The Rhythm Type of Teop: Evidence against the Strict Trichotomy

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Abstract

Since the proposal of the trichotomy of the world's languages into mora-timed, stress-timed, and syllable-timed, there has been ongoing debate concerning whether the trichotomy is strict or gradient. This paper takes a different approach: instead of focusing on those well-researched languages, it examines an understudied language Teop, a member of the Oceanic language family. Teop is spoken in the northeastern region of Bougainville Island in Papua New Guinea. The paper also focuses only on the rhythmic metrics VarcoΔV and vocalic nPVI to guarantee reliable results since they have been generally recognized as discriminative in previous studies. Teop has intermediate results between stress-timed and syllable-timed languages both in terms of VarcoΔV and vocalic nPVI. This demonstrates that Teop belongs to a rhythm type somewhere between stress-timed and syllable-timed rhythms. Statistical analysis results further confirm the validity of this conclusion, challenging the strict trichotomy.

Keywords: *corpus, rhythmic measure, rhythmic type, intermediate, statistical analysis*

1．Introduction

Abercrombie (1965, 1967) proposes the dichotomy of the world's languages into stress-timed and syllable-timed according to their different rhythms (see also Pike 1946, Ladefoged 1975, Ramus et al. 1999). According to Abercrombie (1965, 1967), the stressed feet have the periodic recurrence of movement in stress-timed languages. Therefore, the stressed syllables are isochronous in these languages. Typical examples of stress-timed languages include English, German, Russian, and others. In contrast, syllables recur at equal intervals of time in syllable-timed languages: these syllables are isochronous. Representative syllable-timed languages include French, Mandarin, Spanish, among others. Ladefoged (1975) proposes a third rhythmic type, mora-timed, which is mainly represented by Japanese (see also Bloch 1950, Han 1962). According to Ladefoged (1975), each mora is approximately of the same length.

The concept of isochrony has generally been questioned. For example, De Manrique et al. (1983) examine the durations of vowels, consonants, syllables, and inter-stress intervals in Spanish and report that syllables do not have similar durations in this syllable-timed language as claimed. Dauer (1983) compares stress-timed languages with syllable-timed languages and finds that the durations of feet are as variable in stress-timed languages as in syllable-timed languages. For example, feet in English are as variable in duration as in Spanish (see also Nakatani et al. (1981) against isochrony in English, Scott et al. (1985) against isochrony in English and French, Port et al. (1987) against isochrony in Japanese, Nooteboom (1991) using data from Swedish to argue against isochrony, among others).

Later scholars have proposed several rhythmic measures to discriminate different rhythm-typed languages (Ramus et al. 1999, Grabe and Low 2002, Dellwo 2006). However, disputes continue over whether the trichotomy is gradient or absolute (Mitchell 1969, Dauer 1987, Minagawa-Kawai 1999, Grabe and Low 2002). What is interesting is that this long debate has basically been circling around a few well-known and well-studied languages, e. g., English, French, German, Japanese, Mandarin. The trichotomy of the world's languages cannot just be applied to a few familiar languages. Therefore, this paper takes a different approach: it focuses on an endangered and understudied language Teop to examine its rhythm type. In addition, this paper only uses rhythmic measures that have been generally recognized as reliable and omits highly-disputed rhythmic measures to ensure valid results. This paper also carries out statistical analysis to further examine its results.

The paper is structured as follows. Section 2 gives a review of rhythmic measures in previous studies and identifies the most effective ones. Section 3 introduces Teop, the language of the focus here and acoustic analysis methods for this study. Section 4 presents both rhythmic measure and statistical analysis results concerning the rhythmic type of Teop. Section 5 concludes the whole paper.

Accepted on August 25th, 2025（2025年８月25日受付）

2．Rhythmic measures

Ramus et al. (1999) primarily examine three rhythmic measures: %V, ΔV, and ΔC. The measure %V represents the proportion of vocalic intervals in a sentence. The measure ΔV indicates the variability in the duration of vocalic intervals within each sentence, while ΔC measures the variability in the duration of intervocalic intervals within a sentence. Based on their analysis of eight languages, Ramus et al. (1999) find that %V and ΔC align with the concept of rhythm classes. For instance, Ramus et al. (1999) observe that English has a lower %V compared to French due to reduced vowels in English but not in French. Additionally, English has a higher ΔC due to its more complex onset and coda structures in comparison to French. These differences in %V and ΔC between English and French support the hypothesis that English is a typical stress-timed language, while French is a syllable-timed language.

Dellwo (2006) claims that speech rate is inversely correlated with ΔV and ΔC and needs to be taken in consideration. Dellwo (2006) thus proposes normalized ΔV and ΔC (henceforth VarcoΔV and VarcoΔC), which are respectively the standard deviation of vocalic interval duration divided by the mean vowel duration and the standard deviation of intervocalic interval duration divided by the mean consonant duration.

Grabe and Low (2002) take a different perspective in speech rhythm class study by employing the Pairwise Variability Index (PVI). According to them (2002: 519), the PVI measures "the durations of vowels and the duration of intervals between vowels (excluding pauses) in a passage of speech" and then calculates "the level of variability in successive measures." When the speech rate factor is taken into consideration, the measure is termed as *normalized PVI*, or *nPVI* in short. The following are the equations of rPVI and nPVI, where rPVI stands for raw PVI to show the contrast with nPVI.

（1） Equations of rPVI and nPVI (Grabe & Low 2002: 519-520)

a．rPVI

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

b．nPVI

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

In (1), *m* refers to the number of intervals and *d* the duration of the kth interval (Grabe and Low 2002). Following the trichotomy of the world's languages (Pike 1946; Bloch 1950; Han 1962; Abercrombie 1965, 1967; Ladefoged 1975), stress-timed languages should have more variability between two successive vocalic intervals than mora-timed and syllable-timed languages due to vowel reduction in unstressed syllables. In simpler terms, stress-timed languages should have higher rPVI and nPVI values for vocalic intervals than mora-timed and syllable-timed languages. Intervocalic intervals in stress-timed languages are considered more complex than those in mora-timed and syllable-timed languages. Hence, they should also give the highest rPVI and nPVI values in stress-timed languages.

Since the proposal of the above rhythmic measures, disputes have been continuing, firstly about whether speech rate should be considered, and secondly about which measures are the most reliable. Although an agreement may never be completely reached, a review of previous studies can still present a hint concerning the role of the speech rate factor and effective rhythmic measures.

2.1. Rhythmic measures in previous studies

White and Mattys (2007) give a comprehensive comparison by taking all rhythmic measures reviewed in Section 2 into consideration. According to them (2007), ΔV and ΔC are strongly influenced by speech rate, making them unreliable in discriminating the stress-timed English and Dutch from syllable-timed Spanish and French, while the measure %V and the normalized measures VarcoΔV and vocalic nPVI (henceforth nPVI-V) can. They (2007) recruit second language speakers (hereafter L2 speakers) to examine the influence of their first languages on their second languages in terms of rhythm and find that a combination of %V and VarcoΔV appears to be particularly discriminative.

Liu and Takeda (2021) compare native English speakers with L2 speakers of English by taking all rhythmic measures in Section 2 into consideration. Liu and Takeda (2021) demonstrate that VarcoΔV and nPVI-V are particularly satisfactory in discriminating different groups with the native English speakers having the highest values, followed by the L2 group of native Mandarin speakers. The L2 group of native Japanese speakers has the lowest values. This is in conformity with English being stress-timed, Mandarin syllable-timed, and Japanese mora-timed. The %V measure in Liu and Takeda (2021), however, presents a similar result for all groups and is not discriminative.

Knight (2011) recruits four speakers of Southern British English to read *The North Wind and the Sun* across three consecutive days to examine whether rhythmic measures can give consistent and thus reliable results for the same speakers. After a comparison of results in terms of %V, ΔV, ΔC, VarcoΔV, VarcoΔC, nPVI-V, and intervocalic rPVI (hereafter rPVI-C), Knight (2011) concludes that measures based on vowels generally exhibit greater stability compared to their consonantal

counterparts, as evidenced by higher correlation coefficients. Among all the rhythmic measures, %V gives the most consistent results from the same speakers across time. The measures rPVI-C and VarcoΔC have displayed the lowest level of performance, with only moderately high correlations observed.

Prieto et al. (2012) analyze data from 8 native speakers reading 10 utterances in English, Spanish, and Catalan respectively. They (2012) find that %V, ΔV, and rPVI-V are strongly affected by syllable structure and need to be interpreted with some caution. The two normalized measures for vocalic intervals, VarcoΔV and nPVI-V, are not affected by syllable structure and can effectively discriminate the three languages by separating English from Spanish and placing Catalan close to Spanish. In contrast, the consonantal measures heavily rely on the phonotactic characteristics specific to the materials being utilized.

Olivio (2011) examines the majority of rhythmic measures discussed in Section 2. She (2011) asks two native speakers of Ashanti Twi to read the translation of *The North Wind and the Sun* in Ashanti Twi. Olivio (2011) has tried different combinations of rhythmic measures., e.g., %V and ΔC, rPVI-C and nPVI-V, to place Ashanti Twi into a certain rhythmic class but finds that it cannot be clearly categorized as either a stress-timed language or a syllable-timed language. The VarcoΔV captures the intermediate status of Ashanti Twi, placing it between stress-timed and syllable-timed languages while being closer to syllable-timed languages. This finding is in line with Ramus et al.'s (1999) report that the rhythmic measure VarcoΔV can capture the range of languages along a rhythmic continuum.

Part of previous research only focuses on a few measures. Grabe and Low (2002) specifically examine %V, nPVI-V, and rPVI-C. They (2002) indicate that nPVI-V reflects differences in vowel quality and vowel reduction between French, Spanish, and Catalan. However, the %V measure places Japanese within the stress-timed group, alongside German and English. Concerning rPVI-C, they (2002) could not reach a clear conclusion and state that further research is needed as the rPVI-C value of Spanish is different from that of English but very close to those of Dutch and German, two stress-timed languages. Ling et al. (2000) compare Singaporean English with British English, with the former being claimed more syllable-timed than the latter (Tongue 1974). The nPVI-V measure demonstrates that Singaporean English has less variability in successive vocalic intervals than British English, aligning with the general subjective impression that Singaporean English is more syllable-timed than British English. Ling et al. (2000) question the reliability of %V since its results indicate that Singaporean English is even more stress-timed than British English (39.25 vs. 40.10).

Henrich et al. (2006) adopt a different approach but arrive at a similar conclusion to Ling et al. (2000): they focus on six native speakers of American English with ataxic dysarthria and analyze their limerick reading, sentence reading, passage reading, and spontaneous speech. Ataxic dysarthria is a speech disorder with the disturbance of rhythm, making syllables more equal in length and more syllable-timed. Henrich et al. (2006) compare data from these speakers with data from six control speakers using nPVI-V and %V. Their results show that the nPVI-V measure satisfactorily reflects rhythmic changes in speakers with ataxic dysarthria: (i) nPVI-V reveals significant differences between the speakers with ataxic dysarthria and the control group across all tasks; and (ii) nPVI-V shows that the speakers with ataxic dysarthria exhibit a more syllable-timed rhythm, consistent with the subjective perceptual impressions. In contrast, the %V measure does not yield statistically significant difference between the two groups.

Payne (2022) also raises doubts about the reliability of %V. She (2022) points out that Standard Italian is expected to have a lower %V score than Spanish due to the presence of geminate consonants in Standard Italian. However, both Ramus et al. (1999) and Ramus et al. (2003) report moderately higher %V values for Italian than for Spanish. According to Wagner and Dellwo (2004), the %V measure fails to capture the differences in rhythms and is strongly affected by speech rate. The measure %V reflects syllable complexity and is thus not reliable in distinguishing between different rhythm types. Dorn et al. (2012) focus on the three varieties of Irish English, namely Donegal Irish, Connemara Irish, and Kerry Irish, to examine rhythmic measures. Certain grammatical structures in Irish English may result in sequences of up to four vowels and thus may lead to a higher nPVI-V value compared to British English. Their (2012) results in terms of nPVI-V support this prediction: 65.5 for Donegal Irish, 65.1 for Connemara Irish, and 68.4 for Kerry Irish, while Grabe and Low (2002) report 57.2 for British English. Dorn et al. (2012) also report high values of rPVI-C which concurs with the fact that Irish has a wide range of choices for syllable structure. Similarly, Romano et al. (2011) calculate the nPVI-V values of the claimed syllable-timed languages of Cantonese, Mandarin, Thai, and Vietnamese. Romano et al. (2011) report that the nPVI-V values of these four languages cluster them with representative syllable-timed languages, i.e., Spanish, French, as expected. Most studies reviewed up until now suggest that VarcoΔV and nPVI-V are reliable.

Needless to say, different opinions also exist. To exemplify, Kellogg (2020) reports that Scottish Gaelic has similar results in terms of %V, ΔV, and ΔC as British English, as reported in Ramus et al. (1999), in line with the claim of Scottish Gaelic being stress-timed. O'Rourke (2008) uses %V and VarcoΔC to

examine two regional varieties of Peruvian Spanish, Lima Spanish and Cusco Spanish. Lima Spanish exhibits features of /s/-aspiration and deletion and is therefore expected to have a different overall vocalic ratio compared to Cuzco Spanish, as well as greater consonantal variability (Escobar 1978, O'Rourke 2008). Cuzco Spanish reduces unstressed vowels and thus should have a lower %V value than Lima Spanish. The %V values confirm this prediction: 54.2 for Lima Spanish and 49.6 for Cusco Spanish. O'Rourke (2008) also finds that %V and VarcoΔC place both dialects outside of the stress-timed languages and intermediate between syllable-timed and mora-timed languages. Among them, Lima Spanish is closer to Japanese in terms of rhythm than Cusco Spanish. According to O'Rourke (2008), this can be explained as the weakening of /s/ in coda position in Lima Spanish resulting in open syllables, a syllable structure similar to the mora in Japanese which also does not have coda. Furthermore, the absence of vowel reduction in both Lima Spanish and Japanese may further bring the two languages closer in terms of rhythm. One note needs to be made here: although O'Rourke (2008) claims that both %V and VarcoΔC are effective, questions can still be raised over the validity of these two measures. Cusco Spanish reduces unstressed vowels, a feature that should have given a lower %V value and placed Cusco Spanish near a stress-timed language. In addition, Cuzco Spanish does not possess the features such as /s/-aspiration and deletion as Lima Spanish and thus is not expected to have a syllable structure as close to Japanese mora as Lima Spanish. Consequently, Cuzco Spanish, unlike Lima Spanish, should not have a VarcoΔC value between syllable-timed and mora-timed languages: it should be within the syllable-timed language range. This is clearly not in line with the results in O'Rourke (2008) and undermines the validity of %V and VarcoΔC. Ramus et al. (1999) argue that the measures %V and ΔC are indicative of rhythm classes. They illustrate this by comparing English with French. According to them (1999), English exhibits a lower %V than French due to the presence of reduced vowels in English but not in French. Additionally, English shows a higher ΔC value as a result of its more intricate onset and coda structures compared to French. These disparities in %V and ΔC between English and French support that English is a representative of stress-timed languages while French represents a syllable-timed language. Mok and Dellwo (2008) compare the speech rhythms of Cantonese, Mandarin, Cantonese-accented English, and Mandarin-accented English with the stress-timed languages of German and English and the syllable-timed languages of French and Italian. They (2008) employ both raw and normalized rhythmic measures, including %V, ΔV, ΔC, VarcoΔV, VarcoΔC, nPVI-V, and rPVI-C. Based on their analysis, %V and VarcoΔC classify languages into different rhythm types most efficiently and confirm that Cantonese and Mandarin are syllable-timed. Table 1 gives a summary of all studies reviewed in this subsection.

In Table 1, the tick and cross symbols respectively mean that a related study supports or argues against the validity of a rhythmic measure. The blank cells indicate that the related rhythmic measures are not included in those specific studies. The "✓ (%)" and "× (%)" at the bottom of Table 1 refer to the percentages of the ticks and crosses for each rhythmic measure. For example, the numbers 38.46 and 61.54 indicate that 38.46% of the studies in Table 1 that have examined the rhythmic measure %V report results supporting the validity of %V, while 61.54% of the related studies argue against it. The results from O'Rourke (2008) are not included in Table 1. Although O'Rourke (2008) claims that her results support the reliability of %V and VarcoΔC, part of her results in fact argue against her claim as noted.

Table 1 demonstrates that although not all studies have discussed VarcoΔV, almost all research that has included it in argues for its validity. The rhythmic measure nPVI-V is supported by most previous studies: nine out of the eleven previous studies support its effectiveness. On the contrary, the rhythmic measures of rPVI-V, VarcoΔC, and nPVI-C are either not supported by any research or only supported by very limited research. The rhythmic measures of %V, ΔV, ΔC, rPVI-C, although claimed as effective by some studies, are argued against by a larger number of studies. According to Wagner and Dellwo (2004), this is because the measures of %V and ΔC provide insights into syllable complexity and variety rather than rhythm. Another limitation of them is the lack of sequential analysis. Rhythm can be seen as an ordered sequence of events occurring with some regularity, yet these two measures fail to capture this fundamental characteristic of rhythm.

Following the results in Table 1, this paper will utilize the rhythmic measures of VarcoΔV and nPVI-V. Another reason for this decision is that Loukina et al. (2011) suggest that no single rhythmic measure can succeed in discriminating all languages: a combination of multiple rhythmic measures is more discriminative (see also Harris and Gries 2011). Loukina et al. (2011) ask native speakers of British English, Standard Greek, Standard Russian, Standard French, and Taiwanese Mandarin to read matched texts in their respective native languages. Loukina et al. (2011) reveal that a rhythmic measure that can successfully separate one pair of languages often fail in separating another pair, while a combination of several rhythmic measures is more reliable. According to them, this implies that languages differ in rhythms in a number of dimensions and each rhythmic measure can only catch one aspect of rhythm. Given that VarcoΔV and nPVI-V are both vocalic measures and

Table 1 Summary of results in previous studies

Studies	Vocalic rhythmic measure					Intervocalic rhythmic measures			
	%V	ΔV	VarcoΔV	rPVI-V	nPVI-V	ΔC	VarcoΔC	rPVI-C	nPVI-C
Ramus et al. 1999	✓		✓			✓			
Ling et al. 2000	×				✓				
Grabe and Low 2002	×				✓				
Dellwo 2006			✓				✓		
Henrich et al. 2006	×				✓				
Wagner and Dellwo 2007	×					×			
White and Mattys 2007	✓	×	✓	×	✓	×	×	×	×
Mok and Dellwo 2008	✓	×	×		×	×	✓	×	
Knight 2011	✓	✓	✓		✓	×	×	×	
Olivo 2011	×	×	✓		×	×	×	×	
Romano et al. 2011					✓				
Dorn et al. 2012					✓			✓	
Prieto 2012	×	×	✓	×	✓	×	×	×	×
Kellogg 2020	✓	✓				✓			
Liu and Takeda 2021	×	×	✓	×	✓	×	×	×	×
Payne 2022	×								
Summary	✓ (%)	38.46	28.57	87.50	0	81.82	22.2	28.57	14.29	0
	× (%)	61.54	71.43	12.50	100	18.18	77.78	71.43	85.71	100

normalized, it can be inferred that vocalic measures are more reliable in discriminating rhythm types and need to take speech rate into consideration.

2.2. Strict trichotomy: Fact or fantasy?

Another dimension to the debate is whether the strict trichotomy of rhythms into mora-time, stress-timed, and syllable-timed is valid. Proponents of the strict trichotomy have been using different languages to support this claim. For example, Otake et al. (1993) approach from the perception perspective: they ask native and non-native Japanese speakers to segment spoken Japanese words and report that native Japanese respond in a moraic way, while non-native speakers respond differently from the Japanese speakers. Among these non-native Japanese speakers, native French speakers respond in line with syllabic segmentation. Otake et al. (1993) interpret these findings as that segmentation relies on the different rhythms of their respective native languages, i. e., Japanese and French are respectively mora-timed and syllable-timed (see also, e. g., O'Shaughnessy (1981) for French being syllable-timed, Nakatani et al. (1981) for English being stress-timed).

Lehiste (1990) analyzes the metrical structure of oral poetry in several languages based on the assumption that the poetry of each language reflects its rhythmic characteristics. According to Lehiste (1990), the duration of each line in the nineteen orally produced classical Japanese haikus read by a native Japanese speaker is almost the same, and the standard deviation of each mora is very small. This result supports the proposal that Japanese is a mora-timed language (see a similar conclusion concerning Japanese being mora-timed in Port et al. (1980), Sato (1993), among others).

Other scholars compare multiple languages to investigate whether they each have a different rhythm. Hoequist (1983) asks native speakers of English, Japanese, and Spanish to read words in their respective native languages and finds that stress foot and mora each have a role in the syllable duration in English and Japanese. Spanish does not have as much temporal compensation effects as English and appears to be syllable-timed (see also Strangert 1987, Mok and Dellwo 2008).

On the other hand, some research indicates that the distinction between different rhythmic patterns in languages is not absolute but gradient. Rather than being strictly categorized as mora-timed, stress-timed, or syllable-timed, languages can be considered more or less inclined towards one rhythmic type or intermediate between two rhythmic types (Mitchell 1969, Port et al. 1980, Roach 1982, Miller 1984, Dauer 1987, Sato 1993, Minagawa-Kawai 1999, Grabe and Low 2002). For instance, Mitchell (1969) argues that no language is exclusively syllable-timed or stress-timed; instead, languages exhibit both rhythmic characteristics, with certain languages favoring one over the

other.

Dauer (1987) provides a checklist with eight dimensions for classifying the rhythm of languages. If a language receives more positive points than negative ones, it is more likely to be considered stress-timed, while if it receives more negative points, it is classified as syllable-timed. English is positioned towards one end of Dauer's scale, while French is closer to the other end. Consequently, according to Dauer (1987), there exists a continuum of rhythmic differences among languages, rather than an absolute distinction. Dimitrova (1997) applies Dauer's (1987) methods and reports that Bulgarian falls somewhere between the stress-timed and syllable-timed rhythm types.

2.3. Section summary

The most reliable way to resolve the disputes concerning the strict trichotomy is to examine a language that has not been classified against representative languages by use of rhythmic measures that have been generally recognized as discriminative. Since the rhythmic measures VarcoΔV and nPVI-V have been proven effective in most previous studies, this paper will use them to examine Teop, an endangered language that has not been widely discussed.

3. Data for this study

This paper examines Teop against English and Mandarin since a benchmark for comparison is necessary. English and Mandarin have been respectively considered as representative stress-timed and syllable-timed languages.

3.1. English and Mandarin

A stress-timed language like English usually has more complex onsets and codas than a syllable-timed language. This is because a syllable-timed language more commonly has open syllables. To exemplify, the most common syllable in English is CVC and the largest syllable can be CCCVCCCC (McLeod 2010). In contrast, the most common syllable structure in Mandarin is CV and the most complex syllable structure is CGVC, where G stands for a glide (Duanmu 2000, 2016). In addition, in English, vowels in unstressed syllables are usually reduced and shortened (Bolinger 1986, Nord 1986, Gimson 1989, van Bergem 1993, Kreidler 2004). As a result, when it comes to vowel production, stressed vowels in English are typically pronounced with more strength and longer duration compared to reduced vowels. These stressed vowels are more noticeable and perceptually prominent to listeners (Flemming 2009, Harrington 2010). On the other hand, in a syllable-timed language such as Mandarin, it is uncommon to find reduced vowels in unstressed positions. These languages tend to have a relatively equal level of prominence throughout all syllables (Firth 1948, Dauer 1983, Auer 1993, Dankovičová and Dellwo 2007).

3.2. Teop

The Teop language, spoken in the northeastern region of Bougainville Island in Papua New Guinea, belongs to the Oceanic language family. Specifically, it is categorized as an Oceanic Meso-Melanesian language within the North-West Solomonic linkage (Ross 1988, Lynch et al. 2002, Mosel and Thiesen 2007, Mosel 2010, Eberhard et al. 2023). The syllable structure of Teop is (C)V(M/N/S), where parentheses stand for optional and slashes stand for or (Mosel and Thiesen 2007). The V can be a short vowel, a long vowel, or a diphthong. The vowel phonemes in Teop include /i/, /e/, /æ/, /u/, /o/, and /ɔ/. Thus, the syllable structure of Teop appears simpler than that of English and similar to that of Mandarin, at least in terms of vowels. As Teop is an endangered and understudied language, it is not clear whether it has lexical stress.

Returning to the two rhythmic measures VarcoΔV and nPVI-V, this paper gives the following three predictions: (i) Teop has similar results to Mandarin in terms of VarcoΔV and nPVI-V since Teop seems to have a similar syllable structure to Mandarin, at least in terms of vowels; (ii) following the first prediction, Teop should be classified as a syllable-timed language; and (iii) following the second prediction, the strict trichotomy can find its support in Teop since this language can be clearly classified as a syllable-timed language.

3.3. Corpora

This paper takes the Teop DoReCo dataset as its data source for the Teop language (Mosel 2022, Seifart et al. 2022) since this is one of the few corpora, or even the only corpus, that provides recordings from native speakers of Teop. All the eleven recordings from eleven different Teop speakers in this corpus were narratives. The exclusion of four recordings was due to their low sound quality or short length. Finally, this paper includes seven recordings for acoustic analysis: five produced by females and two by males. The age range was from 18 to 75, with the median age being 40.

To have a parallel comparison with the narrative recordings in Teop, this paper takes story-telling recordings from native English and Chinese Mandarin speakers in the Archive of L1 and L2 Scripted and Spontaneous Transcripts and Recordings (ALLSTAR corpus; Bradlow n.d.). The gender breakdown in each language condition is the same as that of Teop: 5 females and 2 males. The native speakers of English are all from America. The native speakers of Chinese Mandarin are all from the People's Republic of China. All speakers in

ALLSSTAR are around 20 years old.

3.4. Acoustic analysis

For each recording, the first 100 seconds were acoustically analyzed using the acoustic analysis software Praat (Boersma and Weenink 2023). Although the Praat TextGrid files labeled with phonemes for the Teop and English recordings are already available on their respective websites, the author manually re-examined each recording. The Mandarin recordings were not accompanied by any Praat TextGrid files and were acoustically analyzed by the author. Vocalic intervals were defined as the continuous segments of sound between the beginning and end points of a vowel or vowels, which could include single vowels, diphthongs, or, in some cases, overlapping vowels spanning across word boundaries (Peterson and Lehiste 1960, Grabe and Low 2002, White and Mattys 2007). Intervocalic intervals were determined as the duration of sound between the end of one vowel and the beginning of the next vowel, without considering the number of consonants in between (Peterson and Lehiste 1960, Grabe and Low 2002, White and Mattys 2007). Pauses occurring between intonation phrases were not included in the analysis. The length of vocalic and intervocalic intervals was measured in a left-to-right manner using wideband spectrograms generated on Praat. In total, the paper collected 3001 data points from the Mandarin recordings, 3900 from the Teop recordings, and 2475 from the English recordings.

4. Rhythmic measure and statistical analysis results

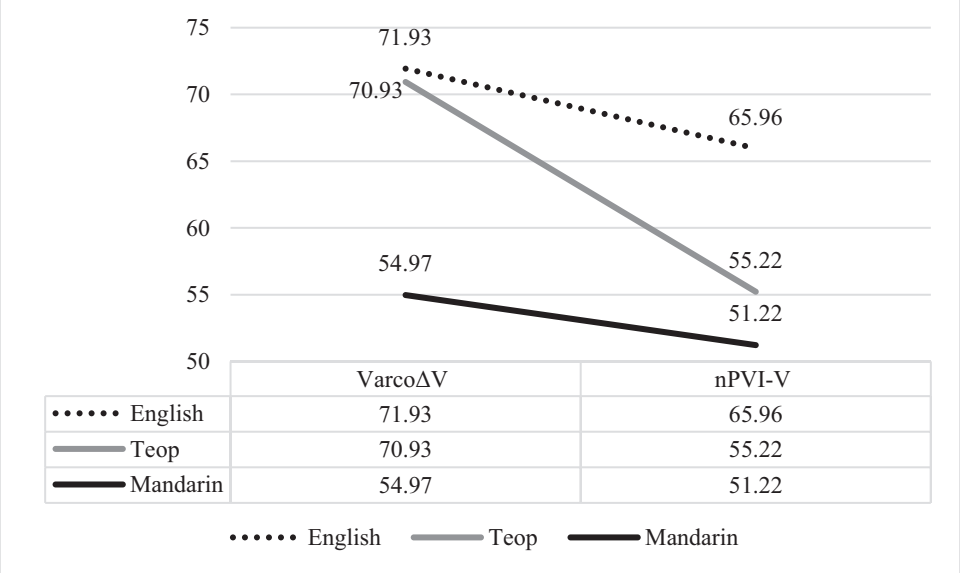
In this section, both rhythmic measures and statistical analysis will be applied to examine the rhythm type of Teop.

4.1. Rhythmic measure results

This section uses the group means of the two rhythmic measures VarcoΔV and nPVI-V multiplied by 100.

As shown in Figure 1, both rhythmic measures have yielded higher results in terms of English than in Mandarin which is in line with the supposition that English is stress-timed and Mandarin syllable-timed. The VarcoΔV value of 71.93 for English is higher than 64 in White and Mattys (2007). Concerning nPVI-V, the result for English in this paper is 65.96, higher than 57.2 for British English in Grabe and Low (2002). However, both the results in White and Mattys (2007) and Grabe and Low (2002) are drawn from sentence-reading tasks, while the results here are drawn from narratives. Thus, more variations and thus higher VarcoΔV and nPVI-V values are expected for the present study (Nakamura et al. 2008, Cichocki 2015). The result of nPVI-V for Mandarin is 51.22, much higher than the 27 in Grabe and Low (2002). The result in Grabe and Low (2002) was drawn from only one speaker, while the result in this study was averaged over seven speakers. In addition, the Mandarin data in Grabe and Low (2002) were collected and recorded in Singapore, representing the specific variant of Mandarin that is spoken in Singapore, while the data in this study were from speakers brought up in the People's Republic of China. The two varieties of Mandarin have differences in terms of phonology, tone, and lexicon, among others (Wang 1999, Zhou 2002).

The grey line representing Teop is located right in the middle of the dotted and black lines which represent Mandarin and English, respectively. There is no occurrence of overlapping



	VarcoΔV	nPVI-V
English	71.93	65.96
Teop	70.93	55.22
Mandarin	54.97	51.22

Figure 1. VarcoΔV and nPVI-V values from English, Teop, and Mandarin

Table 2 One-way ANOVA and post-hoc Tukey HSD tests

ANOVA					
				F	Sig.
nPVI-V	Between Groups	(Combined)		101.065	＜.001
		Linear Term	Weighted	107.155	＜.001
			Deviation	94.974	＜.001
Vocalic Interval	Between Groups	(Combined)		85.047	＜.001
		Linear Term	Weighted	163.088	＜.001
			Deviation	7.007	.008

Multiple Comparisons						
Dependent Variable	(I) Code	(J) Code		Mean Difference (I-J)	Std. Error	Sig.
nPVI-V	Tukey HSD	Teop	English	-.107	-.010	＜.001
		Teop	Mandarin	.040	.010	＜.001
		English	Mandarin	.147	.011	＜.001
Vocalic Interval	Tukey HSD	Teop	English	-.002	.002	.306
		Teop	Mandarin	-.019	.002	＜.001
		English	Mandarin	-.016	.002	＜.001

between any two of the three lines. Figure 1 appears to indicate that Teop stands between Mandarin and English and should be classified as an intermediate rhythm type between syllable-timed and stress-timed. This seems to argue against the strict trichotomy of the world's languages. Before an affirmative conclusion is drawn, this paper will use statistical analysis to examine the related data again.

4.2. Statistical analysis results

This study uses IBM SPSS Statistics for Windows, Version 27.0. (henceforth SPSS) to carry out a one-way ANOVA to examine whether statistically significant differences exist in the data from the three language conditions. The factors for statistical analysis and the statistical analysis results are reported in Table 2.

The one-way ANOVA test in Table 2 shows a statistically significant difference between groups in terms of nPVI-V and vocalic interval as indicated in the p values ($p < .001, .001$). The post-hoc Tukey HSD tests indicate the following two points: (i) the differences in terms of nPVI-V between Teop and English, between Teop and Mandarin, and between English and Mandarin are all statistically significant ($p < .001, .001, .001$); and (ii) the differences in terms of vocalic interval between Teop and Mandarin and between English and Mandarin are statistically significant, while the difference between Teop and English is not ($p < .001$, $p < .001$, $p = .306$). The results of the statistical analysis are generally in line with the results from the rhythmic measures: Teop is statistically different in terms of nPVI-V from both English and Mandarin and different in terms of vocalic interval from Mandarin.

4.3. Discussion: Challenge for the strict trichotomy

The results in this section are not in line with the predictions given in Section 3.2. Firstly, although Teop has a similar syllable structure as Mandarin, the differences in terms of nPVI-V and vocalic interval between them are both statistically significant. A close look at the average VarcoΔV and nPVI-V values in Figure 1 shows that Teop is relatively close to English in terms of VarcoΔV and quite different from both English and Mandarin in terms of nPVI-V. This is in line with the statistical analysis results in Table 2: (i) Teop and English do not have a statistically significant difference in terms of vocalic interval and thus should not have a large difference in terms of the normalized standard deviation of vocalic intervals (VarcoΔV); and (ii) Teop, English, and Mandarin have statistical differences in terms of nPVI-V values. The result here does pose a challenge to the strict trichotomy of the world's languages. As Figure 1 has shown that the results for Teop in terms of VarcoΔV and nPVI-V have placed Teop intermediate between English and Mandarin. This is proof for the existence of an intermediate rhythm.

5. Conclusion

This paper has chosen one understudied language, Teop, and examined it by use of the two recognized rhythmic measures. Both rhythmic and statistical analysis results point to the conclusion that Teop is somewhere between English, a stress-timed language, and Mandarin, a syllable-timed language. This appears to be due to, at least partly, the differences in syllable structure between Teop, English, and Mandarin. The result

here questions the strict trichotomy and supports the existence of intermediate rhythm types. What seems evident, however, is that further investigation is imperative. Future work should choose other understudied languages and further examine whether there are other languages intermediate between stress-timed and syllable-timed, or even whether there are languages somewhere between syllable-timed and mora-timed.

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