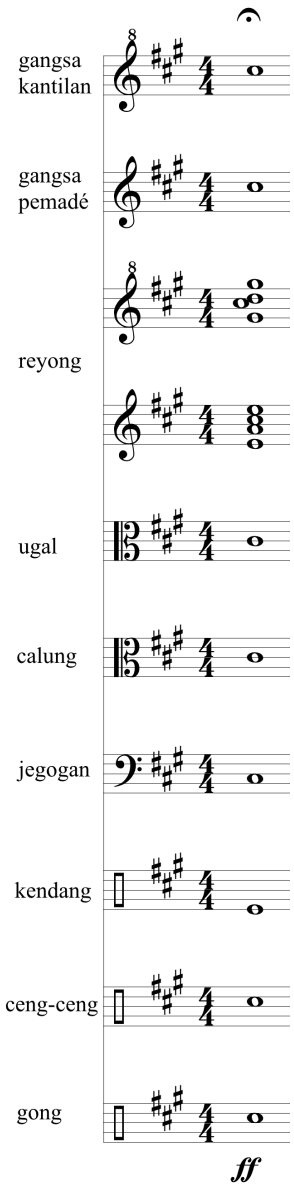

Figure 1. Byar on pitch 1 (ding, C♯).

C♯) byars. Follow this link to hear an example of a byar from the sample set, performed by the ensemble in Jagaraga.

Recording and Selection of Ensembles

Recordings of byars were made using piezoelectric sensors affixed to the ends of gamelan keys and the edges of gongs and in no way impeded the natural performance or sound of the instruments themselves (see McGraw 2013a). Information from the sensors was recorded at 96 kHz on a 24-track JoeCo field recorder. Onset points were determined using the

Aubio plugin in Sonic Visualizer.[3] Six Balinese village ensembles were selected based upon their renown and stylistic distinction as expressed by leading Balinese performers and composers in ethnographic interviews recorded by McGraw. These ensembles include Jagaraga (in Buleleng district), Pengosekan (the Cudamani ensemble, in Gianyar district), Gladag (in Kodya district), Pinda (in Gianyar district), and Perean (in Tabanan district). See Figure 2 for a map indicating the location of each ensemble. Many Balinese respondents described these ensembles' styles as indicative of their geographic region; i.e., that Jagaraga was a strong sonic "representative" of Buleleng; that Perean "represented" Tabanan.

An additional American group, Raga Kusuma (based in Richmond, Virginia), was later recorded for comparison using the same method.[4] Each of the Balinese ensembles

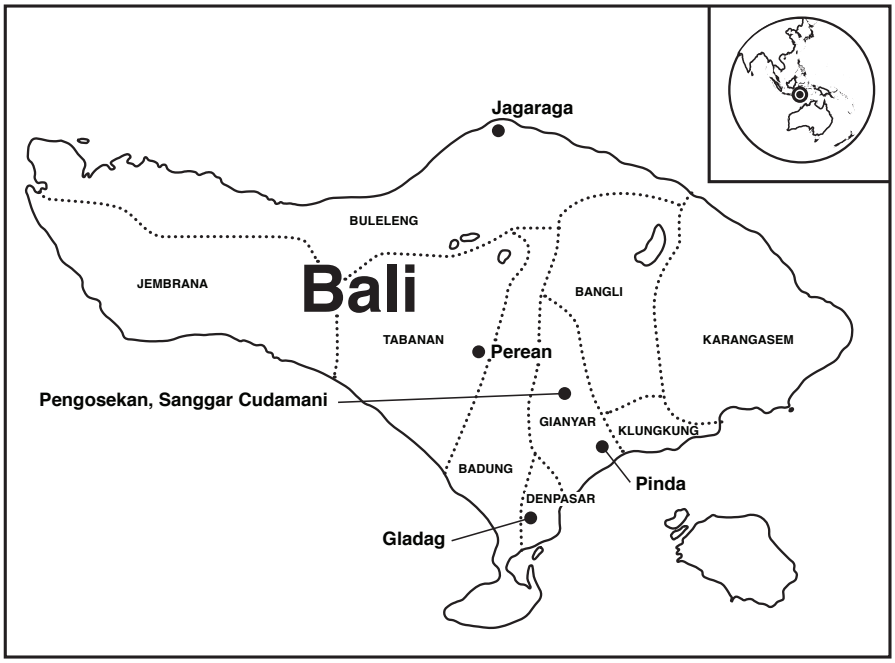

Figure 2. Map of Bali.

3. The original data were captured in the form of .wav files. Because these files occasionally included slight noise (generated by musicians holding and dampening the keys with their left hand prior to and following a strike by their right hand), they were processed using onset detection algorithms with thresholds adjusted to eliminate the false-positives generated by noise. We found the most reliable onset detection algorithm to be the Aubio onset detector using a High-Frequency Content function set to 128 samples per window, such that the minimal temporal threshold for detection was 1.3 ms (at a sample rate of 96,000). Events below the 1.3-ms threshold are treated as simultaneities in this paper and are well below the human threshold for perceptual simultaneity for both simple (sequential) and complex (overlapping) stimuli.

4. This ensemble is composed of non-Balinese (primarily American) students of gamelan and is directed by McGraw.

represented the leading ensemble in its respective village.[5] Ensemble directors were careful to ensure that each of the performers played in their regular spot and that any new or substitute members did not participate in the recordings. This led to occasional, but rare, empty seats in some recordings.[6] Ensemble directors considered this preferable to any potential disruption or confusion that substitutes might cause. In recording sessions it became clear that while each of the ensembles was well regarded, some were clearly past their prime. While all were actively performing and practicing, the ensembles from Pengosekan and Perean appeared to be better rehearsed and "tighter." Members of ensembles from Jagaraga, Pinda, and Gladag admitted that they were somewhat rusty but claimed to faithfully represent their distinct local styles.[7]

Byars were recorded in isolation, independent of any subsequent composition.[8] We believe this methodology was justified for two reasons. First, many pieces in the kebyar style begin with an isolated byar followed by a pause before continuing to the body of the composition. Secondly, some Balinese informants suggested that they could identify ensembles based on opening byars alone. In each of the recording sessions, ensembles performed "ding" (C♯) byars. Ensembles paused for ten to twenty seconds between byars, sometimes to discuss technical improvements and adjustments that needed to be made. Six to nine byar samples were collected from each ensemble. Musicians were allowed to "veto" any byar that was felt by any of the performers to be faulty, lacking in any way or unrepresentative of their musicianship, ability or local style. In most cases, two to three of the byars recorded during a session were vetoed and excluded from the corpus analyzed here.

5. Ensembles were associated with larger collectives, either neighborhood hamlets (*banjar*) or private arts clubs (*sanggar*), in which multiple groups of musicians rehearsed and studied. Each group typically included adult male (*dewasa*), women's (*ibu-ibu*) and children's (*anak-anak*) ensembles. However, only the most proficient and active ensembles, invariably the adult male groups, were recorded for this analysis. Ensembles were paid for recording sessions, which were conducted in the ensemble's regular rehearsal space. Most recording sessions were attended by a large number of inquisitive community members.

6. There were no absences in crucial positions such as kendang, ugal or gong. Jagaraga was missing a calung player, Cudamani two gangsa players, Raga Kusuma a gangsa player, and Perean a gangsa player.

7. The Balinese informants inspiring this study referred to unique performance styles both at the level of region (e.g., "Buleleng") and ensemble (e.g., "Gladag"). Had the informants' claim been based upon strictly regional variation, it would have been more appropriate to randomly pick ensembles in each of the regions. However, this would involve the considerable logistical challenge of controlling for ensemble ability (correlated to average age and rehearsal/performance intensity) and likely require the recording and analysis of many more ensembles. Logistical and time limitations restricted us to six Balinese ensembles, plus one American ensemble. All of the data recorded for this project is presented here; we did not "pick and choose" data from a larger body of recording sessions.

8. During preliminary recordings in Perean, isolated byars were compared to byars performed within the context of a longer compositional passage. No practical differences were noted by the performers or McGraw. A rough, in-the-field comparison in Audacity demonstrated no consistent differences in overall temporal spread or profile of instrument onsets between isolated byars and those performed within a longer compositional context.

Recording Results

Although some Balinese informants suggested that the byar should be a "simultaneity" (*keserentakan*) in which all instruments play exactly together, actual byars are considerably more temporally complex. Each of the ensembles recorded for this project displayed variations in the overall temporal spread of their byars (first-to-last IOI, interonset interval) and in instrumental alignment, as discussed in connection with Figure 3 below.[9]

In this section we first summarize psychoacoustic research on human perception of onsets, noting the possibility for a discrepancy between the algorithmic record of onset time and the perceived onset of individual instruments within a complex musical context such as the byar. We then analyze the temporal profiles of instrumental onsets between the six ensembles, comparing instrument families. We discuss some tendencies unique to specific ensembles and which may play a role in expressing a local musical identity. We then point out some tendencies common to most ensembles, offering musical theories for their presence.

Hirsh (1959) demonstrated that humans can perceive onsets as distinct events if their temporal separation is above 2 ms, but that a greater interval (approximately 20 ms) is required in order to consciously perceive the order of events (i.e., high–low vs. low–high). Hirsh et al. (1990) found that listeners can discriminate a temporal interval difference on the order of 5 to 10% at a resolution of 100 ms and above.[10] The conditions of Hirsh's tests—brief sounds of identical timbre played in non-overlapping sequences—were significantly different from the experience of hearing a byar in which multiple timbres from multiple sources overlap. Depending on the stimulus parameters, humans can detect onsets of complex sounds with thresholds of just a few milliseconds (Patterson and Green 1970; Zera and Green 1993). Rasch (1979), however, found that listeners may perceive onset synchrony in ensemble performances despite actual asynchronies of 30 to 50 ms. Several studies suggest that the perception of synchrony in ensemble stimuli is well above the threshold for discriminating temporal order in asynchronous sequences of simple stimuli (Pastore et al. 1982; Sheft 2008).

The recording apparatus and onset detection algorithms used here recorded the contact of mallet and instrument; we should not assume this neatly corresponds to perceived onset time. "Rise time, along with intensity level, is a primary determinant of the perceptual onset of attack time of musical notes" (Sheft 2008, 245; cf. Vos and Rasch 1981; Gordon 1987). Because the full gamelan incorporates a wide range of timbres, intensities and rise times, the perceived onsets of its many instruments may vary from those recorded and reported here. The timbral richness of the ensemble may encourage the perceptual fusion of spectrally distinct tones (Sheft 2008, 252), or pose difficulties for determining temporal order of onsets (250). Musicians may deliberately manipulate their performance to account for the effects of both acoustics

9. For the purpose of this analysis, results presented here assume that individual byars from a specific ensemble were independent trials given the pauses taken between each recorded sample.
10. For a review of the perceptual literature on human temporal perception in relation to music, see London (2004).

and the peculiarities of human auditory perception. Like Western orchestral musicians, Balinese performers may place their attacks at different times in order to sound synchronized. Alternately, they might deliberately displace their onsets for particular effects. Asynchrony of onsets may encourage perceptual clarity of the elements of complex sounds such as the byar (Sheft 2008, 241; cf. Goebl and Parncutt 2003), and performers may consciously control this asynchrony as an expressive strategy (Repp 1996).

Figure 3 indicates that the temporal spread of all of the byars recorded in this study ranged from 0 ms to 288 ms. Most of the temporal separation between ensembles across all byars straddles the 2-ms to 100-ms range.

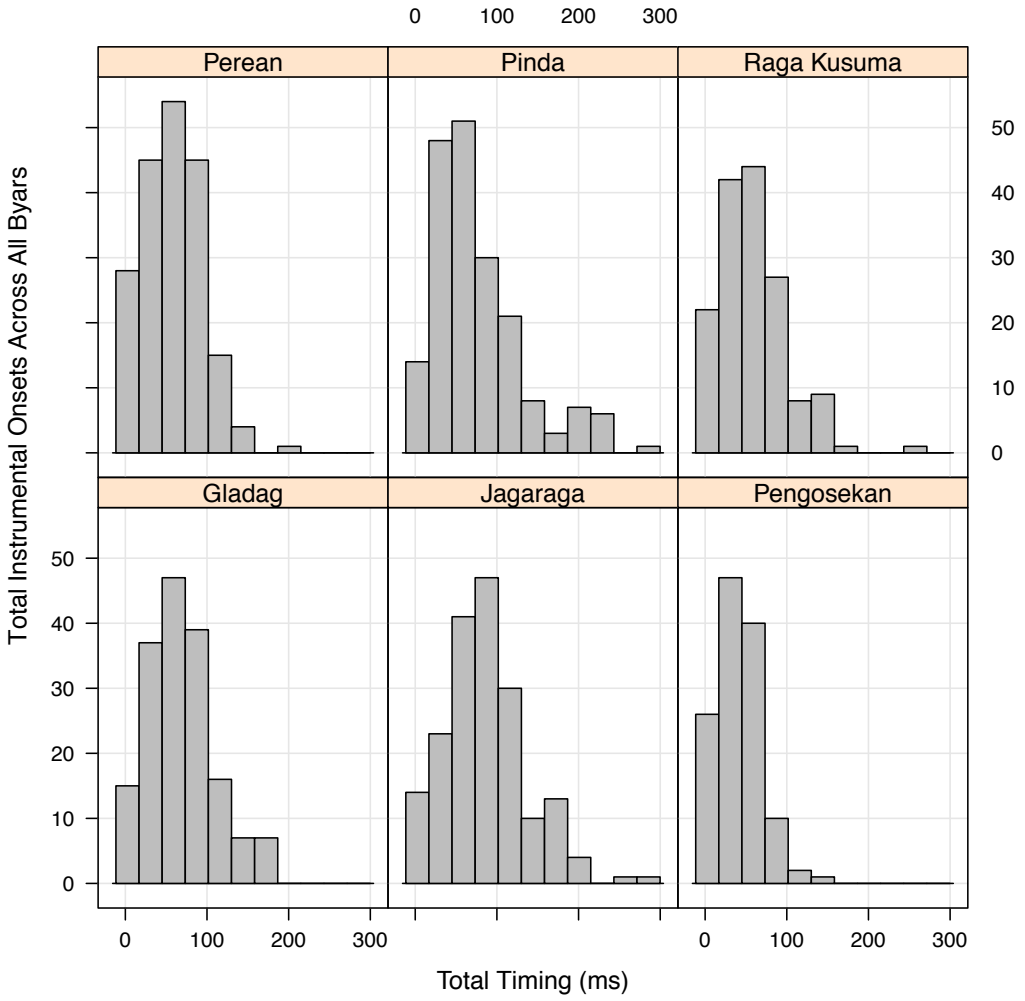

Figure 3. Histogram of total timing of byars, by ensemble.[11]

11. A histogram graphically represents the frequency distribution of data within a predetermined set of ranges ("bins"), pictured in Figure 3 as vertical bars. For example, the leftmost bar in the graph for Gladag indicates that, from the total number of samples collected in that village, approximately fifteen onsets (individual strikes on an instrument) fell within the range of 0 to 25 ms from the initial instrumental onset.

Based on the results of the listening experiment discussed in the second half of the paper, it appears that many Balinese musicians can detect some of the temporal differences between byars, but may have difficulty articulating exactly what those differences are. We might think of the temporal alignment of instrumental onsets within the "moment" of the byar as analogous to the spectra of a single sung tone. If the same pitch is sung by two different singers, most of us can hear that there is a difference, but may not be able to articulate the specific and minute spectral characteristics that determine the difference.

As illustrated in Figure 3, the recorded ensembles displayed a continuum from most compact temporal spread values (Pengosekan with a maximum temporal spread of 130 ms) to widest (Pinda and Jagaraga, at 288 ms and 281 ms, respectively). For some Balinese informants, more tightly synchronized (*incep*) byars were objectively better. For others, a certain amount of temporal distribution (within vague/fuzzy limits) was allowable and even desired. Overall, byar temporal spread readings for all ensembles, over all recorded byars, are centralized between 0 and 150 ms with only 1% of readings above 200 ms. However, to further analyze the right-skewed temporal spread readings, a transformation of the data is required to achieve approximate normality, a necessary requirement for subsequent statistical analyses (see Appendix B for details on the transformation used and explanation of right skewness).

The instrument onset profile comparison shown in Figure 4 combines all of the ensembles and recorded byars and focuses on the differences between the individual instruments, with all of the reyong tones combined. Due to the application of the square root transformation on total timing, the scale of the horizontal axis is in terms of the square root of the recorded value (e.g., $5\sqrt{\text{ms}} = 25$ ms). The circles represent timing values that are statistically considered outliers,[12] such that those specific timing values are different from the majority of the timing readings in either direction. For example, the gong has four outliers at zero, two of which belong to Raga Kusuma, while the two largest temporal spread values correspond to Jagaraga. Overall, the center 50% of all instrument temporal spread values (gray boxes in Figure 4) overlap, and all of the temporal spreads overlap. In Figure 4, the vertical line within the central latency box represents the median or middle latency of a specific instrument, such that 50% of the values were either larger or smaller.

Instrument onset profiles are compared across ensembles in Figure 5. To describe instrumental interactions within ensembles, we must compare the interonset intervals between instruments in single byars. Charts for each of the 45 byars sampled for this study are presented in Appendix C. Comparing these charts we notice some striking tendencies both within and across ensembles. The gong displays a strong tendency to arrive late in several of the ensembles. In all but one of Jagaraga's byars the gong arrives in the last third of the texture; in half of the Jagaraga byars the gong is the last instrument to arrive. In all of Pengosekan's byars the gong arrives in the final third of the texture; this is also the case in all

12. See Appendix B for further details on how values are identified as outliers.

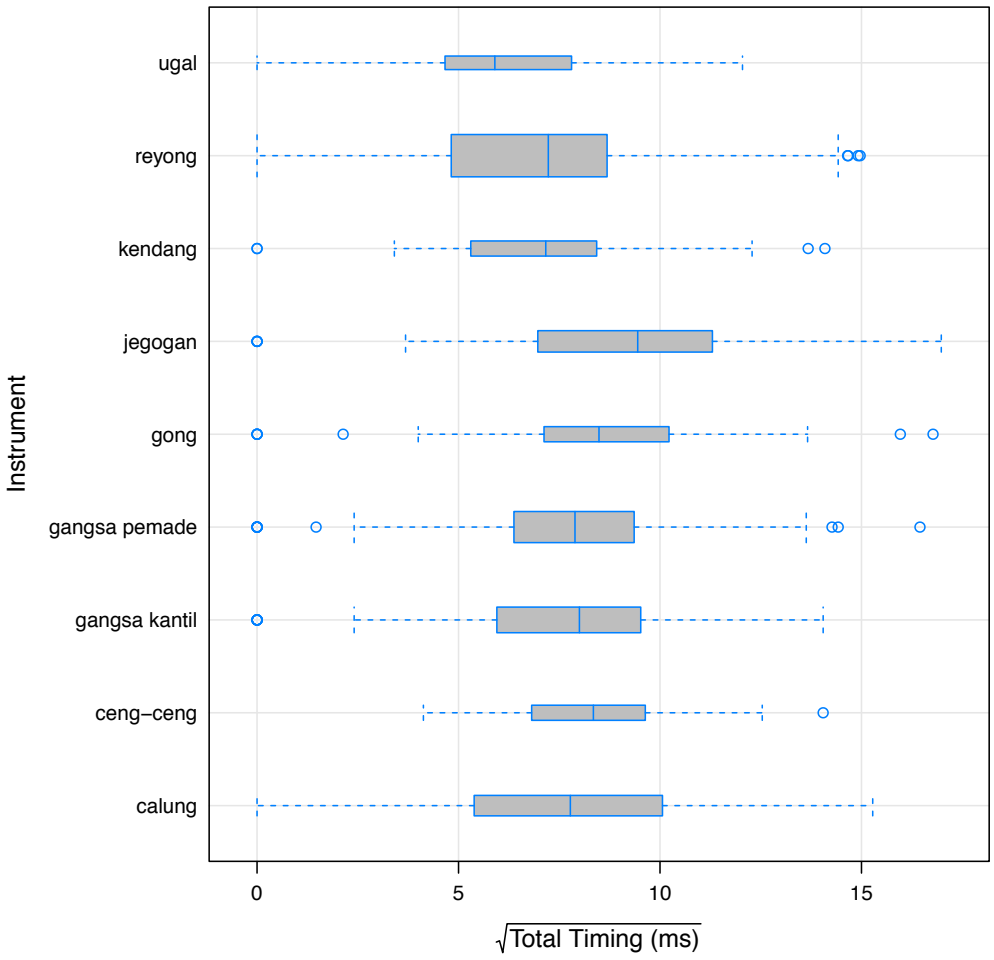

Figure 4. Box-plot comparison of onset (attack) profiles for various instruments.[13]

but one of Gladag's byars. Gong timing is much more variable in the byars performed by Perean, Pinda, and Raga Kusuma.

The kendang demonstrates similar, although less distinctive, tendencies in several of the ensembles. In Jagaraga, the kendang appears in the first third of the texture in all but one byar. In Gladag the kendang appears in the first half of the texture in all but one byar, but never appears as the first instrument, as it occasionally does in Jagaraga. This is also the case in Perean's byars in which the kendang always appears in the first half of the texture. The kendang orients around the center of the texture in all but one of Pinda's byars and in the

13. Box-plot graphs represent data through quartiles. The box represents the interquartile range; the vertical line within represents the median. In Figure 4 the left side of the box represents the first quartile, the right side the third quartile. The lines, or "whiskers" extending from either side of the box represent the minimum (left) and maximum (right) values while the small boxes beyond the whiskers represent statistical outliers (see Appendix B for more on outliers).

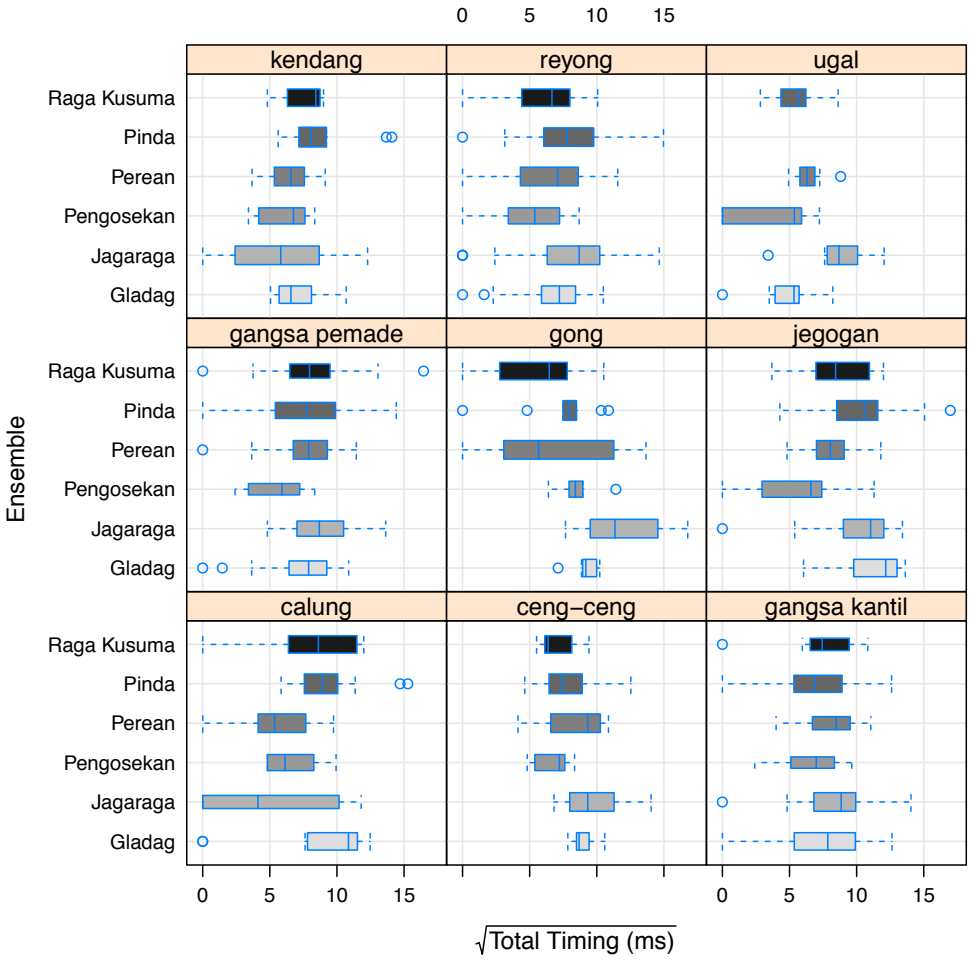

Figure 5. Comparison of ensemble onset profiles, by instrument.

center of all of Raga Kusuma's byars. Somewhat surprisingly, considering the ensemble's very tightly coordinated byars, the temporal placement of the kendang in Pengosekan's byars is comparatively variable.

The ugal consistently appears near the beginning of byars performed by Gladag and Perean. In Pengosekan the ugal arrives in the first half of the texture in all but one byar. Although displaying weaker tendencies than the gong, kendang, and ugal, the ceng-ceng hand cymbals generally avoid the periphery in byars performed by all of the ensembles. Other instruments display weaker tendencies within and across ensembles, being scattered throughout the texture and changing from byar to byar.

Strong tendencies are likely related both to an instrument's timbre and the ergonomics of its performance. Low frequency instruments such as the gong and jegogan have muted, quiet attack tones and a long sustain, meaning that a late arrival is not necessarily noticeable

or disturbing. Their mallets are also considerably heavier than those for other instruments, possibly leading to delayed strikes. The ceng-ceng, with its bright clashing cymbal tone, has comparatively little timbral competition, making it highly audible. Any early or late arrivals by the ceng-ceng would be highly evident. As ersatz ensemble directors, the kendang and ugal may arrive earlier to cue the full ensemble.

Reyong Synchrony

Every byar includes a reyong chord in which each of the four reyong musicians strikes two pots (see Figure 1 for the pitches of each pair). The reyong gong-chime is unique in the orchestra both for its timbre (tuned pots rather than metallophones) and the fact that its four musicians use both the left and right hand, rather than the right hand alone, as is the case for all of the other instruments aside from the ceng-ceng cymbals. In this section we investigate synchrony between the left and right hands and across all reyong onsets, noting a range of synchrony between ensembles.

Analysis demonstrates that individual musicians' right and left hands are highly coordinated, sometimes perceptually simultaneous. In 44 of the 207 reyong tones recorded, the musician was recorded as striking both pots simultaneously.[14] Those 44 instances are separated by ensemble in Figure 6. Since there is only one musician per ensemble striking each pair of tones across the trials, a non-zero value suggests a musician-specific precision. Some American reyong musicians (in Raga Kusuma) were as or more precise than Balinese musicians, but as a group were less precise than most of the Balinese reyong sections.

	Reyong Tone			
	Performer 1 E(4)–A(4)	Performer 2 C#(5)–E(5)	Performer 3 G#(5)–C#(6)	Performer 4 D(6)–G#(6)
Jagaraga	3	1	0	5
Raga Kusuma	3	2	4	1
Perean	0	3	3	0
Gladag	0	4	0	6
Pengosekan	4	0	1	4
Pinda	0	0	0	0

Figure 6. Number of simultaneous strokes by reyong players, by ensemble.

14. The minimal temporal threshold for detection was 1.3 ms. This accounts for a "simultaneity" in this paper. See footnote 3 above for an explanation of how this threshold was determined.

We next explore whether there is a link between perfect unison of the left and right hand and the ensembles. In Figure 7, the red 45° line represents simultaneous reyong strikes, such that the red points on the line correspond to the instances presented in Figure 6. Overall, most of the reyong players in each ensemble tend to strike with their left and right hands nearly simultaneously, indicated by the proximity of the points to the 45° line. The actual trends of right- and left-hand strikes for each ensemble are shown with the black line. For all ensembles, except for Pinda, there is close alignment between the actual and ideal. However, the overall profile for Pinda shows reyong onsets that are rather diffuse.

Certain differences in reyong temporal profiles between ensembles may be traceable to musicians' technique. Musicians in the Gladag ensemble differentiated their reyong technique from other ensembles through their tendency to play at the edges of the mallet,

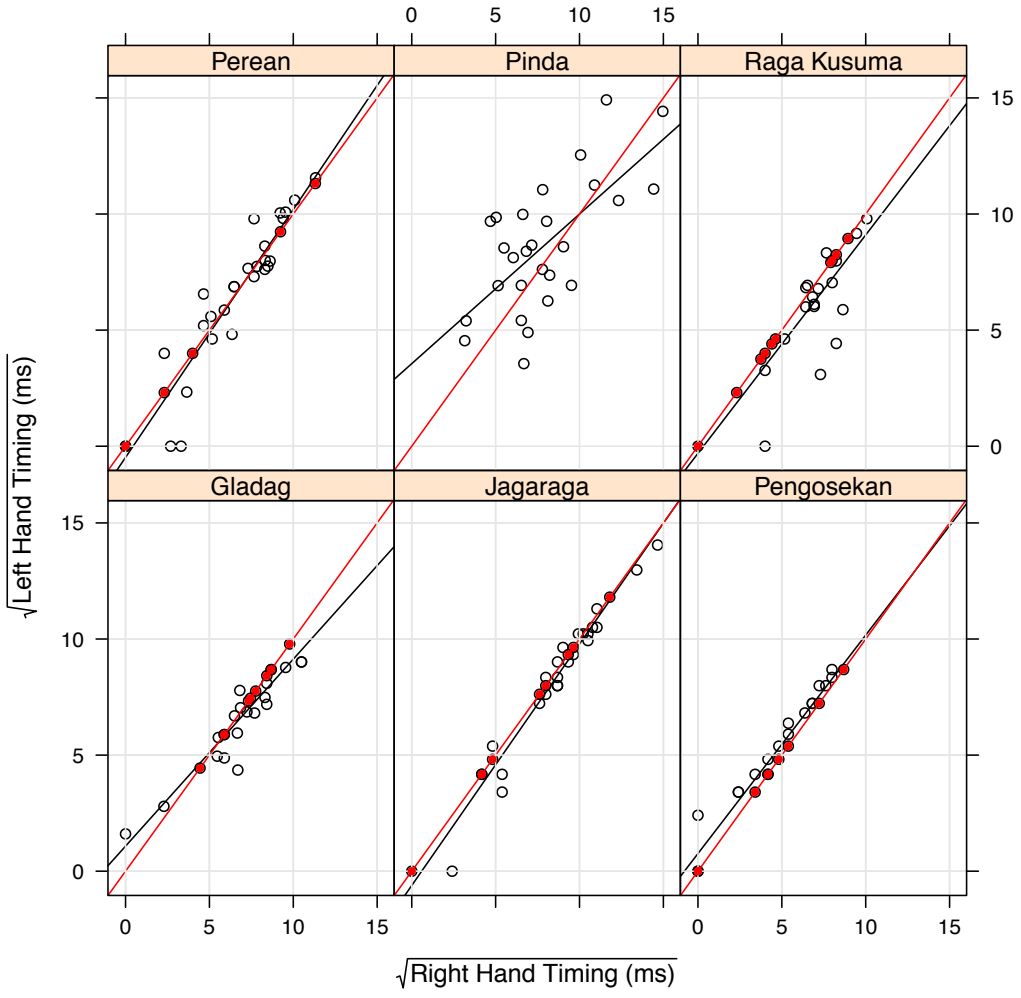

Figure 7. Proximity of right–left reyong strokes to ideal, by ensemble.

shifting its feel and response. Some suggested this allowed them to perform temporally more accurately, although this does not appear to be supported by the data in Figure 7. Reyong musicians in Pengosekan suggested that their use of smaller finger muscles rather than only wrist muscles afforded them greater synchrony, a suggestion that may be supported by the data in Figure 7.

Differences between right- and left-hand timings by ensembles are illustrated in Figures 7 and 8. Slight left-hand precedence (represented by points below the 45° line in Figure 7 and boxplots shifted to the left in Figure 8) in reyong playing appears evident in both the American ensemble (Raga Kusuma, which had a range of -4.2 to .7) and the Gladag ensemble (-2.3 to 1.6). A very slight, but consistent, precedence of the right hand is evident in Pengosekan (range of 0 to 2.4). To compare whether the mean differences between left and right hands are statistically different across ensembles, Welch's analysis of variance test was run, which verified that there is a statistically significant difference between the mean left–right strike difference between ensembles, $F(5,74.984) = 7.39$, $p < .001$.[15]

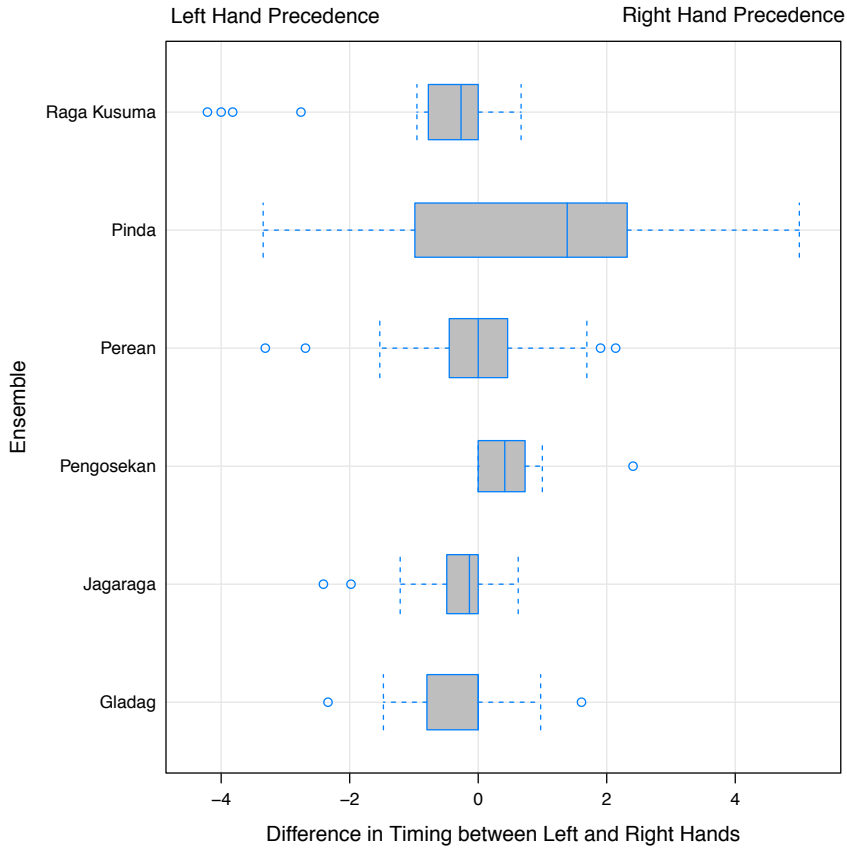

Figure 8. Difference in total timing ($\sqrt{\text{ms}}$) between left- and right-handed reyong strokes, by ensemble.

15. Welch's test was used because the variability across ensembles violated the equal variances assumption of the standard one-way analysis of variance test. The largest standard deviation (Pinda) is more than four times larger than the smallest (Pengosekan).

Confounding Factors

Balinese expert informants were consulted throughout the recording process, experimental design, and discussion of results, and they provided very astute commentary on possible confounding factors. In this section we review their points and discuss additional potential confounding factors. While many informants argued that each ensemble should display unique temporal profiles in their byars—the principal claim investigated in this paper—some suggested that the byar could only be a very fluid and tenuous sign of regional identity. Several expressed some version of the phrase, "different day, different byar," suggesting that the results presented here may look different if the recording sessions were repeated on another day. Others suggested that the exact character of an ensemble's byar was more a function of a group's leader than of regional style or even the musicianship of the supporting musicians. Both I Nyoman Windha and I Dewa Ketut Alit suggested that the quality of an ensemble's byar was "completely determined by the ugal player." It is perhaps not surprising that both Alit and Windha are renowned ugal players. When directing the Jagaraga ensemble in Buleleng, I Madé Keranca decried their first attempts at byars as "*kurang tajam*" (not sharp enough) and he sang examples of what a "true Buleleng byar should be." However, other informants suggested that what was being expressed was not Buleleng's but Keranca's personal style: "It's his byar, not Buleleng's" (I Wayan Sudirana, pers. comm., November 2014). Follow this link to hear a field recording of Keranca coaching the Jagaraga ensemble on the "proper" sound of the Buleleng (Northern Regency) byar.

Many informants suggested that a byar performed before an informal, sympathetic home audience at one's own rehearsal space would be different than a byar performed within a contest (*mabarung*) context in which ensembles face their opponents across the stage, for large, rowdy audiences and for which they rehearse intensively for months in advance. Needless to say, such conditions do not allow for controlled recording conditions such as those employed here. Whether or not such results would be "better" or simply "different" was a matter of debate amongst Balinese informants. Several informants suggested that the byars produced by the contemporary personnel of the ensembles in Jagaraga, Gladag, and Pinda should not be understood to represent the musical qualities which made those ensembles famous in previous decades.

One potential confounding factor not mentioned by Balinese informants was the possible acoustical effects of their rehearsal spaces in which the byars were recorded. While the recording mechanism was in no way impacted by acoustical differences, musicianship possibly was. The "natural habitat" for the Balinese gamelan gong kebyar is an outdoor(s) space, typically along the low brick wall of a Balinese temple, or in the open acoustics of a Balinese *wantilan*, similar to a Javanese *pendopo*, in which a high tile roof is supported above four open sides as in Figure 9. These are comparatively "dead" acoustical environments in which rhythmic precision can be clearly heard and, over time, might potentially help the players improve their synchronicity. Pinda, Jagaraga, and Gladag rehearsed in reverberant, tiled *banjar* meeting halls with more "live" acoustics than are typically found in most

performance contexts in Bali. Pengosekan (Cudamani) rehearsed in a very "dead" space with only one wall and a thatch ceiling. This might partly explain the more compact nature of the Pengosekan byars and the more diffuse nature of those performed by other ensembles. Acoustically, it is simply more difficult to perceive rhythmic "inaccuracies" in a space such as that used by Gladag—a highly reverberant square hall with tiled walls, ceiling, and floor. Brought to Pengosekan's space, they might have performed differently, possibly becoming more synchronous over the course of the recording session. The American ensemble (Raga Kusuma) rehearses in a very dead space including acoustical panels. This, however, seemed to confer them no "advantage" (assuming, for a moment, that absolute synchrony is the aim), as their byars were as or more diffuse than Balinese ensembles recorded within highly reverberant spaces.

An ensemble's decay profile might contribute to regional identification as well. In the northern Buleleng region metallophone keys are sometimes supported below the nodes by posts (*gangsa jongkok*), which can contribute to a faster decay profile as compared to suspended keys (*gangsa gantung*), which are typical of gamelan in the south of the island. Accounting for the potential effects of acoustic decay was not incorporated into this study.

Figure 9. Children's gamelan gong kebyar ensemble from Singapadu village, rehearsing in a traditional *wantilan*. Photograph by McGraw.

Survey Responses

A survey was distributed to 56 Balinese respondents with questions related to the original claim made by Balinese informants, discovered through ethnographic interviews, that they could identify regional ensembles by hearing their byars alone. A large majority indicated that there were regional differences in byars. Only 4% attributed these differences to instrumental qualities such as tuning, timbre, or instrument construction, instead attributing the difference primarily to aspects of technique and generalized "feeling."

To the first question, "Do you think there is a difference between byars performed by Balinese and non-Balinese groups (such as American or Japanese gamelan ensembles)?" 89% of respondents answered in the affirmative, indicating that the byar is first of all conceived among Balinese respondents to be a strong acoustic marker of a generalized Balinese musical identity (responses included one abstention and one "maybe"). Respondents were then asked, "Do you think there is a difference between byars performed by different Balinese regional ensembles?" Ninety-four percent of respondents answered in the affirmative. Additional questions asked respondents to provide their reasoning, in narrative form, for these responses. Answers to these questions generally fell into four categories: *rasa* (or generalized feeling), technique, sociological differences, and instrumental quality. The results are presented in Figure 10 (respondent summaries were in some cases allocated to multiple categories, with seven abstentions).

The most common responses, categorized under rasa, conflate a rather wide variety of responses including "*rasa*" (overwhelmingly the most common response),"*taksu*," "*bayu*," "*bayuning gending*," and "*nafas*." "Rasa" (originally from the Sanskrit meaning flavor or essence) refers to a generalized feeling or emotion. In ethnographic interviews Balinese informants sometimes differentiated byars with "sharp" (*tajam*), "compact" (*kompak*) or "big" (*besar*) rasa, sometimes associating Perean, Pengosekan, and Pinda with these three types respectively. "*Besar*," referenced in two of the responses, might refer to either a wide temporal spread or a lower intonation, or both.

Category	Balinese or Non-Balinese	Village Differences
Generalized Feeling	39%	10%
Technique	47%	65%
Sociological Difference	20%	49%
Instrumental Quality	20%	4%

Figure 10. Respondents' explanations of Byar variations between (1) Balinese and non-Balinese ensembles and (2) Balinese villages.

In describing non-Balinese byars none of the respondents identified anything more specific than a generalized difference in rasa; foreign byars should "feel different" in ways none of them would, or could, specify. "Taksu" is a highly complex term that may refer to any or all of performative charisma, divine inspiration, or even possession (Dibia 2012). A performance may be technically perfect but lack taksu; performances that are less than technically proficient may nonetheless emit taksu, a quality individuals, groups, or even instruments may possess. When respondents evoked taksu in their survey responses, it was most often to suggest it as a quality non-Balinese groups could not possess or communicate through their byars. The Indonesian word "nafas" means breath, and may refer generally to phrasing in music. "Bayu" is a more polysemic Balinese term referring to a special force, energy, power, wind, or breath. Unlike taksu, versions of bayu or nafas were more often viewed as a quality non-Balinese could express or attain.

"Technique" captures the terms "*teknik*" (technique), "*cara pukul*" (striking style), and "*kekompakan*" (compactness), with some respondents suggesting that non-Balinese performers would have "less technique," and especially be "less compact" than Balinese performers. Temporal qualities such as *selah* and *gedig*, both Balinese terms referring to something like "timing" or "groove," are included in this category as well. "Sociological differences" represented the most ambiguous category in which respondents attributed different byars to a generalized "cultural difference" (*perbedaan budaya*), or even "genetic difference" (perbedaan *genetik*), although these differences were not associated with any normative value.

"Instrumental quality" includes references to gamelan's tuning (*laras*), beating (*ombak*) and spectral qualities (*warna swara*). Balinese gamelan are not tuned to any standard; the overall range of gamelan gong kebyar ensembles may vary over as much as a minor third between villages. The beating rate and exact method of tuning the beating relationships between higher (*ngumbang*) and lower (*ngisep*) metallophones, as well as the beating produced by large gongs, differ substantially between gongsmiths and villages. Finally, the spectral quality of an orchestra is a function of the exact alloy of its bronze, its age, the manner of suspending the keys and the hardness of the mallets. It is unclear why instrumental quality would be cited as a potential difference between Balinese and non-Balinese byars. It is possible that respondents are assuming a more homogeneous instrumental quality among exported gamelan, primarily made by two gongsmiths, I Wayan Beratha and I Madé Pandé Sukerta, with their characteristic tuning and manufacturing styles, as opposed to the more varied instrumental qualities found throughout Bali and represented by the ensembles recorded for the present project.[16]

For the third survey question, all but three respondents (6%) indicated that there are differences between the byars of different Balinese village ensembles (three abstentions). When prompted for their rationale in question four (see Figure 10), responses within the

16. An anonymous reviewer for this article suggested the additional possibility that respondents are expressing a belief that climatic differences in America might impact a gamelan's tone, which is certainly the case.

category of technique and sociological differences greatly outnumbered those associated with rasa or instrumental quality, suggesting that variations of "feeling" or ineffable "power" (taksu) were seen to be more proper to Balinese rather than foreign ensembles. Respondents associated differences between Balinese ensembles more often with technique (such as Gladag's unique reyong technique, described above) and sociological differences, than the possession or not of divine power or feeling. Within the latter category some respondents referenced a vague sense of *kemajuan* (progress) between more urbanized versus rural ensembles. This suggests that modernity itself is seen by some respondents to have direct musical consequences within Balinese traditional music, even at the level of the musical moment.[17] None of the respondents described exactly what those differences might be, suggesting the need to conduct follow-up ethnographic interviews. This exact point was raised in previous interviews conducted by McGraw in which some young musicians evinced nostalgia for the feeling, and expression, of *communitas* they perceived to be present in more rural ensembles such as Perean, Pinda, and Jagaraga. Younger musicians—often conservatory-educated cosmopolitan composers living in peri-urban, multicultural housing developments—associated these villages with an image of premodern, tightly knit agrarian lifestyles, as opposed to their own experiences, which many linked to the alienating forces of urban modernity.

Listening Experiment

The final survey question asked respondents if they thought they could identify different ensembles solely by the temporal qualities of their byars—that is, independent of the unique tuning and timbre of their particular instruments. The majority of respondents (70%) indicated either "yes" or "maybe." A listening experiment was administered immediately following the survey to test their accuracy. In this section we summarize the results of the listening test, outlining the construction of the experiment and important caveats to consider. We found that Balinese respondents were moderately successful (40% success rate) only after training in the form of hearing the examples identified with their respective ensembles. While Balinese respondents were considerably more successful than non-Balinese respondents, the survey results appear to contradict the original ethnographic claim.

McGraw worked with several Balinese informants in the effort to construct an ecologically valid listening experiment. Because we wanted to test respondents' ability to differentiate byars purely on temporal, rather than tuning or timbral qualities (the original claim), samples from a "neutral" gamelan outside of the corpus—an in-tune gong kebyar housed at the Consulate of the Embassy of Indonesia in New York—were used to construct the audio examples. This set was made and originally tuned by I Wayan Beratha in the early 1980s, and it was retuned by the American gongsmith Wayne Vitale in 2006. High quality samples were made of each of the keys and gongs and later normalized in Audacity.

17. An anonymous reviewer for this article suggested that an alternate interpretation for this observation could be linked to the greater concentration of academy-trained musicians in the cities as compared to the villages.

A single example byar was chosen at random from the six to nine byars recorded by each of the six ensembles. The timing of each instrumental onset was extracted in Sonic Visualizer and used to resynthesize the exact temporal relationship of the byars in Audacity using the "neutral" samples. That is, respondents never heard the original acoustic recordings of the particular ensembles, but only synthesized versions using the "neutral" samples recorded in New York. This was in order to restrict their response to the temporal structure of the byars. McGraw worked with the Balinese composers I Wayan Sudirana and Ida Bagus Madé Widnyana to manipulate the samples in order to achieve a more naturalistic-sounding byar.[18] In addition, a seventh, "synthetic" byar was produced by aligning all of the samples exactly to zero, creating the absolute synchrony that some Balinese respondents suggested was the aim (if not the result) of performing the byar.

Caveat

Several caveats regarding the examples used in the listening test must be pointed out. Because I Wayan Beratha made both the gamelan in Gladag and New York, the samples used in the listening experiment may not be entirely neutral. Although retuned by an American smith, the New York instruments may still retain the overall range, tuning and beating qualities many Balinese musicians associate with Beratha's gamelan gong kebyar. Although respondents were twice instructed to respond only to temporal, rather than tuning or timbral qualities, some respondents, especially in their first (pre-training) responses, may have heard a "Beratha" gamelan resulting in an artifact favoring Gladag.

The "neutral" samples cannot represent variations in striking styles potentially present in the different ensembles. According to the musician I Gusti Komin Darta from Pengosekan (Cudamani): "some groups seek a sharper sound, some a bigger sound. This partly depends on how you hold your mallet. In the open [more temporally diffuse] byars maybe they hold the [gangsa] mallet between the thumb and forefinger. In Pengosekan [Cudamani] we control the back of the mallet with our fingers (like a drumset player). It's harder, but it makes you more accurate and 'tight'" (pers. comm., November 2014). Like tuning and timbral quality, this information is neutralized in the listening experiment because it was not indicated as a decisive factor in the original ethnographic claim.

The Balinese expert collaborators suggested that manipulation of the neutral byar (including panning, phase inversions and volume adjustments) produced a sound "indistinguishable" from a natural byar. However, this manipulation represents their subjective judgment, one that may not be shared across the respondent population. Finally, the potential discrepancies between human perception of onset time and onset time as

18. According to these Balinese experts, the center-panned, normalized samples of the neutral gamelan produced an unrealistic byar because all instruments were at the same volume and there was no stereo image. They guided the manipulation of volume, phase inversion, and panning to create a stereo image that simulated the typical physical arrangement of a kebyar ensemble and adjusted loudness in accordance with their relative volumes in real ensembles, as heard from the audience.

detected by the algorithm used in Sonic Visualizer (discussed above) are not accounted for in the construction of the samples.

Discussion of Results

The results from all of the listening experiments are presented in Figure 11. The columns represent the tested group, while the rows are the possible responses. Seven byars were played for each of the groups, of which there were seven potential choices (the six ensembles plus the synthetically created ideal byar). The shaded row in each section identifies the actual byar played, while the unshaded rows are the incorrect choices. Balinese respondents first attempted to associate seven randomized resampled byar examples with their respective ensembles: Jagaraga, Raga Kusuma, Perean, Gladag, Pengosekan, Pinda, or Synthetic ("*buatan*"). These responses are collected under the "Pre-Test" column in Figure 11. Next, respondents heard each of the examples (again randomized) while the experimenter identified the source ensembles and prompted respondents to pay special attention to any differences or temporal peculiarities they might notice. Finally, Balinese respondents attempted the task again, with recordings randomized once more. These responses are collected under the "Post-Test" column in Figure 11. Because it was assumed that non-Balinese respondents would not have sufficient knowledge to differentiate examples "cold," they were asked to associate recordings with ensembles only after first hearing identified recordings. In each task all respondents were instructed not to repeat entries and were allowed to adjust (switch) responses as they heard subsequent examples.[19]

As described in the first line of Figure 11, Balinese respondents, as a group, correctly identified Jagaraga's byar (indicated by highlighting) only 17% of the time prior to identification, which is not statistically different than random guessing.[20] After hearing examples of byars with their associated ensembles revealed, Balinese respondents' accuracy increased to 51.8%, $z = 8.02$, $p < .001$.

It is highly unlikely that all subjects were equally familiar with all six ensembles. This potential inconsistency likely played a role in their ability to respond "cold," prior to training in the pre-test. Non-Balinese respondents, attempting the task after hearing identified examples, scored far better than chance, but not nearly as well as did the Balinese in their post-test. Surprisingly, non-Balinese with experience playing gamelan scored only moderately better than those with no experience.

Musicologically and ethnographically, the mistakes listeners made are as, if not more, interesting than their overall accuracy. For instance, in the pre-test Balinese respondents

19. The order of the byars was randomized for each trial. Some respondents participated in groups, others as individuals.

20. A response rate of 1/7 or 14.3% represents an uninformed guess. One-sided hypothesis tests were conducted for each listening trial, comparing whether the observed success rate was greater than that of random guessing. Stars indicate the strength of the resulting *p*-value, where results suggest that groups were able to identify a specific group better than just random guessing (see Figure 11).

tended to associate Jagaraga's byar more consistently with Perean and Gladag and almost never with Pengosekan or the synthetic byar. The comparatively diffuse Jagaraga byar, with its compact reyong section and leading kendang drum apparently evoked in many Balinese listeners (in the pre-test) associations with musical style in Perean and Gladag.

As seen in the second section of Figure 11 Balinese respondents associated Raga Kusuma's rather wide byar—with its late gong and diffuse gangsa—with the ensemble from

	Balinese Musicians		**Non-Balinese Musicians**	
	Pre–Test	Post–Test	Experienced Gamelan	UR Students
Jagaraga	17.0%	**51.8%*** **	37.5%	**32.4%** **
Raga Kusuma	17.0%	16.1%	21.9%	5.9%
Perean	26.4%	5.4%	3.1%	14.7%
Gladag	26.4%	5.4%	6.2%	23.5%
Pengosekan	1.9%	3.5%	12.5%	0%
Pinda	9.4%	10.7%	18.8%	20.6%
Synthetic	1.9%	7.1%	0%	2.9%
Jagaraga	16.4%	7.1%	3.1%	2.9%
Raga Kusuma	5.4%	**25.0%***	12.5%	23.5%
Perean	14.6%	19.6%	12.5%	14.7%
Gladag	20.0%	5.4%	25.0%	14.7%
Pengosekan	14.6%	3.6%	15.6%	20.6%
Pinda	25.4%	30.4%	25.0%	14.7%
Synthetic	3.6%	8.9%	6.3%	8.8%
Jagaraga	14.8%	7.1%	19.4%	5.9%
Raga Kusuma	11.1%	26.8%	22.6%	14.7%
Perean	14.8%	**25.0%***	12.9%	17.7%
Gladag	20.4%	16.1%	16.1%	14.7%
Pengosekan	20.4%	10.7%	12.9%	11.8%
Pinda	13.0%	10.7%	12.9%	29.4%
Synthetic	5.5%	3.6%	3.2%	5.9%
Jagaraga	14.8%	14.3%	9.7%	20.6%
Raga Kusuma	13.0%	8.9%	9.7%	5.9%
Perean	13.0%	8.9%	29.0%	11.8%
Gladag	20.4%	**53.6%*** **	22.6%	**26.5%***
Pengosekan	11.1%	3.6%	9.7%	14.7%
Pinda	20.4%	8.9%	16.1%	5.9%
Synthetic	7.4%	1.8%	3.2%	14.7%

* $p < .05$; ** $p < .01$; *** $p < .001$

Figure 11. Listening experiment results.[21]

21. Percentages may add up to more or less than 100% due to rounding.

	Balinese Musicians		Non-Balinese Musicians	
	Pre–Test	Post–Test	Experienced Gamelan	UR Students
Jagaraga	11.1%	10.7%	9.4%	5.9%
Raga Kusuma	13.0%	3.5%	12.5%	23.5%
Perean	3.7%	5.4%	6.2%	17.7%
Gladag	7.4%	5.4%	9.4%	2.9%
Pengosekan	**31.5%*** **	**48.2%*** **	25.0%	17.7%
Pinda	14.8%	–	15.6%	11.8%
Synthetic	18.5%	26.8%	21.9%	20.6%
Jagaraga	18.2%	1.8%	15.6%	17.7%
Raga Kusuma	12.7%	19.6%	15.6%	20.6%
Perean	12.7%	19.6%	25.0%	17.7%
Gladag	9.1%	12.5%	12.5%	5.9%
Pengosekan	10.9%	7.1%	18.8%	8.8%
Pinda	18.2%	**35.7%*** **	9.4%	11.8%
Synthetic	18.2%	3.6%	3.1%	17.7%
Jagaraga	9.3%	5.4%	3.2%	8.8%
Raga Kusuma	11.1%	8.9%	0%	8.8%
Perean	11.1%	5.4%	12.9%	2.9%
Gladag	7.4%	1.8%	9.7%	11.8%
Pengosekan	18.5%	30.3%	9.7%	29.4%
Pinda	5.6%	7.1%	6.5%	5.9%
Synthetic	**37.0%*** **	**41.1%*** **	**58.1%*** **	**32.4%** **

Figure 11 continued.

Pinda in both the pre- and post-test, as did non-Balinese respondents with gamelan experience. This suggests that there may be a pre-test association amongst the Balinese respondents with Pinda's musicianship and a comparatively open (less compact) sound.

Perean's style also seemed ambiguous to Balinese respondents (and non-Balinese with gamelan experience), who tended to associate it strongly with Raga Kusuma in the post-test. While Balinese respondents tended to associate the Gladag byar equally with Gladag and Pinda in their pre-test, their accuracy as a population increased markedly after hearing identified examples (to 53.6%, $z = 8.4$, $p < .001$), far better than the non-Balinese groups. Surprisingly, the non-Balinese group with no gamelan experience performed better at identifying Gladag than did those with gamelan experience, possibly by noting the audibly early ugal tone.

Balinese respondents were comparatively accurate in correctly identifying the Pengosekan byar in both their pre-test (31.5%, $z = 3.6$, $p < .001$) and post-test (48.2%, $z = 7.3$, $p < .001$). However, like the non-Balinese listeners with gamelan experience, they tended to

confuse it most often with the synthetic byar. The Pengosekan byar was indeed the most compact of the natural examples.

Balinese respondents did not have a clear sense of what a byar from Pinda might sound like, as indicated by their highly divergent responses in the pre-test. The comparatively diffuse sound of their sample byar allowed Balinese listeners to more accurately identify Pinda in the post-test (35.7%, $z = 4.5$, $p < .001$), while neither of the non-Balinese populations were able to predictably identify Pinda.

Training (hearing the samples identified with their sources) seemed to help Balinese subjects eliminate possibilities more than aid them in correctly identifying ensembles. In the pre-test 5.4% of Balinese subjects correctly identified Raga Kusuma, with 20% mistaking it for Gladag and 25.4% mistaking it for Pinda. After training, 25% correctly identified Raga Kusuma, but 30.4% incorrectly identified it as Pinda and 5.4% incorrectly identified it as Gladag. That is, a unique attribute of the Gladag sample may have removed any confusion between it and Raga Kusuma, but perceptually increased the ambiguity between Raga Kusuma and Pinda.

Possibly most interestingly, Balinese respondents fared worse in their ability to correctly identify the synthetic byar than did the non-Balinese population with gamelan experience. Balinese respondents' accuracy improved only minimally (37% to 41.1%, both significant at $p < .001$) between the pre- and post-test, many confusing it for the Pengosekan byar, the most compact byar within the sample set. Non-Balinese with gamelan experience correctly identified the synthetic byar 58.1% of the time, $z = 6.9$, $p < .001$, and non-Balinese with no experience correctly identified it 32.4% of the time, $z = 3.1$, $p < .01$, not far from the Balinese' pre-test accuracy. It is unclear why this might be the case. It may be that non-Balinese, possibly having more experience than the Balinese with "synthetic" music produced on computers and which typically incorporates less complex temporal structuring than that found in Balinese gamelan music, have a comparatively refined sense of human versus machine musicality. Or it may simply be attributed to accurate student guessing.

As summarized in Figure 12, Balinese subjects were able to correctly identify ensembles 40% of the time in the post-test (after training). Non-Balinese subjects with gamelan training were able to correctly identify ensembles 25% of the time (after identification). Non-Balinese subjects with no gamelan training were able to correctly identify ensembles 23% of the time (after identification).

Conclusions

In the listening test, Balinese subjects correctly identified ensembles more often than non-Balinese subjects. We speculate that the perception of onset timing differences played a role in this difference. The finding that the Balinese respondents were better than non-Balinese at distinguishing audio examples of their own music is far from shocking. It is what

	Balinese Musicians		Non-Balinese Musicians	
Correct	Pre–Test	Post–Test	Experienced Gamelan	UR Students
None	11 (21%)	2 (4%)	3 (9%)	8 (24%)
One	23 (43%)	9 (16%)	14 (44%)	7 (21%)
Two	11 (21%)	13 (23%)	6 (19%)	10 (29%)
Three	3 (6%)	16 (29%)	7 (22%)	8 (24%)
Four	2 (4%)	7 (13%)	1 (3%)	1 (3%)
Five	3 (6%)	8 (14%)	1 (3%)	0 (0%)
Six	0 (0%)	1 (2%)	0 (0%)	0 (0%)
Total Correct	77 (21%)	157 (40%)	56 (25%)	55 (23%)
Sample Size	53	56	32	34

Figure 12. Number of correctly identified ensembles, by group.[22]

we would expect. The real lesson is that this occurs at such a minute level. In the case of this single musical atom—the byar—the experience of in-group and extra-group listeners are already divergent. For some non-Balinese listeners the experience of hearing the byar was something akin to noise; they could not capture meaningful information that might allow them to differentiate the examples. For many Balinese respondents, by contrast, these examples suggested meaningful, rich musical experiences. This suggests that Balinese composers cannot assume that their American (or Japanese, European, etc.) audiences are having the same auditory experiences their local audiences are. Musicologists have long realized that the cognition of higher-level musical elements—intonation, affect and structural form, for instance—are complexly conditioned by culture.[23] The results of the listening test suggest that such conditioning can be observed even at the scale of the musical moment.

This study confirms the value of involving local informants as deeply as possible in designing the questions, experimental design, and interpretation of research programs. The Balinese informants were the best equipped to point out potential confounding factors and indicate ways in which the results of both the onset measurements and the listening test were highly contingent and provisional. The challenges involved in closely measuring both the structure and perception of this example of musical minima suggests that we should exercise considerable caution when analyzing more complex musical structures. If a single chord presents such a rich world of performative variation and perceptual complexity, what of our ability to meaningfully analyze our favored musical features: melodies, meters, and overall form? What of the temptation to make sweeping statements about the "cultural" perception and cognition of such features?

22. Percentages may add up to more than 100% due to rounding.
23. On this topic see, for instance, Balkwill and Thompson (1999); Curtis and Bharucha (2009); Eerola and Vuokoski (2013); Fritz (2013); Kesler, Hansen, and Shepard (1984); Krumhansl (2000); McGraw (2013b); Moore (2012); Ali and Peynircioglu (2010); Perlman and Krumhansl (1996); Pressing (2002); Zacharakis, Pastiadis, and Reiss (2014).

The rich variation in the survey responses reminds us of something that has long been generally accepted—that we cannot reduce ethnography (or empirical or cognitive research) to the "native's point of view." There is, as Bourdieu (1993, 4) repeatedly reminded us, no such thing. "Balinese" views are multiple and located in practice. Balinese respondents displayed a considerable range of ability in the listening test and while they were, as a population, more accurate than non-Balinese respondents, there appears to be a significant overlap in abilities and limitations of both populations. This problematizes an absolute or bounded concept of culture, as well as the neat distinction between expert and amateur.

Finally, the limited value of the onset measurements is indicated by the ambiguous relationship between the chronometric data and the data on temporal sensations as represented in both the survey and the responses to the listening test. The chronometric data represent snapshots—byars recorded on a particular day at a particular arc in an ensemble's evolution. They are akin to the artificial interruptions of Zeno's arrow. In contrast, Balinese musicians' association of byars with regional identity appears to be based upon a far more complex and deep flow of information (temporal, intonational, timbral, etc.) gained over a lifetime of experience.

Appendix A: Glossary

bayu: Energy, breath, wind, special power.

byar: A sudden sforzando chord that marks the gong kebyar repertoire. Played by all members of the ensemble, excluding suling (flute), rebab (fiddle) and kempli (time-keeping horizontal gong). Often introduces pieces in the kebyar repertoire.

calung: Single octave, mid-register metallophone found in several forms of Balinese gamelan.

ceng-ceng: Small set of cymbals played by a performer holding a single cymbal in each hand, striking them against a platform affixed with several additional cymbals.

gamelan: Term for percussion orchestras of Bali and Java.

gamelan gong kebyar: Five-tone Balinese orchestra that emerged in the beginning of the twentieth century. The most ubiquitous form of music on the island, internationally famous for its virtuosic compositions and performing techniques.

gangsa: Two-octave metallophone used to perform melodic figurations (kotekan) in several forms of Balinese gamelan. Divided into two sections: gangsa pemadé and, an octave higher, gangsa kantilan.

gedig: A Balinese term referring to timing or groove. Sometimes used as a synonym of the Balinese term selah.

jegogan: Single octave, low-register metallophone found in several forms of Balinese gamelan.

kebyar: The virtuosic, non-metrical tutti introduction to many works in the gamelan gong kebyar repertoire. The term may refer as well to the ensemble itself or its repertoire generally.

kendang: Barrel drums, usually found in pairs in Balinese gamelan. They often function, along with the ugal, as the ersatz conductor of the orchestra and coordinate the connections between music and dance.

nafas: Literally, breath; may refer generally to phrasing in music.

ombak: Waves. A musical term referring to fluctuations in tempo, dynamics, and the destructive interference of paired tuning in Balinese gamelan.

rasa: Feeling, sense, flavor. A category of aesthetic evaluation.

reyong: A row of tuned horizontal pot-gongs performed by four musicians. In the gamelan gong kebyar the reyong typically extends from the low deng (3) pitch to the high dung (5) pitch, including 12 pots total.

taksu: Performative charisma or divine inspiration.

ugal: A large metallophone including 10 keys in the gamelan gong kebyar and extending from the higher jegogan range to the lower range of the gangsa pemadé. The ugal performer typically cues the ensemble, in coordination with the lead kendang player.

Appendix B: Statistical Glossary

outliers: Although there is no universally agreed-upon definition of an outlier, we used the metric based on the calculated boxplots. For instance, if an observation was larger than the 75th percentile (right or upper end of the box) plus 1.5 times the box width or smaller than the 25th percentile (left or lower end of the box) minus 1.5 times the box width, then it was identified as an outlier.

right skewness: A histogram is skewed to the right if the median is less than the mean. Visually, a right-skewed histogram will have most of the data represented on the left of the plot, with very little data on the right. The total timing histogram in Figure B1 is an example of a right skewed histogram.

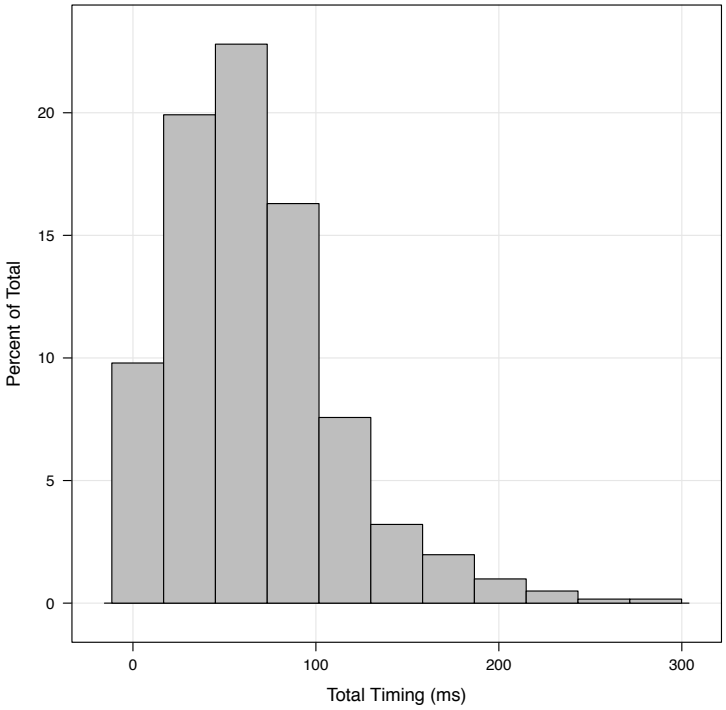

Figure B1. Right skewed histogram.

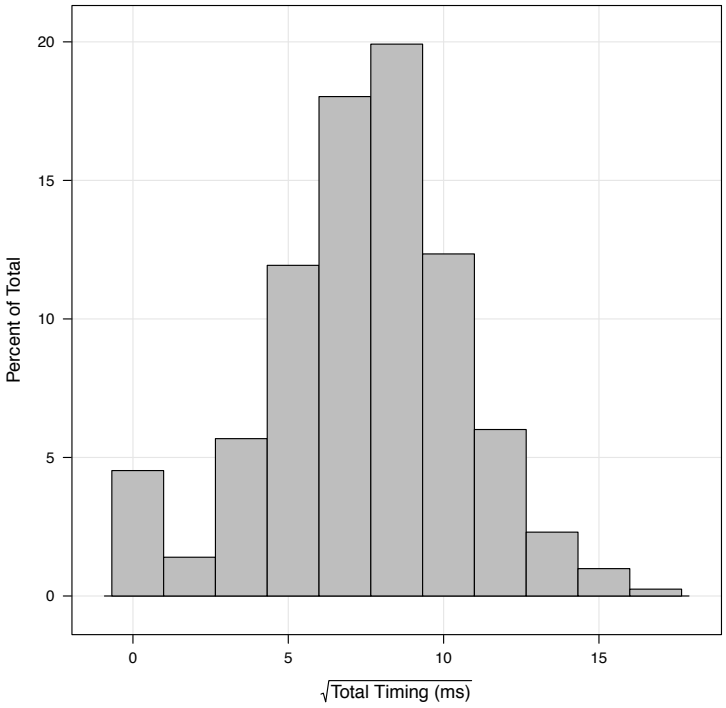

Figure B2. Square-root transformation of Figure B1.

square-root transformation: A square-root transformation was applied to the right-skewed total timing data due to the presence of zeros, which were meaningful values. The underlying goal of a transformation is to change a skewed distribution shape into a symmetric or normal distribution. Many statistical methods and much of statistical theory is based on underlying assumptions of normality. With the exception of the zeros, the square-root transformation of total timing creates a symmetric distributional shape, as shown in Figure B2.

Appendix C: Interonset-Interval Charts for All Byars, by Ensemble

All graphs show the instrument on the *y* axis and timing in seconds on the *x* axis.

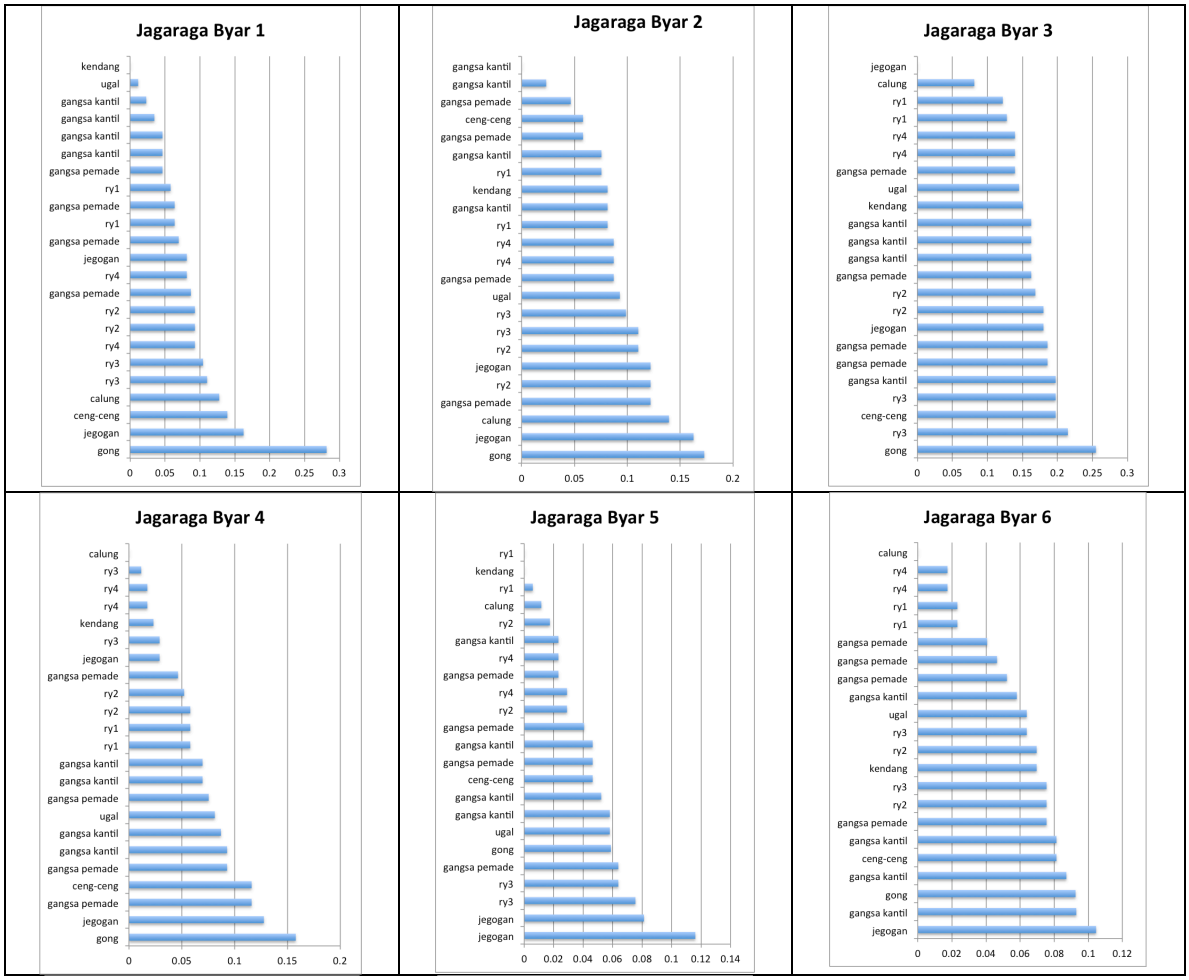

Figure C1. Jagaraga byars.

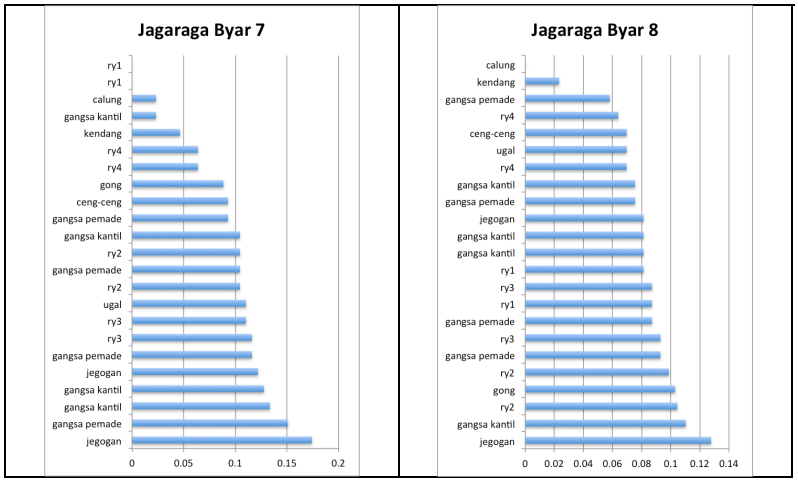

Figure C1 continued.

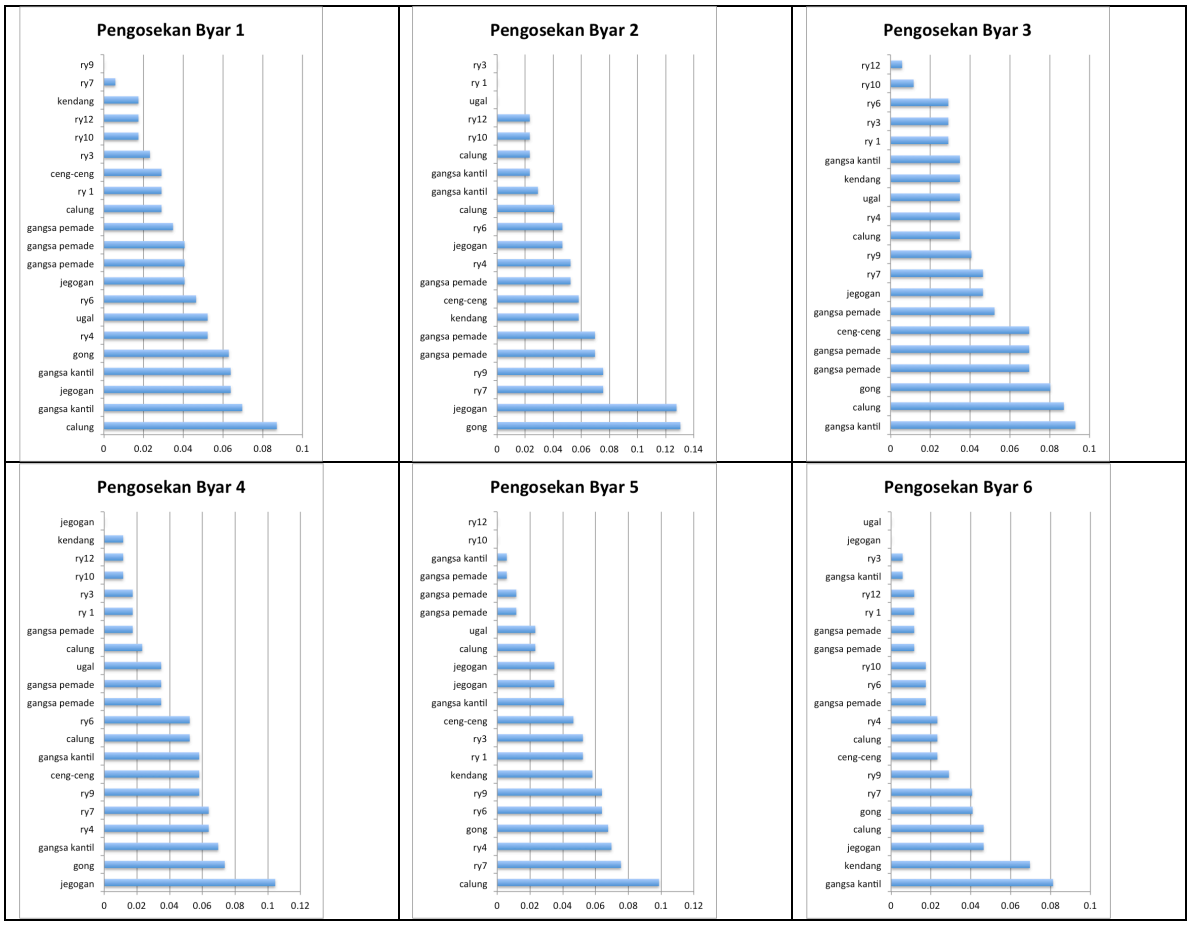

Figure C2. Pengosekan byars.

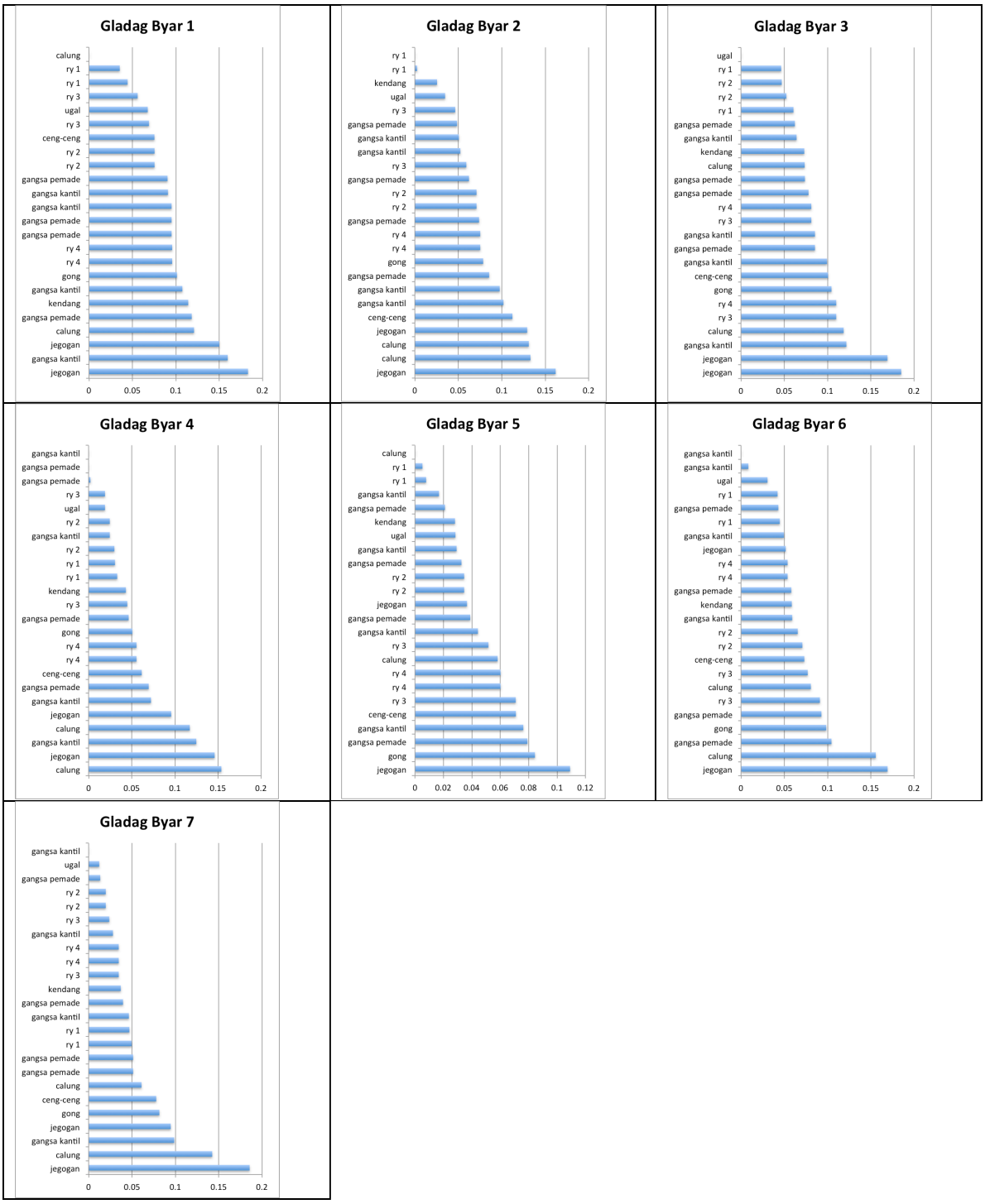

Figure C3. Gladag byars.

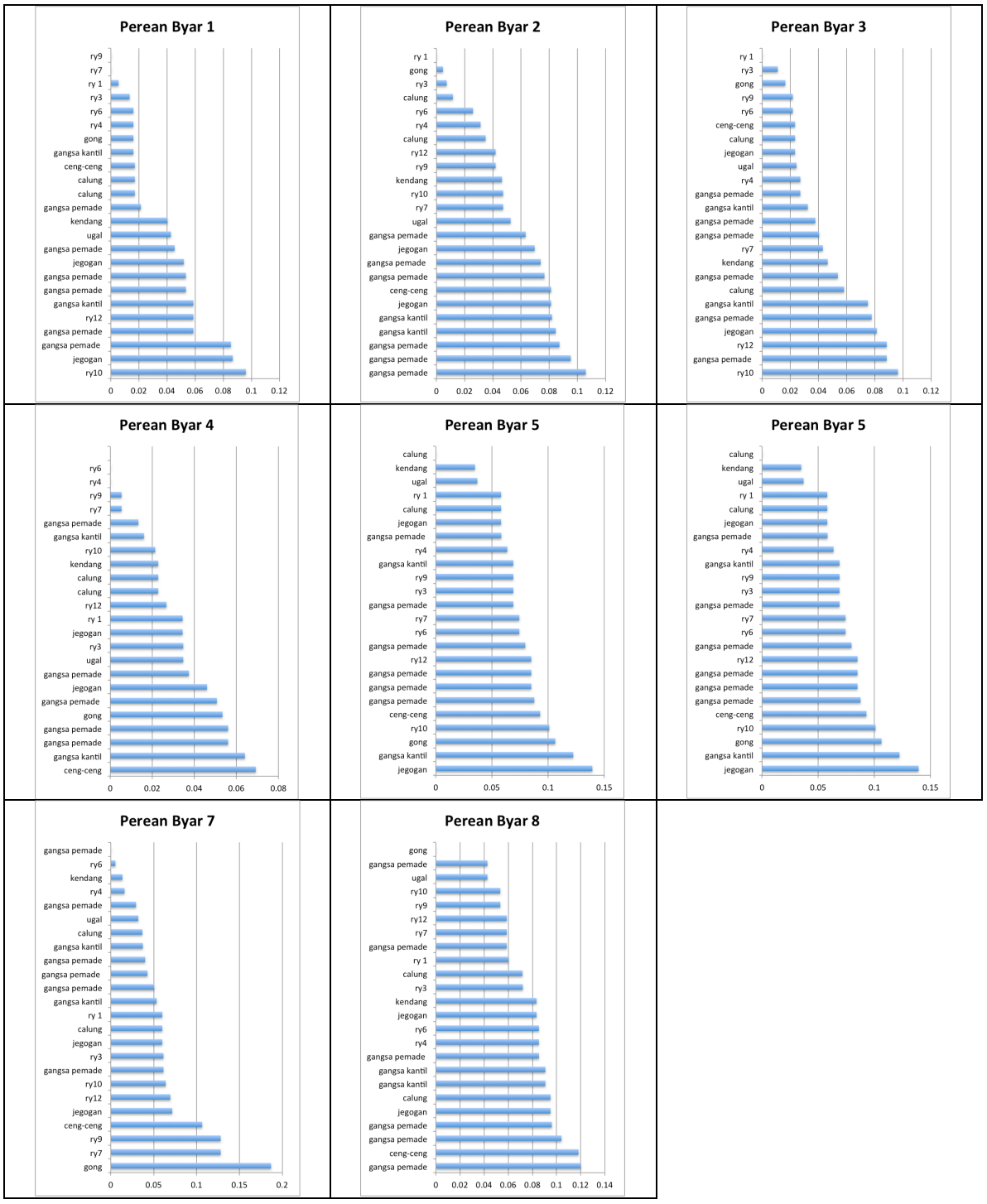

Figure C4. Perean byars.

Figure C5. Pinda byars.

Figure C6. Raga Kusuma byars.

Appendix D: Full Dataset

For a spreadsheet listing the timing of each byar in seconds, follow this link.

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