Rhythmic Characteristics of Colloquial and Formal Tamil

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Key words

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Abstract

Application of recently developed rhythmic measures to passages of read speech in colloquial and formal Tamil revealed some significant differences between the two varieties, which are in diglossic distribution. Both were also distinguished from a set of control data from British English speakers reading an equivalent passage. The findings have implications for the usefulness of the rhythmic measures and also the temporal characteristics of Tamil. High levels of interspeaker variability affected the measures; in some cases differences within each group of five speakers exceeded those separating distinct languages, indicating that such measures may not be reliable indicators of typological status. Discrepancies between previous findings and remeasurements of the same data also show the measures to be sensitive to differences in measurement criteria, specifically the treatment of pauses. The results confirm that the differences between colloquial and formal Tamil encompass durational characteristics, which appear to be largely explicable from differences in their syllabic structure. Provisional comparison with other languages suggests that their rhythmic properties cannot easily be captured by reference to traditional rhythmic classes. This may explain previous confusion in the literature over Tamil's temporal characteristics, which have been variously described in terms of stress-timing, syllable-timing, and mora-timing.

1 Introduction

There have been a number of attempts to describe the global temporal characteristics of Tamil in terms of membership of a rhythmic class: it has been variously described as syllable-timed (Ravisankar, 1994, p. 337), stress-timed (Marthandan, 1983, p. 308), neither stress-timed nor syllable-timed (Balasubramanian, 1980, p. 466), and mora-timed (Ramus, Nespor, & Mehler, 1999, p. 266, following Steever, 1987, p. 734). Several issues may have contributed to this confusion, first among them being the inherent difficulty of assigning a single rhythmic description to any language. Temporal characteristics are determined by a complex interplay of factors, not only phonological

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properties but also speaker- and rate-specific phonetic implementation patterns, which are responsible for variation within a single language.

A further issue is the validity of the hypothesis that all languages can be assigned to discrete rhythmic classes: available acoustic evidence from a variety of languages may be better explained in terms of a continuum of crosslinguistic possibilities. The disagreement over Tamil, therefore, could be due to its occupying an intermediate position between those languages traditionally classed as stress- and syllable-timed. There is also ambiguity over the properties of speech that linguists focus on when they make judgments about rhythmic classification — whether global temporal characteristics or the recurrence of specific units, such as vocalic and consonantal intervals, syllables, or feet, or even regularities in nondurational properties, such as loudness.

A final factor specific to Tamil is the existence of two main varieties of the language, colloquial and formal Tamil, which are sufficiently divergent that the language is classed as diglossic (Britto, 1986). Colloquial Tamil is used for most spoken communication, and formal Tamil is spoken in a restricted number of "high" contexts, such as lectures and news bulletins, and also used in writing. They differ in terms of their lexis, morphology, and segmental phonology, and it is at least possible that there are related differences in their temporal characteristics that would lead them to be labeled as rhythmically different.

The goal of this paper is therefore to investigate the rhythmic characteristics of Tamil, using available rhythmic measures, by addressing some of the issues identified above. In particular, the possibility that the two main varieties differ in their rhythmic characteristics will be tested by comparing data from formal and colloquial Tamil. The extent of interspeaker differences with respect to each measure will also be assessed, and, in the light of these results, Tamil's rhythmic characteristics will be compared with those of other languages.

The results should have the potential to resolve the source of the confusion in the literature over the best description of Tamil's rhythmic characteristics. They should also add to the growing body of literature on rhythmic measures. In particular, comparison of the extent of interspeaker variation with the magnitude of interlanguage differences should help to establish how far each measure distinguishes between or shows similarities among languages.

2 Experimental design

2.1 *Overview*

Native speakers of Tamil were recorded reading aloud two passages, one in formal Tamil, the other its colloquial equivalent. Recently developed rhythmic measures were applied to the data; these are based on the durational characteristics of successive vocalic and consonantal intervals in speech (e.g., Grabe & Low, 2002; Low & Grabe, 1995; Low, Grabe, & Nolan, 2000; Ramus et al., 1999) and the sequential variability of syllable durations (Deterding, 2001). An equal-sized group of southern British English speakers was also recorded reading a corresponding passage, as a control to test whether results were consistent with those reported in previous work (since both Ramus et al. and Grabe & Low included British English in their investigations).

The results were analyzed firstly with a view to establishing the reliability and usefulness of the different measures employed, looking specifically at the extent of speaker dependence and the degree of convergence with previous results. The nature and extent of any differences between colloquial and formal Tamil were then assessed, and also of differences between the two varieties of Tamil and the British English data. Finally, the Tamil results were placed in the context of previous cross-linguistic work to see how its rhythmic characteristics might compare with those of other languages.

2.2 *Materials*

Subjects read aloud texts in either English or Tamil of the fable "The North Wind and the Sun" (see Appendix 1), the passage used by Grabe and Low (2002), so that the data might be closely comparable. The Tamil subjects read first a formal and then a colloquial version; in each case these were presented orthographically using Tamil script. The key differences between the texts involved various lexical contrasts and also morphological differences, particularly in verb forms. Since the colloquial variety of the language is generally reserved for spoken communication, there are no standards, formal or informal, governing its orthographic representation. Some colloquial features of pronunciation were reflected in the text, such as the pronunciation of <ற்ற> as a dental stop (e.g., *kaattu* vs. *kaarru* 'wind') and the insertion of so-called "enunciative" vowels word-finally (e.g., *naaḷu* 'day'). The realization of /ai/ as a monophthong word-finally in nonmonosyllabic words (Asher & Keane, 2005) was also represented by using the < e > symbol, for instance as the accusative ending (e.g., colloquial *kambaḷiye* 'woollen blanket (accusative)' corresponding to formal *poorvaiyai* 'blanket (accusative)'). However, the script cannot represent another key difference, that between nasalized vowels and vowel-nasal sequences. Overall, therefore, the passage was fairly conservative, but subjects were explicitly encouraged to speak in a colloquial fashion and as naturally as possible, even if this led to slight deviations from the written version.

All subjects, both English and Tamil, practiced reading the text aloud before being recorded and repeated it if there were any disfluencies. In the case of the English subjects a single reading usually sufficed, but the Tamil subjects made many more slips and sometimes required several readings before a fluent version was produced.[1] Speakers were instructed to remain still during the recordings to maintain a constant distance from the microphone, and thus avoid fluctuation in loudness levels. Observation of the subjects while reading confirmed that none moved significantly in the course of each passage.

[1] In the case of one Tamil speaker (SR) it proved necessary to use the first half of one rendition of the passage and the second half of another to reduce the number of disfluencies.

2.3 *Subjects*

Five native speakers of Indian Tamil and five speakers of southern British English were recorded. The Tamil subjects ranged in age from 22 to 37; three were male, and two female. All had lived at some stage in Chennai, and most had spent their entire childhood there, so they formed a reasonably homogeneous group in terms of dialect differences. For each speaker Tamil had been used in the home, although for most it was treated as a second language in education (after English). Reading texts aloud was therefore a less familiar activity than for the English subjects, and this presumably accounts for the greater amount of practice needed by the Tamil speakers. The English speakers were all from the south of England, with ages falling within the same range as the Tamil subjects: two were male, and three female. All speakers were free of speaking or hearing difficulties.

3 Rhythmic measures

3.1 *Background*

The measures applied to the data were developed in the context of a long-running interest among linguists in the possibility that all languages belong to one of a finite number of distinct rhythmic classes. This hypothesis has its origin in impressionistic observations of a contrast between the "machine-gun" rhythm of certain Romance languages and the "Morse code" of Germanic languages. Pike (1946, p. 35) first used the term *stress-timed* to refer to the latter type and contrasted it with the rhythm of Spanish, in which syllables, rather than stresses, are said to be more or less evenly recurrent. This dichotomy between stress- and syllable-timing was then formulated in strong terms by Abercrombie (1965), who claimed that all languages of the world fall into one of two categories: being characterized by isochrony either of syllables or of interstress intervals. As examples of syllable-timed languages he adduced French, Yoruba, and Telugu, and for stress-timed languages he cited English, Russian, and Arabic. A third class, that of mora-timing, is sometimes also recognized (Ladefoged, 1975, p. 224), primarily to account for data from Japanese (Han, 1962).

Abercrombie's claim of strict isochrony in speech production has been widely discredited in studies of various individual languages (e.g., Balasubramanian, 1980, on Tamil; Bolinger, 1965, and Lea, 1974, on English; Pointon, 1980, on Spanish; Wenk & Wioland, 1982, on French). Roach (1982) also conducted a crosslinguistic study analyzing the six languages put forward by Abercrombie as exemplars of the stress-/syllable-timing dichotomy. He concluded that his results gave "no support to the idea that one could assign a language to one of two categories on the basis of time measurements in speech" (p. 78), and that the distinction must therefore be auditory and subjective (cf. the attempt by Lehiste, 1977, to maintain the significance of isochrony by recasting it as a primarily perceptual phenomenon).

One response to the difficulties with claims of isochrony was a shift towards finding a phonological basis for rhythmic types. Roach (1982), for instance, commented upon the contribution of syllable structure and the presence of vowel reduction in giving a particular rhythmic impression. Dauer (1983) also drew attention to the role of syllable structure, noting that stress-timed languages tend to have a greater variety of syllable types and that syllable structure and stress commonly reinforce each other, through the reduction of unstressed vowels and quantity-sensitive stress assignment. The possibility that the rhythmic character of a language emerges from its structure, rather than being a phonological primitive, was also raised by Dasher and Bolinger (1982).

A consequence of these developments in the characterization of rhythm was to undermine the binary nature of Abercrombie's classification. Roach, for instance, took the line that individual languages combined both types of timing to differing degrees, depending upon context, whereas Dauer argued for a rhythmic scale, with languages being more or less stress-based. Indeed, in Dauer (1987) she gave concrete proposals for assigning languages a component rhythm score, based on four sets of factors: the length of accented syllables, pitch contours and vowel quality in accented syllables, and the function of accent. The notion of discrete classes was also challenged by Nespor (1990), on the grounds that rhythmically intermediate languages, specifically Polish and Catalan, apparently exist.

The possibility that languages do fall into a fixed number of rhythmic classes and, moreover, that these have identifiable acoustic correlates has recently been raised again by two independent but partially converging lines of research. The first, comprising work by Ramus, Mehler and associates, arose out of studies in the field of language acquisition, specifically on the discrimination of rhythmically different languages by newborns. A key paper (Nazzi, Bertoncini, & Mehler, 1998) demonstrated that French newborns are able to discriminate utterances from two unknown languages (English and Japanese) even when the utterances have been low-pass filtered (400 Hz), so that segmental cues have been largely removed. Furthermore, this result was not replicated when the languages being tested were rhythmically similar (English and Dutch), nor could rhythmically mixed groups of languages be distinguished (English and Italian vs. Spanish and Dutch). Rhythmically similar groups of languages (English and Dutch vs. Spanish and Italian) were, however, discriminable, which Nazzi et al. interpreted as evidence that infants make use of some kind of rhythmic categorization.

Ramus and Mehler (1999) extended this research to adult listeners, using various types of resynthesized speech. One condition, which they referred to as "flat sasasa," involved all consonants being replaced with /s/ and all vowels with /a/ from a French diphone database, while the pitch was leveled to a constant 230 Hz. Phonotactic information was thus eliminated, as well as the intonation contour, leaving only the syllabic rhythm. This proved sufficient for French listeners to discriminate resynthesized English and Japanese successfully, when given the task of differentiating between two supposedly exotic languages.

Ramus et al. (1999) addressed the issue of what information is available to the infant for making discrimination judgments on languages traditionally assigned to different rhythmic classes. Making the assumption that infants focus primarily on vowels (p. 270), Ramus et al. segmented sets of short declarative sentences into sequences of vocalic and consonantal intervals. Three durational measures were calculated: the percentage of the whole sentence occupied by vocalic intervals (%V), the *SD* of the vocalic intervals (ΔV), and the *SD* of the consonantal intervals (ΔC). Five sentences, balanced for number of syllables and approximate length, were produced by each speaker, and four speakers were recorded for each of eight languages (English, Dutch, Polish, French, Spanish, Italian, Catalan, and Japanese). The languages were grouped according to rhythm class (English, Dutch, and Polish as stress-timed; French, Spanish, Italian, and Catalan as syllable-timed; and Japanese as mora-timed), and ANOVAs performed on the data revealed a significant effect of class on both %V and ΔC, but not ΔV. Moreover, when the eight languages were plotted in a (%V, ΔC) two-dimensional space, they formed two clusters corresponding to the standard stress- and syllable-timed classes, with Japanese in an isolated position, apparently representing a third mora-timed class. According to Ramus et al., the ΔV measure does not relate so clearly to the standard rhythm classes because it is affected by a combination of different factors (vowel reduction, contrastive vowel length, vowel lengthening in particular contexts, and the occurrence of phonetically long vowels or diphthongs in a language), whereas %V and ΔC relate more directly to syllable structure.

Although Ramus et al. (1999) interpreted their results as support for the standard rhythm classes, they recognized that data from further languages might change this picture, perhaps revealing a more homogeneous distribution than their sample of languages displays. The possibility that the current typology of rhythm classes might need to be expanded is also acknowledged. Indeed, a later paper (Ramus, Dupoux, & Mehler, 2003) proposed that Polish may be an exemplar of an additional class. This study represents an extension of the resynthesis study reported in Ramus and Mehler (1999) for English and Japanese to further pairs of languages, including Polish and Catalan, the two languages identified by Nespor (1990) as rhythmically intermediate. They concluded that Catalan can reliably be classed as syllable-timed since it is discriminable from English but not Spanish. Polish, however, was discriminated from both a stress-timed (English) and a syllable-timed language (Spanish), suggesting that it may form a category of its own.

The second line of research concerned with the acoustic correlates of different rhythm classes is work by Low and colleagues, which arose out of an attempt to elucidate the rhythmic differences between two varieties of English: Singapore English, which has been impressionistically characterized as syllable-timed (Brown, 1988), and British English, which is prototypically stress-timed (Low et al., 2000). In the course of their investigation they developed the Pairwise Variability Index (PVI), which is a cumulative measure of durational variation between successive pairs of intervals. For intervocalic intervals (CrPVI) the absolute differences in duration between successive syllables are simply summed and divided by the number of differences, providing a so-called "raw" measure.

(1) $$\mathrm{CrPVI} = \left[\sum_{k=1}^{m-1} \left| d_k - d_{k+1} \right| / (m-1) \right]$$

where m = number of consonantal intervals in utterance, and d_k = duration of the k^{th} consonantal interval.

A second measure containing a normalization component was used for vocalic intervals (VnPVI), in which the absolute value of the difference between each pair is divided by the average duration of the pair in order to normalize for differences in speaking rate. The output is multiplied by 100 because the normalization procedure produces fractional values.

$$\text{(2)} \quad \text{VnPVI} = 100 \times \left[\sum_{k=1}^{m-1} \left| \frac{d_k - d_{k+1}}{(d_k + d_{k+1})/2} \right| / (m-1) \right]$$

where m = number of vocalic intervals in utterance, and d_k = duration of the k^{th} vocalic interval.

The VnPVI measure successfully differentiated Singapore and British English, Singapore English showing less variability in successive vocalic intervals, which may contribute to it being described as syllable-timed. Interestingly, application of the %V measure favored by Ramus et al. (1999) to the data of Low et al. (2000) did not reflect the rhythmic difference between the two varieties, although they were separated by ΔV. Low et al., however, argue that their PVI is preferable to the *SD* measure since it controls for changes in speaking rate within intonational phrases and also contains a normalization component for overall differences in articulation rate.

A further variability index, Deterding's (2001) variability index (VI), also contains a normalization component and differs from the PVI measures in being based on whole syllable durations, rather than successive vocalic or consonantal intervals. Deterding too applied his measure to Singapore and British English and succeeded in differentiating between conversational data from the two varieties. His VI is based on the difference in duration between successive syllables and is normalized by dividing by the average duration of syllables within an interpause stretch of speech:

$$\text{(3)} \quad \text{VI} = \frac{1}{n-2} \left[\sum_{k=1}^{n-2} \left| d_{k+1} - d_k \right| \right]$$

where n = number of syllables in interpause stretch of speech, and d_k = normalized duration of k^{th} syllable in seconds.

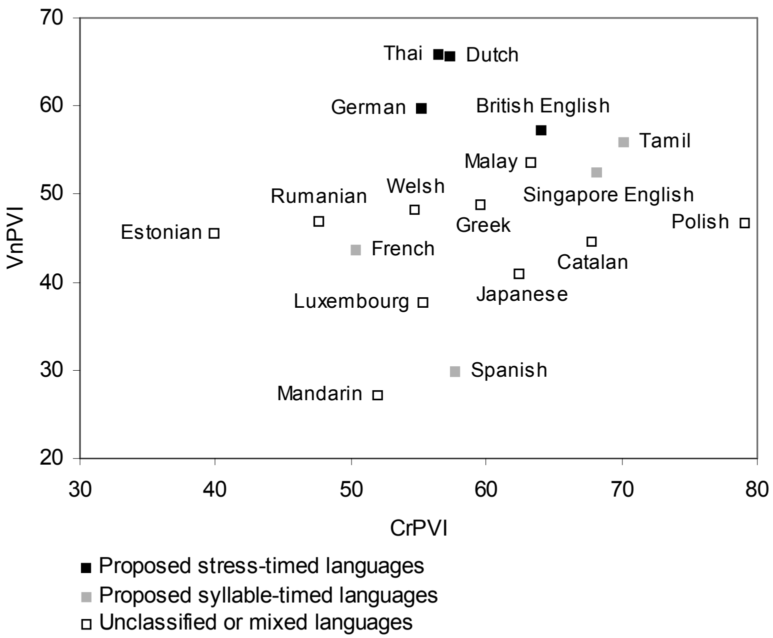
Final syllables are excluded from the calculations to avoid phrase-final lengthening effects.

Grabe and Low (2002) applied their PVI measures to a broad range of languages (18 in all) to test the hypothesis that a combination of vocalic and intervocalic variability measures may reliably indicate rhythm class. In contrast to the strictly controlled sentence sets of Ramus et al. (1999), their data came from the passage used in the current study, the classic phonetics text 'The North Wind and the Sun', read by one speaker per language. The PVI was normalized for speaking rate for the vocalic data, since a significant correlation between interval duration and speaking rate (defined as the average interval duration produced by a speaker) was found. No normalization was applied to the consonantal data, however, on the grounds that intervocalic intervals show considerable crosslinguistic differences in their segmental composition, whereas vocalic intervals mostly consist of single segments.

Grabe and Low predicted that languages conventionally classified as stress-timed would be characterized by relatively high variability of both vocalic and intervocalic intervals, whereas those classified as syllable-timed would have low variability for both. This was borne out only to a limited extent: prototypically stress- and syllable-timed languages were well separated on the vocalic dimension, but ranking on the CrPVI did not accord with the standard rhythm classes. The relative positions of the languages are shown in Figure 1, from which it can be seen that several languages are in an intermediate position, undermining the notion of a categorical distinction between classes. Application of the Ramus et al. (1999) measures to the same data is illustrated in Figure 2. In both figures languages proposed to be either stress- or syllable-timed are marked as such, according to the list in Grabe and Low (2002, p. 523).

Figure 1

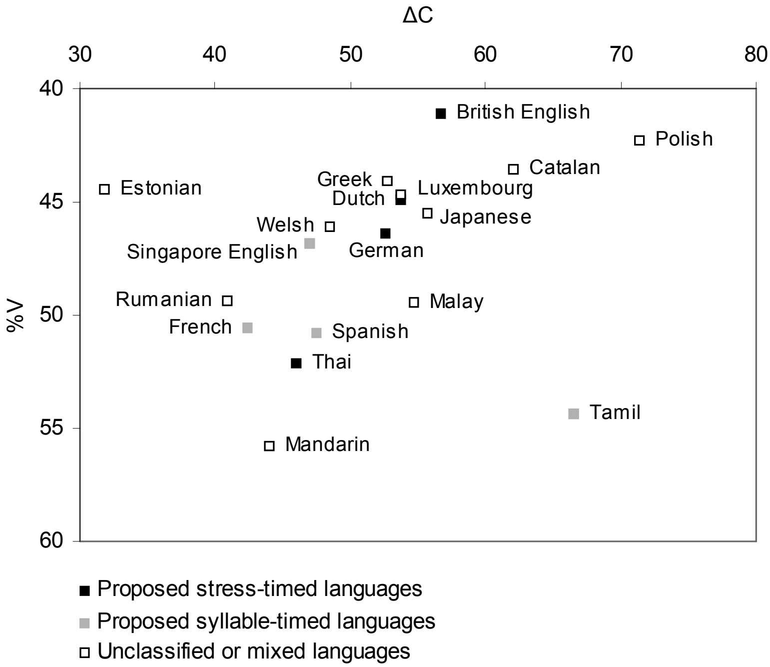
Relative positions of 18 languages classified on the basis of VnPVI and CrPVI. (Reconstructed with permission from the data in Grabe & Low, 2002)



Although there are notable differences in the distribution of languages illustrated in Figures 1 and 2, Grabe and Low (2002) noted some similarities as well. In particular, comparable results are found in the extremes of the two spaces: Polish, Estonian, and Mandarin occupy peripheral positions in both. The prototypically stress-timed Germanic languages (British English, Dutch, and German) are relatively closely clustered in each, but there are also some notable differences in the two configurations.

Figure 2

Relative positions of 18 languages classified on the basis of %V & ΔC. (Reconstructed with permission from the data in Grabe & Low, 2002)



Tamil and Thai show the greatest discrepancies, patterning with the stress-timed languages in the PVI (vocalic, consonantal) space but nearer prototypically syllable-timed languages such as French and Spanish on the Ramus et al. (1999) measures.

Taken together, work from these two groups of collaborators may suggest that acoustic regularity underlies linguists' judgments of rhythmic structure. It is unclear at this point whether these (or some improved set of) acoustic measures would support a partitioning of all languages into a small number of distinct rhythmic categories such as syllable-timed, stress-timed, or mora-timed, or if, instead, rhythmicity should be viewed as a continuum in which individual languages are more or less proximal to prototypical instances of the categories that linguists have used to describe rhythmic structure. The infant discrimination results would be consistent with this second possibility. A more complex measure incorporating information about further phonetic parameters, such as loudness, may form the basis of a more reliable rhythmic typology (as recognized by Ramus et al., 2003, p. 341; and Ramus & Mehler, 1999, p. 518). The rhythmic measures in this study were therefore applied not only to duration but also loudness.

It is also important to evaluate how far each of the proposed measures reflect rhythmic characteristics in the narrow sense of the recurrence of particular units over time, as opposed to general temporal properties. %V provides a simple and apparently stable measure of overall syllable complexity but captures nothing of sequential variability. ΔV and ΔC, by dint of being global measures, are also open to the same criticism. In contrast, the pairwise variability index of Grabe and Low was specifically designed to reflect variability in successive intervals, providing a cumulative measure of local durational differences. However, since the normalization procedure incorporated into the VnPVI averages adjacent intervals, it may thereby reduce the very variability it was intended to capture. Deterding's VI may overcome this particular drawback by normalizing over a whole interpause stretch of speech, but it represents a rather different type of approach, taking as its base a phonological constituent, the syllable, rather than acoustically defined stretches of the speech signal.[2]

3.2
Measurement procedures

All recordings were made in a sound-proofed booth in Oxford University Phonetics Laboratory and digitized at a rate of 16kHz (16-bit resolution). Segmentation into vocalic and consonantal intervals was performed using both auditory and visual cues on wide-band spectrograms generated by ESPS *xwaves*™. The criteria used by previous investigators were followed as closely as possible (Grabe & Low, 2002, p. 524; Ramus et al., 1999, p. 271). Thus vocalic intervals were bounded by vowel onset and offset, and intervocalic intervals were defined as the stretch between vowel offset and onset, including the voice onset times of stops. Postvocalic fricatives were deemed to start at the point where the noise pattern began for voiceless fricatives, and where high-frequency energy commenced for their voiced counterparts. The onset of the second formant marked the boundary between a fricative and a following vowel. Nasal-vowel sequences were segmented by observing the fault transitions between them, which again conforms to Grabe and Low's stated practice.

One point of possible divergence between Grabe and Low and Ramus et al. (1999) concerned the treatment of glides. Ramus et al. treated all prevocalic instances as consonantal and no postvocalic examples. By contrast, Grabe and Low adopted a strictly acoustic approach, only counting initial glides as consonantal when there were clearly observable changes in either the amplitude of the signal or the formant structure, and otherwise including them within a vocalic interval. The policy followed here was to count glides as consonantal only when a region of reduced intensity relative to an adjacent vowel could be identified, in which case the boundaries were placed at the points of marked decrease and increase in amplitude. This was of particular concern in the Tamil recordings, where there was variability both between and within speakers, for instance, over whether the word *cuuriyan* 'sun' contained two or three distinct vocalic portions (i.e., [suː.ɾɨẽ] or [suː.ɾɨ.jẽ]).

There was no division of the passages into prosodic units; clear pauses, however, were taken as boundaries for the measurements, on the assumption that interpause stretches of speech are the unit over which temporal characteristics are most likely

2 Barry, Andreeva, Russo, Dimitrova, and Kostadinova (2003, p. 2694) propose a similar measure intended to capture the varying complexity of consonant-vowel groupings, which they term the *PVI-CV*.

to be judged. This is in line with Deterding's approach, although the conversational nature of his data meant that individual stretches of speech were not necessarily temporarily adjacent. It differs, however, from the policy adopted by Grabe and Low (2002, p. 525), who applied segmentation into vocalic and intervocalic intervals to the text as a whole, operating across IP boundaries. (The nature of the materials used by Ramus et al., 1999 — short unconnected declarative sentences — meant that their data were free from pauses.) Grabe and Low therefore combined intervals spanning pauses, while excluding the duration of the pause itself.

The impact of this difference in approach obviously depends upon the number of pauses and is accordingly expected to be greater for speakers with more pauses. Grabe and Low's method would produce fewer intervals for the same passage of speech than the policy adopted here, and this reduction might be expected to affect vocalic more than consonantal intervals for the following reason. Two vocalic segments of any kind on either side of a pause would be combined using the Grabe and Low method, but a combined consonantal interval is only possible if there are no stop consonants on either side. In addition to reducing the overall number of intervals, Grabe and Low's method should boost the proportion of longer intervals, vocalic and consonantal. This could increase *SD*s and might also be expected to raise the variability indices, so higher values for ΔV, ΔC, VnPVI, and CrPVI are predicted, but the proportion of the signal made up of vocalic intervals as opposed to consonantal does not vary, so %V should be unaffected. In order to test these predictions and establish the magnitude of any differences, Grabe and Low's Tamil data were remeasured according to the policy adopted here, so that the results could be compared with their original figures. Finally, and this is independent of the treatment of intervals spanning pauses, the proportion of vocalic to consonantal intervals should be slightly inflated for speakers who pause more frequently because pre- and postpausal stops have to be excluded using either method. Thus speakers with more pauses might be expected to have a higher %V.

The following measures were computed from the successive vocalic and consonantal interval durations: their relative proportions (%V), the *SD*s (ΔV and ΔC), and also the pairwise variability indices of Grabe and Low (VnPVI and CrPVI). The formula for %V is given in (4), those for the PVI measures in (1) and (2) above, and the *SD*s are those of all vocalic or consonantal intervals in milliseconds.

(4) $\%V = 100 \times \Sigma V / (\Sigma C + \Sigma V)$

where ΣV = sum of all vocalic intervals, and ΣC = sum of all consonantal intervals.

Similar calculations were also made for the mean loudness of each interval (ΔVloud, ΔCloud, VnPVIloud, and CrPVIloud), operating on the spectral power density derived from $L = 50$ ms wide, $1 + \cos(2\pi(t - t_c)/L)$ windows, shifted by intervals of 10 ms. The loudness measure used is a good approximation of steady-state perceptual loudness and is a modified version of Stevens's Mark VII computation (itself an improved version of the ISO-R532 Method A standard noise measurement), using 0.7-octave frequency bins rather than the full- or third-octave bands for which it was originally defined (Kochanski, Grabe, Coleman, & Rosner, 2005; Stevens, 1972). This was employed in preference to RMS amplitude, since it is less susceptible to influence from F0 and mirrors the sensitivity of the auditory system to increased energy in higher frequency bands.

Finally, Deterding's VI was calculated for the Tamil data, according to the formula given in (3) above. Syllable boundaries were marked following Deterding's policy of treating word boundaries as syllable boundaries, except in cases where no boundary between word-final and word-initial vowels could be identified. Syllable boundaries were also placed before all intervocalic single consonants and before obstruent-liquid clusters, which form complex onsets in Tamil, but between a sonorant consonant and a following obstruent. There is an orthographic distinction between single and geminate obstruents in Tamil, and considerable attention has been paid to the phonetic correlates of this difference (e.g., Balasubramanian & Asher, 1984; Firth, 1934; Lisker, 1958, 1972). In intervocalic position it is marked primarily by lenition, rather than a durational distinction, and so orthographic geminate obstruents have been treated simply as onset consonants and not ambisyllabic. Intervocalic geminate sonorants are, however, significantly longer than their single counterparts (Balasubramanian, 1982), and so syllable boundaries have been placed at their midpoint. Finally, Deterding's treatment of postpausal stops was followed, assigning stop durations of 50 ms to each.

3.3
Potential problems

The potential for rhythmic measures to be sensitive to different measurement criteria has already been raised and could constitute a problem for cross-study comparisons of data. Other factors have also been shown to have a significant effect on the measures, with serious implications for the conclusions that can legitimately be drawn about rhythmic classification. Barry and Russo (2003), for instance, consider the influence of an individual speaker's style, the nature of speech materials, and tempo-related differences, concluding that neither the measures of Grabe and Low nor those of Ramus et al. form reliable indicators of a language's typological status.

The degree of speaker dependence is of particular concern. In Spanish data reported by Grabe (2002, p. 128), PVI measures for seven speakers of Castilian Spanish revealed interspeaker differences at least as great as those found between some languages. Barry and Russo (2003) in their comparison of spontaneous German and Italian also reported "massive combined effects of speech material and individual speaking style" (p. 4) affecting the ΔV, ΔC, VnVPI, and CrPVI measures; %V alone differentiated consistently between the two languages. Since these findings seriously undermine the usefulness of the rhythmic measures as a means of characterizing a single language, determining the extent of interspeaker differences relative to the magnitude of interlanguage differences was a priority in the analysis and will be reported first.

A further problem, which may account in part for differences between speakers, is the effect of speech rate: Barry and Russo (2003) demonstrated that measures of variability reduced as tempo increased. This caused large shifts in the position of language groups within rhythm spaces defined by (ΔV, ΔC) and (CrPVI, VnPVI), although language differences were generally maintained across speech rates. A follow-up study (Barry et al., 2003), which included additional data from read German and Bulgarian, confirmed the tendency towards greater values of the same four measures at a higher tempo. The nature of the materials, whether read or spontaneous, affected the degree of the shift. As discussed above, the normalization component in the VnPVI of Grabe and Low was intended to address this problem of tempo-related variability, and, indeed, Barry and Russo found that such differences were lower for the VnPVI than the other variability measures. However, they criticize the local nature of Grabe and Low's normalization procedure, arguing that it masks the stress-related differences and quantitative length distinctions that help to determine a language's rhythmic character. A key respect in which tempo may be pertinent to the current study is the comparison between the two varieties of Tamil, since colloquial Tamil is typically spoken at a faster speech rate than formal Tamil. This would predict higher levels of ΔV, ΔC, and CrPVI (and, perhaps to a lesser extent, VnPVI) in colloquial Tamil, subject to other differences between the two varieties. The nature of these differences and how they may be reflected in the rhythmic measures will be discussed in the next section, after a review of phonological properties common to both varieties.

4 Background on Tamil

The occurrence of phonological quantity distinctions in vowels marked by substantial durational differences (Balasubramanian, 1981) suggests that Tamil is characterized by relatively high vocalic variability, and this should be reflected in the ΔV measure. As discussed, this property has been associated with prototypical stress-timed languages, such as English, and may explain Marthandan's claim (1983, p. 308) that Tamil too is stress-timed. The situation in Tamil, however, presents a marked contrast to the robust use of durational cues to lexical stress in prototypical stress-accent languages, such as English (Beckman, 1986). There are no lexical distinctions based on stress in either variety of Tamil; indeed, recent work (Keane, 2003, 2006) suggests that duration and loudness are not reliable cues to word-level prominence in nonemphatic speech. Word-level prominence may be signaled by the association of phrasal pitch accents, by differences in vowel quality distinctions affecting a few vowels, and by subtle differences in duration that are restricted to certain vowel types.

These prosodic differences between Tamil and English have two potential consequences for their performance on the rhythmic measures. The first concerns the function of loudness: in Tamil loudness at the word level seems to reflect only intrinsic segmental differences (Balasubramanian, 1972, p. 529; Keane, 2006) but in English may be associated with lexical stress. The VnPVIloud measure may therefore distinguish between the two languages, being greater in English. Another possible result is that English may be marked by a higher VnPVI than Tamil. Since the distribution of long and short vowels is to some extent governed by stress, there is a tendency in English towards alternation between long and short vowels in successive syllables, to which the locally based VnPVI should be sensitive. In Tamil, however, variability in vocalic durations is linked primarily to phonological quantity distinctions, so there is no pressure towards alternation of long and short. It is conceivable, therefore, that the VnPVI will be lower than in English, although the global ΔV measure may be comparable in the two languages.

Syllable structure, which has been proposed to play a key role in determining the rhythmic characteristics of a language (Dauer, 1983), is relatively simple in Tamil compared to English, which permits considerable complexity in its consonant clusters (e.g., [sɪksθs]). Lower values of both ΔC and CrPVI are therefore to be expected in Tamil. In addition, a greater proportion of total duration should be occupied by vocalic rather than consonantal intervals, which should be reflected in a higher %V.

Important differences between the two varieties of Tamil that may be pertinent to their rhythmic characteristics involve syllable structure. In both colloquial and formal Tamil, consonant clusters are permitted only word-medially in the native vocabulary. In the formal variety the first member of any cluster is usually either a sonorant consonant or the first half of a phonological geminate. Such clusters are largely restricted to two consonants, but some triple clusters are permitted in formal Tamil, including *-kk-*, *-cc-*, *-tt-*, *-pp-*, and *-nd-* preceded by either *-r-* or *-ɻ-* (Asher, 1982, p. 259). Colloquial Tamil permits a wider range of clusters, arising from the elision of word-medial vowels and even syllables, for example, [oːɖɾɑ̃ː] 'run.pres.3sm' (formal [oːɖuɦɪɾɑːn]). This example also demonstrates the alternation between word-final nasalized vowels in the colloquial variety and vowel-nasal consonant sequences in formal Tamil. Consequently word-final nasals do not occur in colloquial Tamil (with the possible exception of monosyllables), and the addition of so-called "enunciative" vowels to other final consonants, together with the deletion of word-final /ɭ/, conspires to make colloquial Tamil words uniformly vowel-final. In connected speech, therefore, sequences of consonants spanning two words are to be found only in formal Tamil, which accordingly has greater complexity in its consonant clusters.

The likely impact of these differences on the rhythmic measures is not easy to judge, as the greater complexity of cross-word clusters in formal Tamil may to some extent be counterbalanced by the greater range of clusters permitted word-medially in colloquial Tamil. However, one might still expect higher values of ΔC and CrPVI in formal Tamil and a lower proportion of total duration to consist of vocalic intervals, reflected in a lower %V. Since the differences in syllable structure mainly affect consonants, there is no expectation that ΔV and VnPVI will differ significantly between the varieties, unless the relatively lower tempo often associated with formal Tamil causes an across-the-board increase in measures of durational variability relative to colloquial Tamil. Whether or not the vocalic intervals are affected, the syllable-based VI measure should presumably be sensitive to increased consonantal variability, so a higher value is expected for formal than colloquial Tamil.

4.1
Previous application of rhythmic measures to Tamil

Tamil was not among the languages analyzed by Ramus and his colleagues; however, it was included in the sample of 18 languages investigated by Grabe and Low (2002) and therefore appears in Figures 1 and 2 above, which show the relative positions of the different languages according to the PVI measures and also in the (%V, ΔC) space. Tamil was found to have high variability on both vocalic and consonantal dimensions, a combination predicted to hold of prototypically stress-timed languages and largely substantiated in the data from such languages. Indeed, in terms of its vocalic variability, Tamil's nearest neighbor is British English. Application of the Ramus et al. measures gives a very different picture, however, placing Tamil in a rather isolated position. Its consonantal variability, as measured by *SD*, is high, again being surpassed only by Polish. Unusually, though, Tamil's %V is also high, second only to Mandarin, and it is thus distant from the prototypically stress-timed languages, which have relatively high ΔC values but low %V values. The high vocalic variability of Tamil is not surprising, given the distinctive role played by vowel length in the language. However, the high consonantal variability is rather unexpected, given the relatively restricted range of syllable clusters permitted in the language.

The possibility that Tamil may belong to a mora-timed class of languages has also been raised (Ramus et al., 1999, p. 266, following Steever, 1987, p. 734), and there are several pieces of potentially supporting evidence. One is the set of conventions holding of classical Tamil verse, in which syllable length is calculated using a unit known as the *maattirai*, which seems to correspond roughly to the notion of a mora (Zvelebil, 1989, p. 6). Direct inference from classical poetry conventions to the modern colloquial variety is perhaps unwarranted, but it may be more relevant to formal Tamil, which still largely conforms to standards set in the 13th century by the grammarian Pavanandi. Experimental data lending some support to the significance of the mora in the timing of Tamil are presented by Balasubramanian (1980). In a study originally designed to test whether syllables or interstress intervals (assuming that stress falls consistently on word-initial syllables) are isochronous in Tamil, he showed that neither was the case but provided some indication that the duration of a syllable is correlated with its moraic structure.

A third, indirect type of evidence for the importance of the mora in Tamil comes from work by Cutler, Murty, and Otake (2003) on segmentation strategies. Japanese listeners were asked to respond by pressing a button to CV and CVN targets at the beginning of words in a list of words from Telugu, a Dravidian language related to Tamil and sharing similar syllable structure (Krishnamurti, 1998, p. 207). Their responses proved very similar to those found by Otake, Hatano, Cutler, and Mehler (1993) for Japanese speakers listening to their own language, namely that CVN sequences were detected easily in words of the structure CVN.CV but not of the structure CV.CV.CV, whereas CV sequences were detected equally easily in either structure. This was interpreted as evidence that mora boundaries are significant, since the one situation in which a relatively high proportion of target sequences were missed involved a mismatch with the mora boundaries. Furthermore, the reverse situation—Telugu speakers listening to Japanese words—also yielded a similar response pattern. Cutler et al. (2003) therefore proposed that speakers can successfully extend their native listening strategies to a non-native language that shares its rhythmic characteristics, even if it is genetically unrelated. Whether or not listeners were drawing on rhythmic properties, it suggests that Japanese and Telugu are similar in some crucial respect and, by extension, that Tamil may also share certain characteristics with Japanese, the classic instance of a mora-timed language.

The specific implications for the rhythmic measures of the possibility that the mora plays a significant role in Tamil are difficult to pin down, apart from the expectation that the results for Tamil may resemble those for Japanese. In this regard, it is notable that Tamil appears at some distance from Japanese on both sets of acoustic measures. Tamil has much higher levels of vocalic variability and percentage of total duration occupied by vowels, and on the consonantal measures it also exceeds the Japanese values, though not by such a great margin. However, the considerable differences between the figures for Japanese in the two studies (53.1%V and 35.6 ΔC for Ramus et al., 1999, vs. 45.5%V and 55.8 ΔC for Grabe & Low) casts some doubt on their reliability. One explanation, advanced by Grabe and Low (2002, p. 529), is that their figures may be skewed slightly by their decision to count devoiced vowels between voiceless consonants as part of an intervocalic interval, not a vocalic interval.

Application of acoustic measures of rhythmicity to Tamil therefore does not allow us to position it neatly into the rhythmic classes as traditionally proposed. It does, however, make some sense of the contradictory nature of previous claims about Tamil. If the hypothesis that all languages fall into distinct rhythmic classes is to be maintained, a previously unrecognized rhythm type might be needed for Tamil to make sense of its isolated position in Figure 2. In discussing the exceptional nature of the Tamil results in the (%V, ΔC) space, Grabe and Low point to the complementary nature of the %V and vocalic PVI values in both the prototypically stress-timed and syllable-timed languages:

> This complementarity of overall vowel time and vocalic variability in English and German on the one hand, and French and Spanish on the other may contribute substantially to impressions of stress- or syllable-timing. If the relationship between the two measures provides the acoustic basis for an impression of stress- or syllable-timing, … Tamil would not be classifiable.
>
> (Grabe & Low, 2002, pp.537–538)

As previously noted, however, these results are based on single speakers only. Given the considerable difference between the values obtained for a single language, Japanese, by the two groups of collaborators, some investigation of the robustness of these measures across speakers is needed before too much confidence is placed in individual results.

5 Results

5.1 *Interspeaker differences*

Comparison of the recordings made by different speakers revealed some variation, although the texts from which they read were identical for each language or variety. This is reflected in slightly different numbers of vocalic and consonantal intervals produced by each speaker, primarily affecting the Tamil data (see Table 1 in Appendix 2). In formal Tamil these differences mainly involved the presence or absence of a glide in the lexical item *cuuriyan* 'sun' and the presence or absence of an accusative marker on certain nouns.[3] In colloquial Tamil one source of variability was the number of identifiable pauses within the passage, which ranged between 15

[3] In colloquial Tamil inanimate nouns tend to be explicitly marked for accusative case only in a definite context (Schiffman, 1999, p. 36), but even then there is variation over whether or not it is included.

and 27 for different speakers. As mentioned above, this has the effect of increasing the number of vocalic intervals relative to consonantal intervals (80 more vocalic than consonantal intervals overall in colloquial Tamil, as compared to 60 more in the formal variety) and may be partly responsible for the overall higher proportion of vocalic interval durations in colloquial Tamil (52.9% mean value across speakers for colloquial Tamil, but 49.4% for formal Tamil).

The colloquial Tamil data also showed a much greater degree of variability than formal Tamil in other respects. In part this can be attributed to the lack of any official standardization of the colloquial variety, which therefore displays much more regional and social variation than formal Tamil.[4] In part, however, the variation observed between speakers reflects the extent to which they were producing authentically colloquial Tamil. As discussed by Asher and Keane (2005), it is difficult to elicit genuinely colloquial Tamil in a recording situation, even if orthographic influence is excluded, and different speakers appear to fall at different points on a continuum of formality. They differ, for example, in the extent to which word-final vowel-nasal sequences are realized as a nasalized vowel, which is a characteristic feature of colloquial Tamil. Much of the variation involved verb forms: sometimes alternative endings were substituted for what was written, for example, *aḍiccuccu* in place of *aḍiccudu* 'beat.past.3sn', which may reflect dialectal variation. In other cases, complex forms were simplified by eliding syllables, which is characteristic of colloquial speech, for example, *ottukiccu* rather than *ottukiḍuccu* 'agree.past.3sn'. This modification of what was written to make it more colloquial contrasts with behavior shown at points by the two female speakers, who instead "corrected" the colloquial text in the direction of the formal variety, for example, by failing to pronounce the "enunciative" *u* written at the end of *naaḷu* 'day'. This particular difference has a direct impact on syllable structure, bringing the distribution of syllable types more into line with formal Tamil and so reducing differences between the varieties to which the measures of rhythmicity may be sensitive. The impact of the other differences on the measures is less easy to predict. Interestingly, JA, the subject who differentiated his colloquial and formal speech most clearly, was the only one to have been educated in Tamil as a first language for both his primary and secondary education, and seemed most comfortable with reading aloud.

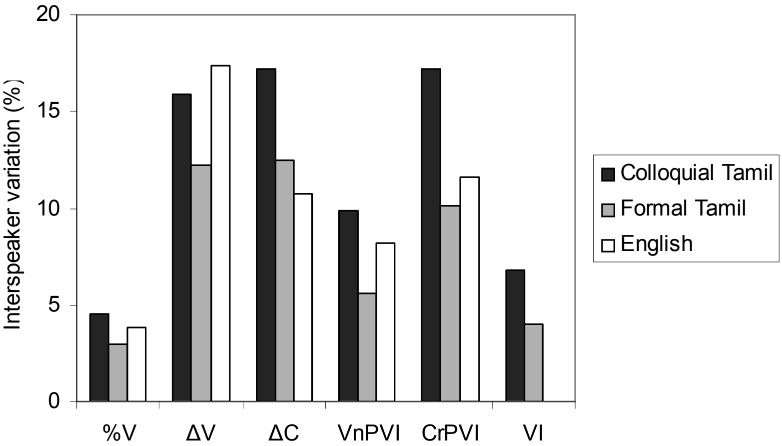
The different degrees of separation between colloquial and formal varieties shown by different speakers are reflected to some extent in the measures calculated from their data, which are shown in Tables 2 and 3 in Appendix 2. Thus JA has the greatest difference between colloquial and formal varieties on all six of the durational measures that were calculated (%V, ΔV, ΔC, VnPVI, CrPVI, and VI). Figure 3 displays the extent of interspeaker variation for the different duration measures by plotting the associated *SD*s as a percentage of the mean value across speakers for each measure. Note that the levels of variation are consistently higher for colloquial Tamil than formal Tamil, reflecting the greater variability in productions of the passage that

[4] There is growing recognition among Tamil scholars that some kind of standard spoken Tamil is gradually emerging, by a process of informal consensus (e.g., Asher & Annamalai, 2003, p. 3; Britto, 1986, p. 130; Karunakaran & Jeya, 1995, p. 142; Schiffman, 1998; and Zvelebil, 1964, p. 257).

has been discussed. Since the English data were not affected by the use of alternative forms that has been discussed above for Tamil, the figures for interspeaker variation (reported in Table 4 of Appendix 2) presumably reflect tempo-related differences and personal idiosyncrasy.

Figure 3

Levels of interspeaker variation for each of the duration measures, calculated by expressing the *SD* associated with each measure as a percentage of the mean value across speakers



The %V measure favored by Ramus et al. shows the greatest consistency across the five speakers, followed by the two measures which contain a normalization component: Deterding's VI and the VnPVI. All the other measures in each of the language types, including the loudness measures, show variability upward of 10% between speakers. Such high levels of interspeaker variation mean that results based on single speakers cannot be accorded much weight. In the case of the loudness measures, differences in overall levels between speakers may be responsible. Tempo-related differences may have contributed to the variability in the duration measures; this would be consistent with the reduced levels associated with the measures to which normalization procedures were applied. The greater stability of %V is slightly puzzling, given that vocalic and consonantal intervals may be differentially affected by differences in speech rate, with vocalic intervals decreasing more as tempo increases. However, Barry and Russo (2003) also found %V to be surprisingly stable, remaining constant across different tempos in Italian and increasing only slightly with tempo in their German data. It is possible that their proposed explanation — that the number of consonants reduces as tempo increases, counterbalancing the proportionately greater decrease in vowel durations — may also have some bearing on the current results.

The magnitude of speaker dependence is of particular interest in relation to the size of interlanguage differences, since the usefulness of the rhythmic measures as indicators of a language's typological status largely stands or falls on this point. Figures 4 and 5 plot the results for individual speakers on the two diagrams reproduced from Grabe and Low (2002).

Figure 4

Relative positions of 18 languages classified on the basis of %V and ΔC, with the new results for colloquial and formal Tamil emboldened and individual speaker values displayed

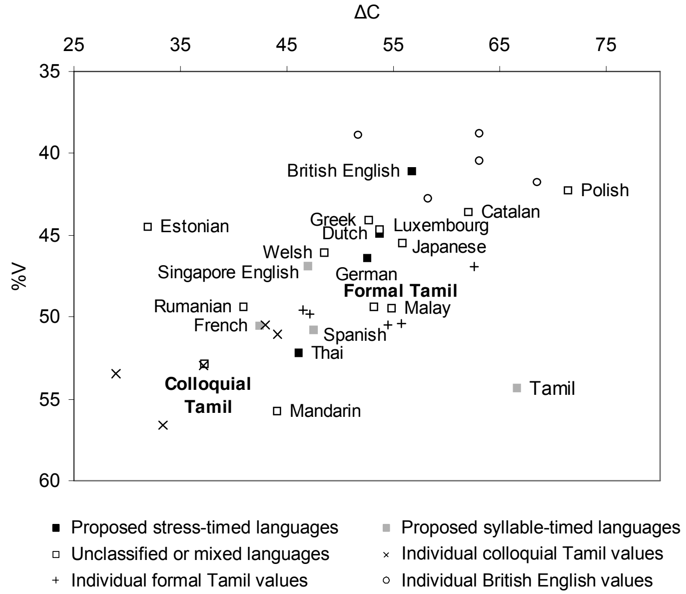
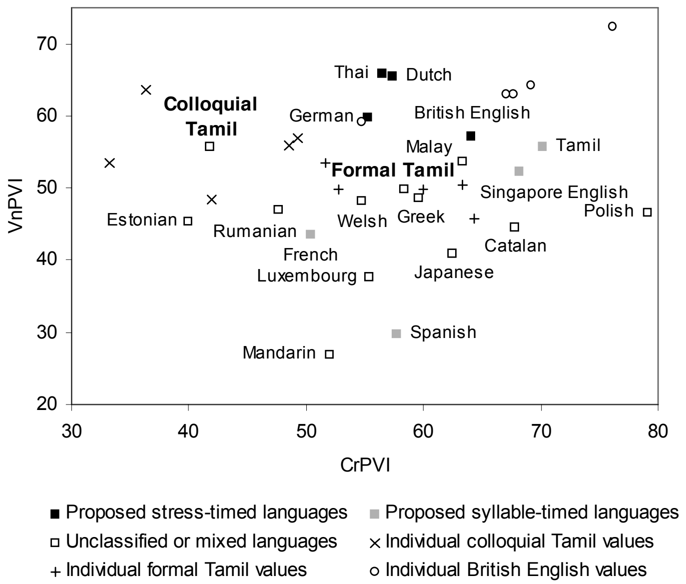


Figure 5

Relative positions of 18 languages classified on the basis of their PVI measures, with the new results for colloquial and formal Tamil emboldened and individual speaker values displayed



They demonstrate that a large proportion of the interspeaker differences are indeed greater than many of those between languages, in line with the Spanish data reported by Grabe (2002, p. 128) and the findings of Barry and Russo (2003). The cumulative weight of evidence strongly suggests that the range of variation in temporal characteristics within a language is too great for a single overall measure of the type currently available to reflect its relation to other languages.

5.2
Comparison with previous studies

The measures calculated from the English data prove to be reasonably consistent with those reported in previous studies, as Table 1 illustrates. The %V figures are particularly close: the 40.8% result from this study falls within the 1% range spanned by the findings of Ramus et al. (1999) and Grabe and Low, which fits with the low level of interspeaker variation for %V reported above. The *SD*s of both vocalic and consonantal durations are somewhat higher than in the previous studies, but this may reflect slower speech rates. Interestingly, in each case the measures for the current study are closer to those of Grabe and Low than Ramus et al., which is presumably due to the different nature of the materials employed by Ramus and his colleagues — sentence sets rather than a connected passage. The PVI measures are also higher than the figures reported by Grabe and Low but still consistent with British English clustering with other prototypically stress-timed languages such as German and Dutch.

Table 1

Comparison of mean results for British English. Figures in parentheses show the number of vocalic and consonantal intervals on which the results are based

	Measure				
	%V	*ΔV*	*ΔC*	*VnPVI*	*CrPVI*
Ramus et al.[5]	40.1%	46.4 (307)	53.3 (320)	—	—
Grabe and Low	41.1%	46.6 (124)	56.7 (124)	57.2	64.1
Current study	40.8%	47.5 (669)	60.8 (665)	64.1	67.0

The results for Tamil show considerable differences from those reported by Grabe and Low for their single speaker, as Table 2 illustrates. Since she was from Singapore, dialectal variation might be responsible, although a direct comparison of Singapore spoken Tamil and the emerging standard spoken in mainland India indicated that differences between the two were minimal (Schiffman, 1998, p. 381). Moreover, the text used by Grabe and Low was in the formal variety, which is less likely to be affected by dialectal variation.

[5] Note that Ramus et al.'s figures for ΔV and ΔC have been multiplied by a factor of 10 to make them directly comparable with the other data in the table.

Table 2

Comparison of mean results for Tamil. Figures in parentheses show the number of vocalic and consonantal intervals on which the results are based

	Measure				
	%V	*ΔV*	*ΔC*	*VnPVI*	*CrPVI*
Grabe and Low original	54.4%	76.4 (149)	66.6 (150)	55.8	70.2
Grabe and Low remeasured	55.6%	66.5 (167)	55.3 (163)	49.5	61.9
Colloquial Tamil	52.9%	46.0 (1389)	37.3 (1309)	55.7	41.8
Formal Tamil	49.4%	41.8 (1187)	53.2 (1127)	49.9	58.4

As described above, the impact of different measurement criteria, specifically in the treatment of pauses, was tested by remeasuring Grabe and Low's data. Their policy (p. 525) was to combine intervals spanning a pause while excluding the duration of the pause itself, whereas in this study pauses were taken as boundaries for measurements. The new figures are given in the second row of the table and bring their data more into line with the results reported here. The discrepancies between the two sets of measures are in conformity with the differences predicted to follow from the two approaches to pauses. As expected, the overall number of intervals is lower in Grabe and Low's figures, and the effect on vocalic intervals is slightly greater than for consonantal intervals (a difference of 18, as opposed to 13). The greater *SD*s and higher PVI values in Grabe and Low's figures are also as predicted, arising from the greater proportion of long intervals in their measures. It is salutary to note the sensitivity of the results to such a difference in policy, showing the need for rigorous consistency in applying measurement criteria. Comparisons across studies in which different measurement procedures have been followed are therefore suggestive at best.

If the remeasured figures are compared with the formal Tamil results (in Table 3 of Appendix 2), Grabe and Low's speaker is seen to fall within the range covered by the ΔC and PVI measures for different speakers in this study. For this speaker both %V and ΔV are higher than expected: %V falls within the range covered by colloquial, not formal, Tamil, and ΔV exceeds even the highest result for colloquial Tamil. The unusually slow tempo adopted by Grabe and Low's speaker may well be responsible: it seems that the vocalic intervals have been drawn out more than the consonantal ones. The fact that the difference in VnVPI is just 0.4% suggests that its normalization component is successfully factoring out tempo-related variability.

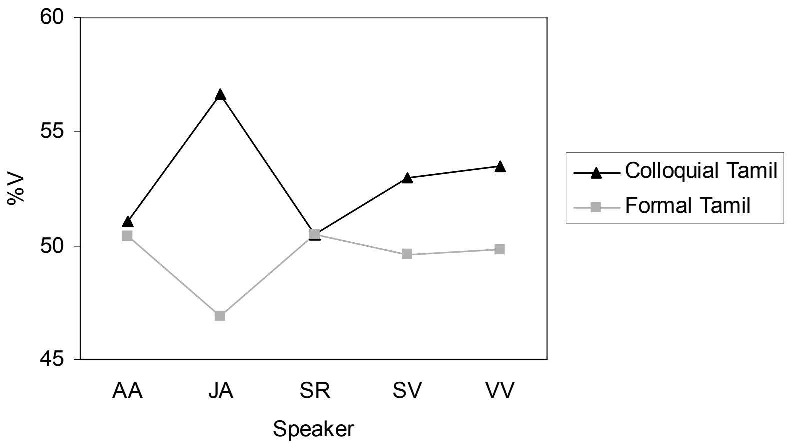
5.3
Formal versus colloquial Tamil

A series of paired-samples *t*-tests were performed to compare mean values of each of the measures in turn for formal and colloquial Tamil. Significant differences between the two varieties were found for several of the duration measures but none of the loudness measures.

Vocalic intervals accounted for a higher proportion of the total duration in colloquial speech, although the difference in %V fell short of significance, $t(4) = 2.045$; *ns*. Figure 6 displays the values for individual speakers, four of whom had higher %V in colloquial Tamil, whereas speaker SR had the same percentage in both varieties. The difference for speaker AA was very small, which fits with the generally low occurrence of informal features in the speech of the two female speakers. The generally higher percentage of vocalic intervals in colloquial Tamil may reflect its simpler syllable structure, involving the insertion of the so-called "enunciative" vowels word-finally and the simplification of some of the consonant clusters of formal Tamil.

Figure 6

Vocalic intervals as a proportion of the whole (%V) in colloquial and formal Tamil for each speaker



There were highly significant differences between varieties for both ΔC and CrPVI, but only for ΔV, not VnPVI. This contrast between the consonantal and vocalic measures is illustrated by the clear separation on the horizontal but not vertical axes in Figures 7 and 8.

The *SD* and PVI of the consonantal intervals were significantly higher in the formal variety, $t(4) = -4.4$, $p < .012$ for ΔC; $t(4) = -5.53$, $p < .005$, for CrPVI. ΔV was also significantly higher in formal Tamil, $t(4) = 3.01$, $p < .04$, but this was not matched by a significant difference in VnPVI, $t(4) = 2.046$, *ns*. As discussed above, greater consonantal variability in formal Tamil may have two possible sources: the greater complexity of cross-word consonant clusters and the lower speech rate of formal Tamil relative to colloquial Tamil. The second explanation, tempo-related differences, would be expected to affect vocalic intervals too: Barry and Russo (2003) reported higher levels of ΔV and slightly higher levels of VnPVI at slower speech rates. The pattern for ΔV is replicated here, but not for VnPVI, suggesting that the first factor, differences in syllabic structure between the two varieties, may have some impact on the rhythmic measures.

The mean VI measure advocated by Deterding, which is based on syllables rather than individual consonantal or vocalic intervals, was generally higher in colloquial

Figure 7

Individual speaker values of ΔV and ΔC for colloquial and formal Tamil

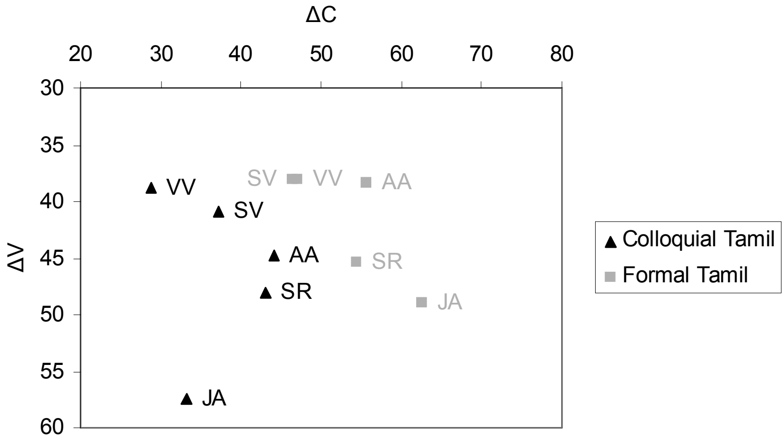
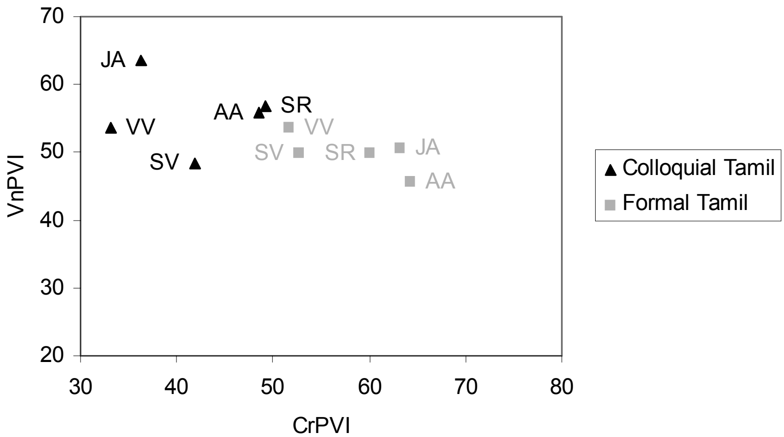


Figure 8

Individual speaker PVI values for colloquial and formal Tamil

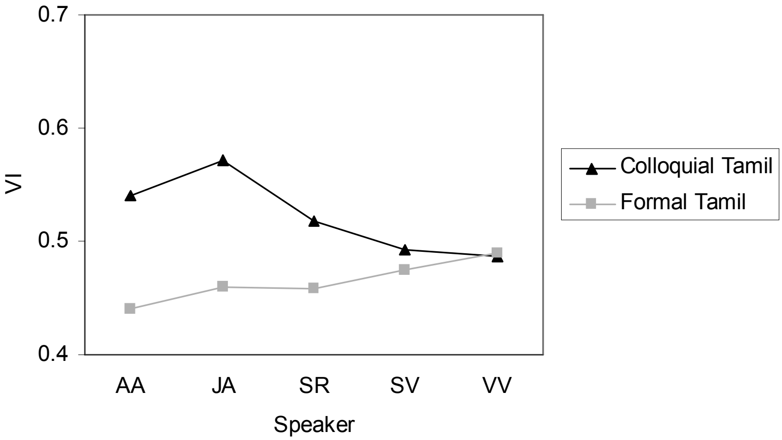


than formal Tamil, as illustrated in Figure 9, although the paired-samples t-test fell just short of significance, $t(4) = 2.693$, $p < .055$.

This tendency is puzzling and contrary to prediction, since the colloquial variety is otherwise associated with reduced levels of variability. One possibility is that the reduction in the occurrence of coda consonants in the colloquial variety increases the relative proportion of short syllables. The distribution of syllables of different lengths is thus altered, and this may make it more likely that adjacent syllables will contrast in length, so raising the variability of syllable durations. Whether or not this explanation is correct, this unexpected tendency demonstrates that a syllable-based measure may reflect something very different from those based on vocalic or consonantal intervals.

Figure 9

Individual speaker values of VI for colloquial and formal Tamil



Given the variability discussed above in the authenticity of different speakers' colloquial Tamil, the differences between varieties in the data are probably under-represented. Nevertheless, significant results are found for three of the six duration measures, indicating that formal and colloquial Tamil are distinct in their temporal characteristics. This differentiation, it seems, derives largely from differences in their syllabic structure, although differences in speaking rate may also play a part.

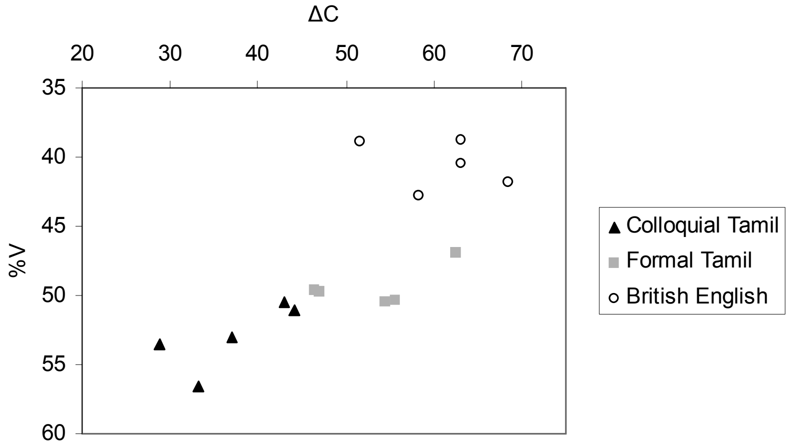
5.4 *Tamil versus English*

Comparisons between English and the two Tamil varieties were made by performing a set of one-way ANOVAs on mean values for each speaker. A three-level variable called Type (English vs. colloquial Tamil vs. formal Tamil) was the independent variable, and each of the measures in turn formed the dependent variable. The effect of Type on the %V measure was highly significant, $F(2, 12) = 56.7$, $p < .0005$; post hoc Tukey tests revealed that all three groups formed homogeneous subsets and confirmed that English differed significantly from both colloquial and formal Tamil ($p < .0005$ for both). Vocalic intervals form a much lower proportion of total duration in English than Tamil, and this can be related, at least in part, to the greater complexity permitted in English syllable structure. Hence it is no surprise that significant differences also surfaced in the *SD* of consonantal intervals, $F(2, 12) = 16.9$, $p < .0005$, as illustrated in Figure 10.

Pairwise comparisons of ΔC performed using the Tukey test revealed a significant difference between English and colloquial Tamil ($p < .0005$), but not English and formal Tamil. Similar results were also gained for the CrPVI measure, $F(2, 12) = 16.7$, $p < .0005$; again English and formal Tamil patterned together to form a homogeneous subgroup in contrast to colloquial Tamil. As noted above, formal Tamil allows greater complexity in its consonant sequences, particularly across words, than the colloquial variety, which presumably explains why it is closer to English on all the measures considered thus far.

Figure 10

Relative positions of the individual speakers for English, colloquial Tamil, and formal Tamil on the basis of %V and ΔC



In addition to %V, the two languages were also significantly differentiated by the VnPVI measure, $F(2, 12) = 11.6$, $p < .002$, but not by ΔV. Post hoc Tukey comparisons of VnPVI between English and both varieties of Tamil proved to be highly significant (English vs. colloquial Tamil $p < .037$; English vs. formal Tamil $p < .001$). In each case the English measure was considerably higher, although comparison of overall means showed it to be closer to colloquial than formal Tamil in this respect. As discussed above, the higher level of VnPVI but not of ΔV in English might be explained by the two languages using differences in vocalic duration in different ways. In Tamil, durational differences primarily signify phonological quantity distinctions, so the distribution of long and short vowels is more or less random. In English, however, length differences may signify stress-related phonological vowel reduction, and since there is a tendency towards regular alternation of stressed and unstressed syllables, syllables containing long and short vowels tend to alternate. ΔV, as a global temporal measure, is not sensitive to this difference, but the VnPVI is, being based on durational differences between successive vowels, and this may account for its higher level in English.

As predicted, an overall significant result was also found for the corresponding loudness measure (VnPVIloud), $F(2, 12) = 4.6$, $p < .034$, and post hoc Tukey comparisons showed the differences between English and each of the Tamil varieties to be very close to significance at the .05 confidence level (English vs. colloquial Tamil $p < .056$; English vs. formal Tamil $p < .054$). The mean English value (38.7) was considerably higher than the Tamil figures (27.0 for colloquial, 26.9 for formal), and this can perhaps be related to differences in loudness being associated with lexical stress in English. In Tamil, by contrast, loudness at the level of the word is primarily determined by intrinsic segmental differences (Balasubramanian, 1972, p. 529; Keane, 2006), and the degree of variation is accordingly somewhat lower.

5.5
Crosslinguistic comparisons

The fact that interspeaker differences in this study exceed many of those between languages makes this section tentative at best, particularly when languages are positioned on the basis of data from a single speaker. Nevertheless, the successful differentiation of the three language types investigated here by certain of the measures suggests that they may capture differences in rhythmic characteristics even if they do not position languages reliably within a typological rhythm space. On the (%V, ΔC) space shown in Figure 4, the mean values for both varieties of Tamil fall within the general area staked out by the other languages when the measures of Ramus et al. (1999) are applied to Grabe and Low's data. Colloquial Tamil is in the bottom left quarter, with French, a prototypically syllable-timed language, falling within the area demarcated by the individual speaker values. Formal Tamil, by contrast, is on average higher up and further right; differences on both axes are significant. It is thus somewhat closer to the prototypically stress-timed languages, but at the same time a near neighbor to Spanish. This would be consistent with describing colloquial Tamil as having syllable-timed characteristics, whereas formal Tamil occupies an intermediate position, edging towards but not clearly clustering with the stress-timed Germanic languages.

As discussed above, the two Tamil varieties do not differ significantly from each other in their VnPVI values, although this is the dimension on which the traditional syllable-timed and stress-timed languages are most clearly distinguished in Figure 5. Both fall in the upper middle section of the graph, nearer the stress-timed than the syllable-timed languages. In terms of their consonantal PVI values, which are significantly different, formal Tamil is roughly aligned with the stress-timed Germanic languages. Colloquial Tamil is separated from formal Tamil on the left side of the graph but is actually farther from prototypically syllable-timed languages such as Spanish and French. Overall, therefore, this figure offers little grounds for assigning either variety of Tamil to one of the conventional categories or of characterizing the difference between them in terms of the traditional "stress-" and "syllable-timed" labels.

The position of colloquial and formal Tamil in Figures 4 and 5 is markedly different from Grabe and Low's Tamil speaker, whose data points (marked simply 'Tamil') are outside the range of interspeaker variation for either variety. As discussed above, this is partly due to differences in measurement criteria: Grabe and Low's speaker proved less exceptional when her data were remeasured. Her unusually slow tempo may also have contributed, since in both figures the greatest difference is on the consonantal axis, highlighting again the susceptibility of non-normalized measures to differences of tempo. The results of this study strongly suggest that the isolated position of Tamil on Figure 2 merits little attention as evidence of its rhythmic distance from other languages and indeed may not be representative of either the colloquial or the formal variety.

6 Conclusions

The application of acoustic measures of rhythmicity to data from Tamil and British English has produced results with implications both for the usefulness of the measures and the rhythmic characteristics of the two varieties of Tamil. The first concerns the robustness of the measures against differences in the detailed criteria used for making measurements. There were some substantial discrepancies between Grabe and Low's figures for their single Tamil speaker and the results of remeasuring their data, which were largely traceable to a difference in the treatment of pauses. These results raise serious concerns for the validity of cross-study comparisons involving different measurement techniques. If the rhythmic measures currently available are to be applied more extensively in the future, then explicit criteria for segmentation and the treatment of pauses will have to be agreed upon, and rigorous testing of differences between experimenters is desirable.

High levels of interspeaker variation are associated with the different measures within all three language types. The %V measure favored by Ramus et al. is least affected: it displayed a high degree of stability between speakers within each language type, and it also produced similar results across studies. The relatively low levels of variability associated with the two measures containing a normalization component — the normalized vocalic PVI and Deterding's VI — suggest that the heavy speaker dependence of the other measures may be largely attributable to differences in speech rate, both between speakers and within the speech of individuals. If this is correct, the stability of %V is somewhat surprising but in line with Barry and Russo's (2003) findings that it proved relatively immune to changes in tempo in Italian and German. As discussed above, they propose that a reduction in the number of consonants at faster tempos counteracts the proportionately greater reduction in the duration of vocalic intervals.

The magnitude of interspeaker differences is of particular interest in relation to differences between languages. As Figures 4 and 5 illustrate, individual data points for each of the three language types, even for normalized measures, are widely dispersed, and distances between them exceed those separating many pairs of languages. This finding, in conjunction with previous indications that interspeaker differences may be larger than those between languages (Barry & Russo, 2003; Grabe, 2002, p. 128), casts serious doubt upon the wisdom of marking single points in rhythmic space to indicate typological relations between languages.

Keeping these caveats in mind, the application of the different rhythmicity measures has nevertheless revealed some significant differences, both between the two varieties of Tamil and also between Tamil and British English. Colloquial and formal Tamil were differentiated significantly by ΔV, ΔC, and also CrPVI, despite two of the five speakers apparently modifying their renditions of the colloquial passage in the direction of the formal variety. Significant differences between the two varieties were confined to durational measures alone, but the normalized value of the average loudness of vocalic intervals distinguished successfully between Tamil and English. This suggests that consideration of variation in loudness levels may be worth pursuing in future investigations of crosslinguistic rhythmic differences, in conjunction with the established duration-based measures. In languages traditionally labeled "stress-timed," differences in loudness may serve to reinforce the alternation between strong and weak syllables and so contribute to the overall impression on which linguists base rhythmic judgments.

The durational differences between the two varieties of Tamil can largely be attributed to differences in syllable structure and specifically the greater complexity of cross-word consonant clusters in formal Tamil, although differences in speech rate may also have played a part. Application of Deterding's syllable-based index to Tamil, however, produced a rather unexpected result: a higher VI measure, reflecting greater variability, in colloquial, not formal Tamil. As discussed above, this may be due to simplification of consonant clusters in colloquial Tamil altering the relative proportions of long and short syllables, and thereby increasing the probability that adjacent syllables will be substantially different in duration. Whatever the correct explanation, the syllable-based measure is clearly sensitive to a difference in the contrast between Singapore and British English, as compared to that between formal and colloquial Tamil, which the interval-based measures do not reflect.

The question is therefore which type of measure, if either, reflects the differences responsible for the perception of different types of rhythm. Overall it appears that the results from the interval-based measures correspond more closely to the way that the labels "syllable-timed" and "stress-timed" have traditionally been applied. These interval-based measures may therefore have a greater claim to reflect what linguists have been perceiving than Deterding's syllable-based index; in other words, the successive durational variation of acoustic intervals (regardless of syllabic affiliation) may be more salient than the sequential variability of phonological constituents in judging rhythmic type. This provides some support for a view of rhythm as an emergent acoustic property, determined by a complex interplay of factors such as syllable structure, phonotactics, the existence of quantitative distinctions, the inherent duration and loudness of different segments in the language, and the phonetic correlates of prominence. What relevance this has for a native speaker's awareness of the rhythmic structure of their own language and their response to other languages is less clear, although the perceptual studies of Ramus and his colleagues suggest that infants and adults alike may draw on these properties when asked to discriminate between languages.

Given the wide range of interspeaker variation, possible tempo-related differences, and the significant impact of adopting different measurement criteria, large-scale crosslinguistic comparisons on the basis of single speakers — or even sets of five speakers — should be treated with caution. Figures 4 and 5 reveal no clear clustering of languages into discrete groups corresponding to the traditional rhythmic classes, although prototypical stress- and syllable-timed languages are partially separated. Formal Tamil is closer to the Germanic stress-timed languages in the (%V, ΔC) space than colloquial Tamil, but the difference between the two varieties cannot be captured by reference to the traditional categories. Given these results, the failure of previous attempts to assign Tamil to a single rhythmic class is unsurprising.

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Appendix 1: Texts

English passage:

The North Wind and the Sun were disputing which was the stronger, when a traveller came along wrapped in a warm cloak. They agreed that the one who first succeeded in making the traveller take his cloak off should be considered stronger than the other. Then the North Wind blew as hard as he could, but the more he blew the more closely did the traveller fold his cloak around him; and at last the North Wind gave up the attempt. Then the Sun shone out warmly, and immediately the traveller took off his cloak. And so the North Wind was obliged to confess that the Sun was the stronger of the two.

Formal Tamil passage:

In the native Dravidian vocabulary voicing alternations are predictable and so not reflected in the script: obstruents in word-initial position are voiceless, voiced after nasals, and voiced or lenited or both when they occur as singletons intervocalically. However, since these passages contain lexical items (borrowed originally from Sanskrit) that have word-initial voiced plosives, the transliterations depart from Tamil orthography in marking voicing distinctions. For the obstruent series represented by <c> the affricate [tʃ] is the realization of an intervocalic geminate and may be found word-initially. [s] may also occur in this position; the relative distribution of the two sounds is highly variable and determined by complex sociolinguistic factors. The rhotic liquid represented by <ṟ> is produced with a preceding epenthetic stop in formal Tamil when written as a geminate or following a nasal, and this is reflected in the transliterations as <tṟ> and <ndṟ> respectively.

oru kaalattil kaatr̲um cuuriyanum yaardaan periyavan endr̲u paarppoom endr̲u vaadaaɖikkoɳɖirundadu. kaatr̲u “naandaan periyavan,” endr̲adu. cuuriyan “naandaan periyavan,” endr̲adu. anda camayattil avviɖam vaɻippookkan oruvan cendr̲aan. appoodu namadu vaɻakkai tiirkka iduvee camayam endr̲u yaardaan anda vaɻippookkan meel cutr̲i irunda poorvaiyai tuukkiviɖukiraarkaɭoo avardaan periyavan endr̲u iruvarum cammadittaarkaɭ. appaɖiyee kaatr̲u balamaaka aɖikka aarambittadu. kaatr̲u balamaaka aɖippadai paarttu vaɻippookkan poorvaiyai ir̲ukkamaaka cutr̲ikkoɳɖaan. pir̲aku cuuriyan pirakaacikka aarambittadu. vara vara veyil adikarikkavee uɖambil cuuɖu eer̲itr̲u. vaɻippookkan poorvaiyai kaɻatr̲a aarambittaan. idaikkaɳɖadum kaatr̲u cuuriyandaan periyavan endr̲u oppukkoɳɖadu.

Colloquial Tamil passage:

oru naaɭu kaattum cuuriyanum romba caɳɖe pooʈʈukiʈʈu yaaru balacaalinnu pandayam pooʈʈaaŋga. kaattu colluccu taandaan balacaalinnu. cuuriyan colluccu taandaan balacaalinnu. appa anda vaɻiyaa oru vaɻippookkan kambaɭiye poottikkiʈʈu poonaan. kaattum cuuriyanum yaaru vaɻippookkan kambaɭiye eɖukka vaikkiraaŋgaɭoo avaŋgadaan balacaalinnu pandayam pooʈʈaaŋga. modalle kaattu veekamaa aɖiccudu. romba balamaa aɖikka aɖikka vaɻippookkan kambaɭiye iɻuttu iɻuttu poottikiʈʈaan. aɖuttu cuuriyan ukkiramaa kaaɲcudu. veyil adikam aaka aaka vaɻippookkan veppam taaŋga muɖiyaama kambaɭiye eɖuttu pooʈʈaan. ide paattuʈʈu kaattu cuuriyandaan balacaali, adu pandayattile jeyccuruccunnu ottukiɖuccu.

Appendix 2: Tables of measures

Table 1

Numbers of vocalic and consonantal intervals for different speakers

		Speaker					
Language	*Interval type*	*AA*	*JA*	*SR*	*SV*	*VV*	*Total*
Colloquial Tamil	Vocalic	237	221	233	220	235	1389
	Consonantal	226	212	218	207	225	1309
Formal Tamil	Vocalic	239	242	246	231	229	1187
	Consonantal	225	232	231	221	218	1127
		AS	*EK*	*NK*	*LW*	*TW*	
English	Vocalic	133	132	135	134	135	669
	Consonantal	131	131	136	133	134	665

Table 2

Colloquial Tamil measures

Measure	Speaker AA	JA	SR	SV	VV	Mean	SD	Interspeaker variation
%V	51.1	56.6	50.5	53.0	53.5	52.9	2.40	4.5%
ΔV	44.8	57.4	48.1	40.9	38. 8	46.0	7.31	15.9%
ΔC	44.1	33.3	43.0	37.1	28.9	37.3	6.43	17.2%
VnPVI	55.9	63.6	56.9	48.4	53.5	55.7	5.52	9.9%
CrPVI	48.5	36.3	49.3	41.9	33.2	41.8	7.17	17.2%
VI	0.54	0.57	0.52	0.49	0.49	0.52	0.04	6.8%
ΔVloud	5.38	9.29	8.39	5.01	6.35	6.88	1.88	27.3%
ΔCloud	5.39	6.80	8.34	6.47	7.39	6.88	1.09	15.8%
VnPVIloud	24.4	37.4	27.9	20.3	24.9	27.0	6.42	23.8%
CrPVIloud	53.2	64.3	85.5	72.0	74.5	69.9	12.03	17.6%

Table 3

Formal Tamil measures

Measure	Speaker AA	JA	SR	SV	VV	Mean	SD	Interspeaker variation
%V	50.4	46.9	50.5	49.6	49.8	49.4	1.47	3.0%
ΔV	38.4	49.0	45.4	38.1	38.1	41.8	5.09	12.2%
ΔC	55.7	62.5	54.4	46.5	47.1	53.2	6.64	12.5%
VnPVI	45.7	50.5	49.9	49.8	53.5	49.9	2.78	5.6%
CrPVI	64.3	63.3	60.0	52.8	51.6	58.4	5.89	10.1%
VI	0.44	0.46	0.46	0.47	0.49	0.46	0.02	4.0%
ΔVloud	5.93	10.1	7.31	4.78	6.22	6.87	2.02	29.4%
ΔCloud	5.88	7.62	6.26	5.41	6.50	6.33	0.83	13.1%
VnPVIloud	20.9	34.7	28.4	24.3	26.0	26.9	5.16	19.2%
CrPVIloud	58.9	73.8	68.7	56.0	64.2	64.3	7.21	11.2%

Table 4
English measures

	Speaker							
	AS	*EK*	*NK*	*LW*	*TW*	*Mean*	*SD*	*Interspeaker variation*
%V	38.9	38.8	41.8	40.5	42.8	40.8	1.56	3.8%
ΔV	36.5	44.0	58.5	47.2	51.4	47.5	8.28	17.4%
ΔC	51.7	63.1	68.5	63.1	58.3	60.8	6.52	10.7%
VnPVI	59.1	63.0	72.4	64.2	63.0	64.1	5.27	8.2%
CrPVI	54.8	67.7	76.2	69.2	67.1	67.0	7.77	11.6%
ΔVloud	9.0	8.49	6.31	9.77	5.92	7.91	1.71	21.6%
ΔCloud	4.82	6.72	4.5	6.76	3.4	5.25	1.46	27.8%
VnPVIloud	34.8	33.5	34.0	55.1	36.0	38.7	9.21	23.8%
CrPVIloud	48.3	62.7	47.9	68.0	34.4	52.6	13.22	25.1%