

# Acoustic Correlates of Listener-Identified Boundaries and Prominences in Spontaneous Vietnamese Speech

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## Abstract

*This paper reported a study that investigated the acoustic correlates of prosodic prominence and boundary, as they are perceived by naïve listeners, in spontaneous speech of Vietnamese interview conversations. Forty Vietnamese listeners without training in phonetics or prosody participated in the perception experiment. Twenty listeners were asked to mark a vertical line between words at locations where they perceived a boundary between different chunks of the utterance. The remaining twenty listeners were instructed to underline words that they heard as “prominent”. Results from inter-transcriber agreement tests show that naïve listeners are consistent in their labeling of prominent words and prosodic boundaries. The results also showed a tight linkage between the occurrence of boundaries and prominences. In addition, acoustic examination showed that the final and also the prominent words of the chunk consistently had higher intensity, expanded F0 contour and longer duration. Furthermore, correlation results showed that there are strong four-way correlations between syntactic category information, pauses, vowel duration, and perceived prosodic boundaries. Regression analyses show that syntactic category information is the strongest predictor of prosodic boundary perception, followed by pauses and vowel duration while intensity was excluded by the prediction model.*

## Keywords

*Prosodic prominence, prosodic boundary, spontaneous speech, Vietnamese*

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## 1. Introduction

This paper reported a study that investigated the acoustic correlates of prosodic prominence and boundary, as they are perceived by naïve listeners, in spontaneous speech of Vietnamese interview conversations. In speech communication, prosodic prominence and

phrasing serve different functions: while prominences encode focus and possibly also rhythmic structure, prosodic phrase boundaries demarcate speech chunks that typically cohere semantically (Frazier, Clifton, & Carlson 2004; Selkirk 1984). The hierarchical organization of words and phrases and the prominence relation among them is defined and reflected in prosodic structures. The hierarchical prosodic phrase structure is marked by the prosodic boundaries which serve to demarcate chunks of words, while a word or a phrase and their status as focused or discourse-new is usually highlighted by prosodic prominences. Therefore, understanding prosodic structures plays an important role in the listener's comprehension of speech utterances (Mo, Cole and Lee 2008). The acoustic correlates of prosodic structure vary from language to language, which may include patterns of pitch, duration, and loudness modulation, and spectral features related to phone quality. In order to recover the syntactic, semantic and pragmatic content of an utterance, the listener must recognize the prosodic context from the acoustic correlates of prosody in the speech signal.

### **1.1. Previous Studies of Naive Listeners' Perception of Prosody**

The perception of prosodic boundaries and prominences by naive listeners has been investigated in several languages by previous studies (e.g., English: Cole et al. 2010a,b; French: Portes 2000, Smith 2011; Dutch: Streefkerk et al. 1997; Kabyle and Hebrew: Mettouchi et al. 2007, among others). "Because these studies involve listeners without formal linguistic training, they do not define in linguistic terms the group of words that they are asking listeners to identify; thus, the nature of a "group of words" may differ considerably among the different studies, even beyond any differences among the languages that were investigated"(Smith 2011, page 143).

Mettouchi et al. (2007) asked both native speakers and non- speakers of Kabyle and Hebrew to mark boundaries in samples of speech in their own respective native language by listening to speech that had been filtered to render segmental information unintelligible. This was designed in such a way in order that the subjects had to respond on the basis of prosody alone. The results showed that the native speakers' responses were closer to an expert transcription than were the non-speakers' labelling. In a study undertaken in English (Cole et al. 2010 a, b), untrained native speakers of American English were asked to mark prominent words, or boundaries between groups of words, while listening to a sample of spontaneous, conversational speech. Half the listeners marked prominence first for one set of materials, then boundaries on a different set, while the other half performed the tasks in the reverse order. The listeners underlined a word they perceived as prominent or marked a slash between two words where they perceived a boundary between two chunks of speech. Cole et al. obtained high rates of agreement among their listeners, particularly for the

marking of boundaries. In a recent study, Smith (2011) uses a methodology similar to that of Cole et al., but by comparing two types of speech materials, one was a map task and the other was a broadcast discussion/ debate. The aims were to uncover additional factors contributing to listeners' perceptions of the structure of spoken French. Her results showed that listeners demonstrated a strong tendency to mark as prominent those words immediately preceding locations perceived as boundaries. Analyses of acoustic and syntactic properties of these locations are consistent with the idea that listeners used similar strategies in labeling both prominent words and boundaries.

### **1.2. Prosodic Prominence and Phrasing in Vietnamese**

Vietnamese is a contour tone language that has no system of culminative word stress; nevertheless, it is widely accepted that there is stress in the sense of accentual prominence at the phrasal level (Thompson 1965; Nguyễn Đăng Liêm 1970, among others). Duration, intensity, and full tonal realisation of accented syllables have been observed to be important parameters for describing stress in Vietnamese (Đỗ 1986; Chaudhary 1983; Hoàng & Hoàng 1975; Gsell 1980).

At the word level, some linguists assume a correlation between phrase/compound headedness and phonetic prominence (Ngô 1984), but these studies are generally based on auditory impressions without empirical evidence. In other words, these studies of stress in Vietnamese have been largely based on a notion of "morphosyntactic" weight of syllables (Cao 2003; Ngô 1984; among others). In recent studies on more carefully phonetically controlled and specialized sets of Vietnamese disyllabic compounds and reduplications, Nguyen and Ingram (2007a, b) have found that there was at least a tendency for the right hand element of a disyllabic compound word to be more prosodically prominent by a number of relevant phonetic measures: greater tonal  $f_0$  range, higher intensity, greater duration of the second syllable, and formant measurements indicative of more centralized vowel nuclei (vowel reduction) on the first syllable. Nevertheless, the results of a recent perception experiment (Nguyen and Ingram 2013), in which listeners listened to disyllabic words and judged which syllable of the two (the first or the second) is more prominent or both syllables are of equal prominence, show that subjects performed at chance level for most of the disyllabic word types and only the tone sandhi forms (with constant segmental makeup but with an alternation of tones) were judged to have more prominent on the second syllable. This perception result does not support the acoustic asymmetry of disyllabic words found in acoustic studies (Nguyen and Ingram 2007a b). In other words, the acoustic right-headed tendency was not perceptually salient enough to be reliably reported by native listeners. This contradicts findings showing that listeners in

other languages, such as English, can hear stress contrasts regardless of syllable segmental composition (Fry 1958) and implies that prosodic asymmetry at the level of the disyllabic word is merely a phonetic tendency in Vietnamese; a ‘sub-phonological’ threshold phonetic effect originating in rhythmic or metrical tendencies at the level of post-lexical phonology or perhaps the level of ‘motor programming’ or speech gesture co-ordination and control.

At the level of phrasal prominence, Thompson (1965) is marking 3 degrees of stress, but in practice, this seems to be no more than an impressionistic attempt and Thompson is not explaining what the acoustic correlates of these “stresses” would be. Regarding the stress patterning in utterances, it is generally agreed by some researchers that there is an alternating pattern of strong and weak syllables. Thompson (1965) stated that the majority of the syllables have medium stress. In a sequence of syllables, alternating ones are slightly louder (but not in a distinctive manner): “each pause group has at least one heavy stress and weak stresses are fairly frequent in rapid passages, rarer in carefully speech” (p. 50). Jones and Huỳnh (1960) stated that “normally the stresses in a Vietnamese utterance are conditioned by the junctures,” and regarded the fundamental stress pattern of Vietnamese as consisting of the alternating occurrence of a strong and weak stress, with the last word of the phrase receiving a strong stress. Consistent with Jones and Huỳnh’s observation, it is remarked by Cao (2003) that due to the demarcative function of stress/accent in Vietnamese, native listeners tended to hear a juncture after a stressed syllable even though there is no such pause in reality as examined by spectrograms. Cao (1978, 2003) also provides evidence for stress being a syntactic boundary in Vietnamese phrases, in classifying compounds, and a quality of content words as opposed to functional words, with longer duration, stronger amplitude and more completed tonal contour. Nevertheless, these earlier studies are generally based on auditory impressions without empirical evidence by instrumental study. In a recent study, Nguyen (2010) investigated the rhythmic patterns in Vietnamese polysyllabic words by examining the rhythmic patterns and their acoustic correlates in polysyllabic reduplicative words (2-,3-,4-,5-,6- syllable pseudo-words). The results showed that there is a tendency of syllable coupling indicated mainly by syllable duration pattern and supported by the native listeners’ perception results, suggesting that polysyllabic words in Vietnamese tend to be parsed into bi-syllabic iambic feet with a rightward or retrograde rhythmic pattern. This result is further supported by data on the rhythmic structure of Vietnamese folk poetry (Nguyen 2013) and narrative prose speech (Nguyen 2014), which shows an iambic pattern of acoustic prominence of bisyllabic and trisyllabic words/phrases.

In a recent paper, Schiering, Bickel and Hildebrandt (2010) remarked that “Vietnamese provides ample evidence for a genuine stress domain that is preferably disyllabic and

maximally trisyllable. Within this domain, stress is realised on the final syllable in the default case. Crucially, this domain is computed irrespective of the morphosyntactic status of its constituent syllables, i.e. stress phonology does not distinguish between a word-level and a phrasal-level of prosodic structure. Metrically, polysyllabic words are thus indistinguishable from other combinations of syllables. Since the most complex structures which are referenced by the rules for iambic rhythm are phrasal, stress may most adequately be attributed to the prosodic domain of the Phonological Phrase.”(p. 673).

### **1.3. The Relation between Syntax and Prosodic Domains**

The relation between syntax and prosodic domains has been studied by many researchers (Selkirk 1984; Nespor and Vogel 1986; Truckenbrodt 1999; among others). According to the Prosodic Hierarchy Theory (Selkirk 1980; Nespor and Vogel 1982, 1986), there exists a suprasegmental, hierarchically arranged organization of the utterance, called prosodic structure. This structure is composed of a finite set of universal prosodic constituents, which are the domains of application of phonological rules and phonetic processes. From the bottom up, these constituents are the syllable, the foot, the prosodic word, the clitic group, the phonological phrase, the intonational phrase, and the utterance. These constituents are mapped from morphosyntactic structure by algorithms which make reference to syntactic information, but prosodic structure and the constituents that compose it are not isomorphic with syntactic structure. In other words, “prosodic phrases group words together in units that reflect syntactic structure, but syntactic structure does not fully predict prosodic phrasing”(Cole et al. 2010a, page 1146). In addition to syntax, other factors that influence on the prosodic structure include semantic factor (Selkirk, 1984) and phonological structure such as the length of the syntactic phrase, the distance from the previous prosodic boundary, and the location of the nuclear pitch accent (Nespor & Vogel 1986; Watson & Gibson 2004). Studies also find corresponding evidence that perceived prosody influences the interpretation of syntactic structures (Price et al. 1991; Schafer et al. 2000; Weber, Grice, & Crocker 2006). Cole et al. (2010a) found that listeners are guided in their perception of prosody by acoustic cues and syntactic context, and that the effect of syntactic context appears to be partly independent of the effect due to final vowel duration, the primary acoustic cue to prosodic phrase boundaries.

The structure of phrases in Vietnamese as well as the existence and realization of higher prosodic constituents (phonological phrase, intonational phrase) has never been systematically investigated in Vietnamese (only a basic description of Vietnamese is found in Thompson 1965). According to Schiering, Bickel and Hildebrandt (2010) “two distinct levels of prosodic structure can be established for Vietnamese, namely the syllable as the

locus for generalizations related to phonotactics, stress and tone, and the phonological phrase, which provides the basis for the iambic (or anapestic) rhythm of the language. Neither the prosodic foot nor the prosodic word can be motivated for the language.” (p. 680). This study seeks to identify some of the measurable prosodic properties that might be signaling prosodic prominences and phrasal boundaries to listeners as well as the role of syntactic factors in guiding listeners’ boundary perception.

## **2. Method**

### **2.1. Speech Materials for the Listening Experiment**

A total of 30 sound files were created from excerpts of interviews of six speakers (3 females and 3 males) of Saigon dialect. They were students at University of Queensland and came from Ho Chi Minh city. They had been in Australia from 1-3 years. These excerpts consisted of a single-speaker passages of spontaneous conversational interview speech. The selected samples include five excerpts from each of the six speakers. The duration of these excerpts is from 15 to 30 seconds. Excerpts were selected according to the following two criteria. (1) speech excerpts were selected from segments of the interviews in which there are no technical recording problems, and (2) speech excerpts were selected to minimize the occurrence of disfluencies, though it was not possible to avoid all the disfluent regions for the selection of speech excerpts.

Orthographic transcriptions of the excerpts were prepared by the experimenter (a native speaker of Southern Vietnamese). In these transcriptions which were prepared for use in the listening test, punctuation and line breaks were removed except as necessary to fit on the page, aiming to avoid providing any hints as to the structure. Disfluencies such as repeated or partial words were included in the transcripts but filled pauses (“à, u...”) were not indicated.

### **2.2. Participants and Testing Procedures**

Forty listeners without training in phonetics or prosody were recruited at a university in the South of Vietnam. Most were tertiary students and in the age range from 18 to 30 years of age. The experiment was administered in a sound-attenuated room. Each listener was presented with a packet containing instructions and the printed transcripts of the practice and test extracts. They responded by marking on these printed answer sheets.

Listeners were randomly assigned to one of two groups. 20 listeners were asked to mark a vertical line between words at locations where they perceived a boundary between different chunks of the utterance. The remaining 20 listeners were instructed to underline words that they heard as “prominent”. Instructions for participants are presented in the

appendix 1. All listeners heard the extracts twice with brief pauses between them. The extracts in each group were presented in a random order. The transcription was performed in real time, and was solely based on auditory impression; listeners were not aided by any visual, graphic display of the speech signal. Listeners also were neither able to start or stop the auditory presentation, nor could they repeat any excerpt after the second presentation.

### **2.3. Analyses**

A modified form of Cohen's Kappa was used to assess agreement among listeners. This method takes into account the amount of agreement that can be expected by chance. Kappa values can vary between 0 and 1. The particular form of Kappa used here is based on Brennan and Prediger (1981). It is suitable for tasks with multiple raters in which the raters are not constrained as to how many items they assigned to each category ("free marginal"). Calculations were made using the Online Kappa Calculator (Randolph, 2008). Kappa values were determined for each extract, pooling across all the listeners.

Then, boundary scores (B-scores) and prominence scores (P-scores) were calculated for each word, equal to the proportion of listeners who marked that word as followed by a boundary or as prominence. Those words marked by two-thirds or more of listeners (14 or more of the 20: equal to or above 70%) were considered to have "consensus" agreement. This criterion was arbitrary but indicates a substantial consensus and had been used by Smith (2011).

In addition to the coding of B-scores, the syntactic structures of the chunks immediately preceding the boundaries were annotated, based on a manual syntactic parse based on Penn Treebank annotation guidelines (Marcus, Marcinkiewicz, & Santorini 1993). The syntactic categories specified in the parse and their frequencies are listed in Table 3.

The analyses of listeners' perception was followed by the acoustic analyses which involved the vowel duration(ms), vowel intensity (dB), and fundamental frequency (F0) of words and syllables immediately preceding all locations of interest. These acoustic parameters were taken manually via Praat (Boersma & Weenink 2009). Peak intensity (dB) was taken at vowel midpoint of all syllables in the chunks. F0 min and max of the tonal contours were taken through Praat's minimum and maximum F0 commands and F0 range (F0max-f0min) was computed. All silent pauses with duration greater than 150 ms were also identified. This minimum pause duration has been used in a number of studies such as Stirling et al. (2001) and Smith (2011) as it exceeds the likely duration of silence due to an epenthetic glottal stop, for example). Intervals labeled as pauses included periods of silence, filled pauses, breathing, or a combination of these.

In addition, the counting of incidences of acoustic cues of the final words preceding the

boundary was conducted manually by the experimenter relying on the spectrogram in Praat. The target acoustic cues included pauses, high intensity (the final words/syllables had highest intensity i.e., higher than the other words/syllables in the chunk), F0 expansion, F0 declination and no cue. The results are reported in table 4.

Furthermore, a restricted maximum likelihood (REML) applied to mixed model methodology was performed on each of the acoustic parameters. Mixed model two-way ANOVAs were conducted on vowel intensity, vowel duration and F0 range. The fixed factors were positions [boundary final vs. non final] and vowels. The random factor was speakers. The use of REML overcomes the potentially serious deficiency of the ANOVA-based methods which assumed that data are sampled from a random population and normally distributed. REML also avoids bias arising from maximum likelihood estimators in which all fixed effects are known without errors, consequently tend to downwardly bias estimates of variance components. Moreover, REML can handle unbalanced data. The data analysis was carried out using SAS program

Then correlations and regressions were calculated between boundary scores and the acoustic parameters.

## 2.4. Results

### 2.4.1. Agreement among Listeners

The kappa statistic was used to assess agreement among listeners. Kappa values for boundary marking for each excerpt ranged from 0.79 to 0.97 with a mean of 0.89. Kappa values for prominence marking for each excerpt ranged from 0.77 to 0.84 with a mean of 0.88. Randolph (2008) suggests that for this form of kappa, 0.7 or above is “adequate”, so the values obtained in this study are well above this proposed cut-off.

	Mean	Min	Max
Number of words in excerpts	47	18	79
Number of consensus boundary locations	5.4	3	10
Number of words between consensus boundaries	9.1	3.4	24
Number of consensus prominence markings	7	3	11
Number of words between prominence markings	7	3	14

Table 1. Number of words and number of consensus boundary and prominence markings  
The investigation of the intervals between locations marked as boundaries should “shed light on the type of units that listeners were perceiving” (Smith, 2011: 146). The means of

interval between boundary markings was 9.1 words across all 30 excerpts and 20 listeners, ranging from 3.4 to 24 words. The means of interval between prominence markings was 7 words, ranging from 3 to 14 words, indicating that listeners marked boundaries less often than prominences. It is noted that the definition of word in Vietnamese is controversial, as it can involve more than one syllable. The corpus generally consisted of monosyllabic words (e.g., em, viết, đọc, rất, yếu), disyllabic reduplications (trục trặc, khó khăn), disyllabic compounds (e.g., học trò, cách thức, hữu ích), and disyllabic proper names (e.g., Nha Trang, Hà Nội). Therefore, in counting the words, disyllabic reduplications, compounds and proper names were considered as one word.

In order to further investigate the relation between the listeners' marking of boundaries and of prominence words, a Pearson correlation was calculated between the prominence scores and boundary scores of the words in the excerpts. The result showed that there was a strong correlation between boundaries scores and prominence scores ( $r= 0.71, p<0.001$ ). In addition, as shown in table 2 below, 74% of words that were marked as prominence were also marked as preceding a boundary, indicating that listeners tend to perceive prominence on words where they perceive a boundary following.

	Total number
Number of consensual boundaries	168
Number of consensual prominent syllables	201
Number of syllables that are prominent and precede a boundary	150 (74%)

Table 2. Total number of consensus markings of boundaries and prominences

If listeners are perceiving prominences and boundaries at the same locations, then these should be cued by similar either syntactic and/or acoustic features. The following sections reported the analysis of the acoustic cues to boundary and prominence perception.

## **2.4.2. Acoustic Cues to Boundary and Prominence Perception**

### **2.4.2.1. Pauses.**

The first acoustic cue investigated was whether boundaries were marked at the location of silent pauses. As shown in table 3 below, 76% (128 out of 168) of the consensus boundary markings was with pauses, indicating that locations where pauses occur are favored as locations for boundaries. Nevertheless, there were several locations in the excerpts where there were pauses but were not marked as boundaries, indicating that for listeners, pauses are strong but not sufficient cues for a boundary. A close examination of the 24% of cases (40 cases) with boundary perception but without pauses shows that the boundaries were

perceived either at the end of a phrase or a clause.

<b>Acoustic cues to consensus boundary</b>	<b>Total number</b>	<b>Percentage</b>
Total Consensus boundary	168	100%
Consensus boundary with no acoustic cue	2	1.2 %
Consensus boundary with pauses	128	76%
Consensus boundary with high intensity on the final syllable	131	77%
Consensus boundary with F0 expansion on the final syllable	138	82%
Consensus boundary with F0 declination on the final syllable	16	10%
Consensus boundary with a combination of all 3 cues: pause, F0 expansion and high intensity	121	72%

Table 3. Total number of consensus boundary markings with acoustic cues

#### 2.4.2.2. Intensity.

As shown in table 3, 77 % (131/168) of words preceding a boundary had higher intensity compared with their preceding words/syllables in the chunks. This is supported by the result of a mixed model two-way ANOVA on vowel intensity. The fixed factors were positions [boundary final vs. non final] and vowels. The random factor was speakers. The results showed a significant effect for positions  $F(1, 1036) = 11.4, p < 0.001$ , vowels  $F(10, 1036) = 1.74, p < 0.01$ , and the interaction between positions and vowels  $F(10, 1036) = 2.75, p < 0.0001$ . Post hoc examination of the interaction effect by the Tukey method (figure 1) show that the vowels at boundary final position significantly had higher intensity than those at non-final position. This result applied to all vowels except vowels / $\epsilon$ / and / $\check{a}$ /.

The results are similar for prominence: the result of a mixed model two-way ANOVA on vowel intensity indicates that the words that were marked as prominence had significantly higher intensity than words within the chunks (positions:  $F(1, 1036) = 26.43, p < 0.001$ , vowels:  $F(10, 1036) = 1.52, p = 0.1$  ns., positions x vowels : $F(1, 1036) = 2.67, p < 0.01$ ). Post hoc examination of the interaction effect by the Tukey method shows that this result applied to all vowels except vowels / $\check{a}$ /.

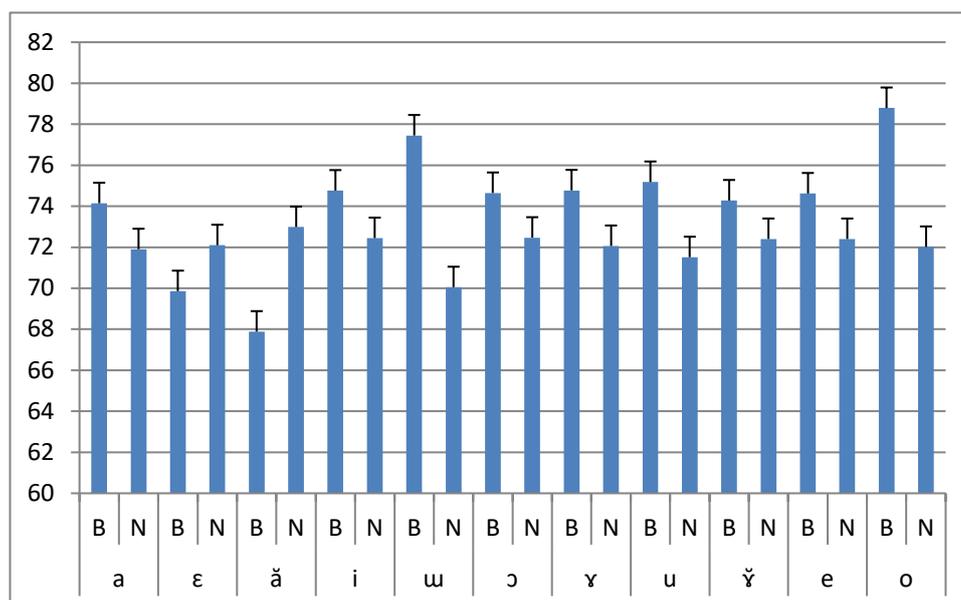


Figure 1. The mean intensity (dB) of vowels in boundary final vs. non final positions. B: boundary final, N: non final.

Of 23% (37 cases) in which intensity was not the criteria that listeners used for prominence, 19 cases may have been judged relying on a combination of F0 expansion, pause and lengthening, 11 cases based on the combination of F0 expansion and lengthening and 7 cases may have been perceived relying on lengthening and pause.

#### 2.4.2.3. Duration.

A mixed model two-way ANOVA was conducted on vowel duration. The fixed factors were positions [boundary final vs. non final] and vowels. The random factor was speakers. The results showed a significant effect for positions ( $F(1, 1028) = 89.45, p < 0.0001$ ), vowels ( $F(10, 1028) = 5.39, p < 0.0001$ ), and the interaction between positions and vowels ( $F(10, 1028) = 5.21, p < 0.0001$ ). Post hoc examination of the interaction effect by the Tukey method (figure 2) show that the vowels at boundary final position significantly had longer duration than those at non-final position. This result applied to all vowels except vowel /i/.

The results are similar for prominence: the result of a mixed model two-way ANOVA on vowel duration indicates that the words that were marked as prominence had significantly longer duration than words within the chunks (positions:  $F(1, 1028) = 62.92, p < 0.0001$ , vowels:  $F(10, 1028) = 6.21, p < 0.0001$ , positions x vowels :  $F(1, 1028) = 5.99,$

$p < 0.0001$ ). Post hoc examination of the interaction effect by the Tukey method shows that this result applied to all vowels except vowels /i/.

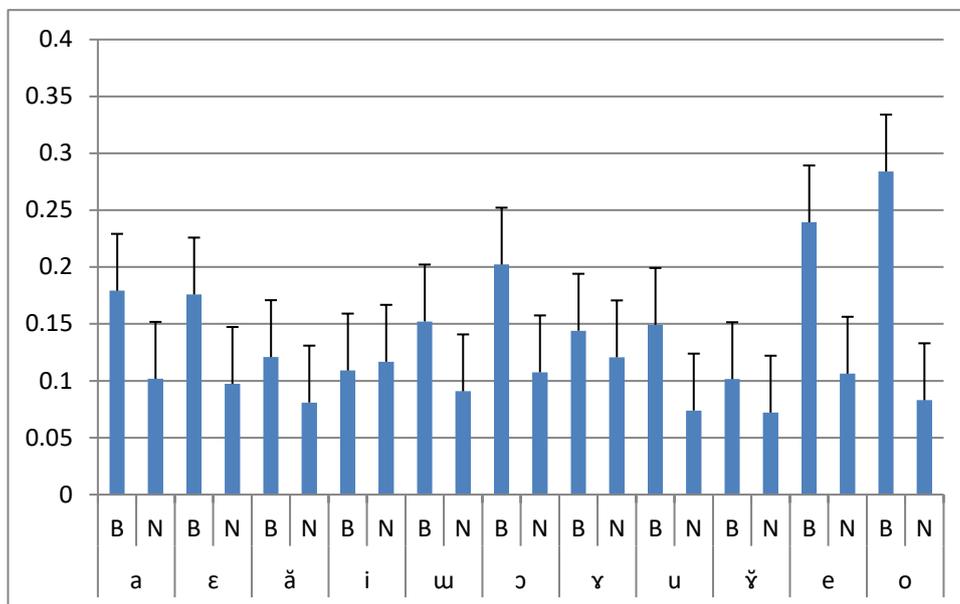


Figure 2. Mean duration (seconds) of vowels in boundary final vs. non final positions. B: boundary final, N: non final.

#### 2.4.2.4. Fundamental frequency.

In order to examine F0 range and F0 contour of non-final words and final words of a chunk /preceding a boundary, there need to be a comparison between words with the same segmental makeup and tones. Therefore, 18 pairs of words with constant segmental composition and tones were identified from the excerpts. The word pairs differ only in position: one was a non-final word while the other was the final word of the chunk which preceded a boundary marking and received a prominence marking. F0 range of these words were measured manually via Praat.

A two-way ANOVA (positions x speakers) was conducted on the F0 range value of the pair of words. The result showed a significant effect for positions:  $F(1, 36) = 12, p < 0.01$  and speakers ( $F(5, 36) = 5, p < 0.05$ , but no significant effect for the interaction of positions x speakers ( $F(5, 36) = 0.75, p = 0.59$  ns.). In addition, as shown in figure 3 below, F0 contour of the final and prominent words were more expanded than that of the non-final non-prominent words. By contrast, syllables in non-prominence positions have shorter tones. Also, as indicated in table 3, there was an F0 range expansion on 82% (138/168) of

final words while only 10% (16/168) of final words had F0 declination which is shown to be accompanied by intensity and energy declination.

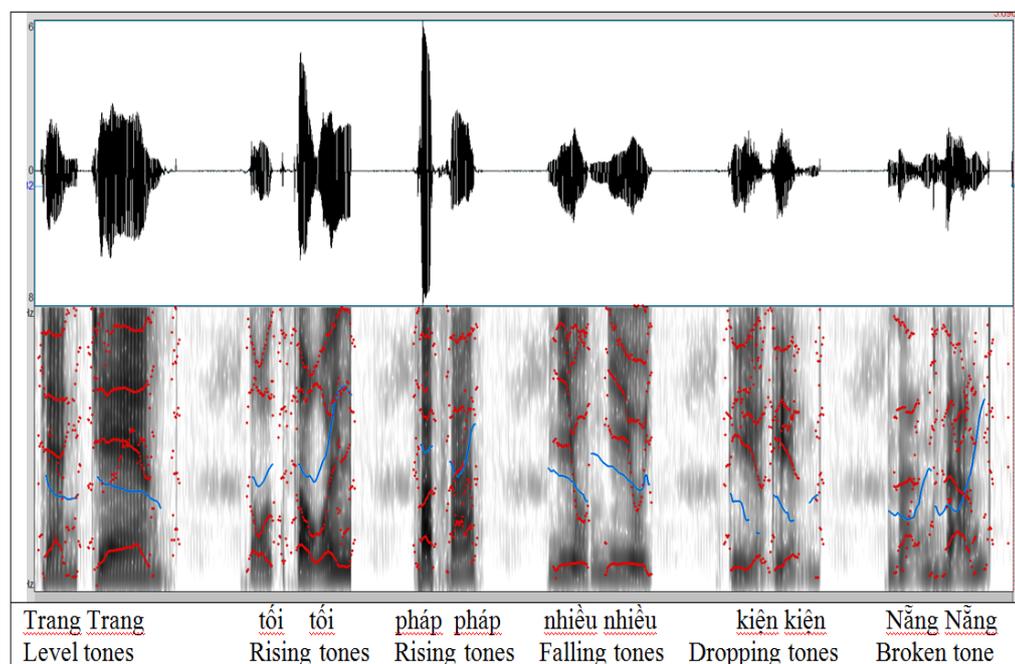


Figure 3. F0 contours of pairs of non-final vs. final and prominent words/syllables. F0 contours are the blue lines in the speech signal. The first syllables of the pairs are non-final and unaccented words/syllables and the second ones of the pairs are final and prominent syllables/words.

Summarising the results on acoustic cues, generally it is found that the final and prominent words/ syllables have longer duration, higher intensity and more expanded F0 range and F0 contours than the non-final non-prominent ones in the chunks. Since the prominent words/syllables are followed by a boundary, it can be argued that the effects found here are simply caused by a phrase-final lengthening rather than any kind of iambic stress. Nevertheless, as shown in table 3, 72% of the prominent words/syllables not only followed by pauses but also have high intensity and expanded F0 range and contours. It is found by Kim (1974) and Rao (2010) that phrase final position results in increases of duration, but decreases in intensity and F0. It is also found from the data of this corpus that final lengthening is accompanied by a declination of intensity and spectral energy. Therefore, it is affirmed that the acoustic prominent patterns which is confirmed by naive listeners' perception in this study is a genuine iambic stress effect.

### 2.4.3. Syntactic Categories of Boundary Perception

As shown in table 4, listeners tended to perceived boundaries at the end of clausal and phrasal constructions. There is a higher rate of boundary marking at the edges of clauses than at the edges of lower-level syntactic constituents such as phrases (main clause or sentence: 52%, S-BAR: 13% and CC-S: 9.5%, while the markings at the end of phrasal units were only 26% all together (ADVP: 3.6%, NP:13%,VP: 4.8%, PP: 4.8%). This suggests that syntactic phrasing influences the production and perception of prosody. Prosodic phrases are shown to be most likely to occur at the edges of syntactic constituents, with greater probability for higher-level constituents such as clauses than for lower-level constituents such as NPs, ADVPs, PPs or VPs. These syntactic units with an accent/prominence on the last word/syllable, which possesses phonetic cues such as pause, high intensity, longer duration, and expanded F0 (see section 2.4.2. above), can be said to be equivalent with phonological phrases since they constitute the prosodic domain for phrasal stress and “provides the basis for the iambic (or anapestic) rhythm of the language” (Schiering, Bickel and Hildebrandt 2010, page 680). The relationship between syntactic phrasing and prosodic boundary perception is further investigated by correlation and regression methods in section 2.4.4 below.

Labels	Syntactic categories	Examples	Frequency	Percentage %
ADVP	Adverbial phrase	Lúc mới sang,.....(When just arriving), thật ra (frankly)	6	3.6
NP	Noun phrase	Đặc sản của Quảng Nam ( the specialties of Quảng Nam)	22	13
VP	Verb phrase	Đi câu cá (go fishing), đi nghe ca nhạc (go to the concert)	8	4.8
PP	Prepositional phrase	Về khí hậu (about climate), ở Đà Nẵng (in Đà Nẵng)	8	4.8
S	main clause or sentence	Tôi đi đến được các vùng biển vùng núi (I went to the seashore and mountain areas)	87	52
CC-S	coordinate clause	Nhưng sau đó thì mọi thứ cũng được khắc phục (but later everything was overcome.)	16	9.5

S-BAR	Subordinate or relative clause	Tại vì em dạy chỉ có được có một hai học kỳ thôi (because I have taught for only one or two semesters) Đây là một nơi đẹp nhất của Úc mà tôi đã từng đến (This is the most beautiful place that I have ever come.)	21	13
<b>Total</b>			<b>168</b>	<b>100</b>

Table 4. Frequency and percentage of syntactic categories preceding boundary perception

#### 2.4.4. Correlation and regression

Non-parametric correlation analysis (Pearson) and linear regression analyses are used to test the strength of the relationship between B-scores, right-edge syntactic category labels (separate correlations were tested for clauses (S, S-BAR, CC-S), phrases (NP, VP, PP, ADVP) and within phrase [W/P]), final vowel duration, silent pauses and intensity. Since there are no inherent numerical values for syntactic categories of different types, this categorical variable is recoded into a series of binary dummy variables that code, for example, if a word-edge label is VP (yes=1, no=0) or if a word-edge label is S or SBAR. Similar variables were applied to silent pauses (yes=1, no=0).

The results show that, as shown in table 5, there are significant correlations between each pairing of the B-scores and the six variables under discussion. Looking at the correlations between B-scores and syntactic features, it is shown that clause endings (S, SBAR and CC-S) have a stronger correlation ( $r = 0.763$ ) with B-scores than non-clause endings (Phrases:  $r = 0.46$ ), indicating that listeners are most consistent in hearing prosodic boundaries at the ends of clauses, and are pretty consistent in not hearing a boundary in phrase-medial locations (W/P:  $r = -0.90$ ).

The strongest correlation among these variables is between B-scores and the syntactic categories of clauses (S, SBAR and CC-S), and this correlation is even stronger than the correlation between B-scores and pauses ( $r = 0.477$ ), or between B-scores and vowel duration ( $r = 0.32$ ). The weakest correlation was between B-scores and intensity ( $r = 0.07$ ). This finding suggests that syntactic context plays a direct role on prosodic boundary perception, supporting prior works showing a syntax-prosody dependency (Selkirk 1984; Nespor and Vogel 1986; Truckenbrodt 1999; among others)

	Variable	Pearson r	Significant level
Boundary scores	Clause (S, S-BAR, CC-S)	0.763	p<0.0001
	Phrase( NP, VP,PP, ADVP)	0.46	p<0.0001
	W/P (within phrases)	-0.90	p<0.0001
	pause	0.477	p<0.0001
	Vowel duration	0.32	p<0.0001
	intensity	0.077	p<0.01

Table 5. Correlation results

Adding all factors individually to a stepwise regression model indicates which variables contribute the most, and in which order, in predicting B-score variance. Table 6 presents the results from the stepwise linear regression with five predictor variables: clauses (S, S-BAR, CC-S), phrases (NP, VP, PP, ADVP)), final vowel duration, silent pauses and intensity. The results show that the syntactic variable of clause categories (S, SBAR, and CC-S) emerge as the strongest predictors of B-scores in the first step, clauses and phrases in the second step, clauses, phrases and pauses in the third step, and clauses, phrases, pauses and vowel duration in the fourth step while intensity was excluded by the model.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Significant F change
1	.775 <sup>a</sup>	.600	.600	3.446	p<0.0001
2	.907 <sup>b</sup>	.823	.823	2.293	p<0.0001
3	.914 <sup>c</sup>	.835	.835	2.212	p<0.0001
4	.916 <sup>d</sup>	.839	.838	2.191	p<0.0001

a. Predictors: (Constant), clauses  
b. Predictors: (Constant), clauses, phrases  
c. Predictors: (Constant), clauses, phrases, pauses  
d. Predictors: (Constant), clauses, phrases, pauses, vowel duration

Table 6. Regression results

Summarising the findings from correlation and regression analysis, it is found, first of all, that there are strong four-way correlations between syntactic category information, pauses, vowel duration, and perceived prosodic boundaries. Regression analyses show that syntactic category information is the strongest predictor of prosodic boundary perception, followed by pauses and vowel duration while intensity was excluded.

### **3. Discussion and conclusion**

This study looks at variability in the prosodic features naive listeners perceive in conversational speech. First, results from inter-transcriber agreement tests show that naive listeners are consistent in their labeling of prominent words and prosodic boundaries, indicating regular patterns in listeners' perception and that ordinary listeners can perceive prosodic prominences and boundaries with consistency that is well above chance. This is consistent with results of naive listeners' perception of prosodic prominence and boundaries in other languages in previous studies (Streefkerk et al. 1997; Mettouchi et al. 2007; Cole et al. 2010 and Smith 2011).

Second, the results of the study showed a tight linkage between the occurrence of boundaries and prominences, supporting Jones and Huynh (1960) and Cao (2003)'s impressionistic observations about the demarcative function of stress/accent in Vietnamese. Furthermore, analyses of acoustic properties of these locations are consistent with the idea that listeners used similar strategies in labeling both prominent words and boundaries.

Third, among the acoustic cues, locations where pauses occur are favored as locations for boundaries, supporting Jones and Huynh (1960)'s remarks that "normally the stresses in a Vietnamese utterance are conditioned by the junctures." In addition, the final and also the prominent words/syllables of the chunk consistently had higher intensity, expanded F0 contour and longer duration. This indicates that "each pause group has at least one heavy stress" and that "the last word of the phrase receiving a strong stress", consistent with observations by previous researchers (Schiering, Bickel and Hildebrandt 2010; Jones and Huynh 1960; and Thompson 1965). The acoustic cues of accent including higher intensity, longer duration and fuller tonal shape are also consistent with findings from previous studies (Đỗ 1986; Chaudhary 1983; Hoàng & Hoàng 1975; Gsell 1980).

Fourth, the last word of the chunk/phrase receiving a strong stress seems to suggest that Vietnamese has right-headed or iambic rhythm, consistent with acoustic results found by Nguyen and Ingram (2007a, b), and Nguyen (2010, 2013, and 2014) and supporting Schiering, Bickel and Hildebrandt (2010)'s remark that "the phonological phrase provides the basis for the iambic (or anapestic) rhythm of the language" (p. 680).

Finally, the correlation results show that the strongest correlation among the variables is between B-scores and the syntactic categories of clauses (S, SBAR and CC-S). The regression result also indicate that the syntactic variable of clause categories emerge as the strongest predictors of B-scores. This finding suggests that syntactic context plays a direct role on prosodic boundary perception in Vietnamese, supporting prior works showing a syntax-prosody dependency in other languages (Selkirk 1984; Nespor and Vogel 1986; Truckenbrodt 1999; among others). In addition, pauses and vowel duration are acoustic cues that have significant contribution to boundary perception, indicating that Vietnamese listeners are not only guided by syntactic structures but also responsive to acoustic cues to prosody in judging the location of prosodic phrase boundaries, consistent with findings by Cole et al, 2010a).

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## Appendix 1

### Instructions for participants in the boundary transcription experiment

Lời nói thường bao gồm một hay nhiều ngữ đoạn. Ngữ đoạn là các đơn vị trong chuỗi lời nói, không nhất thiết được kết thúc bằng dấu chấm, dấu phẩy hay các dấu câu khác. Ngữ đoạn có thể bao gồm một từ hay nhiều từ. Quý vị sẽ lắng nghe các trích đoạn hội thoại và xác định các ngữ đoạn mà người nói diễn đạt bằng cách đánh dấu | ngay sau ngữ đoạn mà quý vị nghe được. Mỗi trích đoạn sẽ được đọc lại hai lần.

*Utterances often consist of one or many speech chunks. Speech chunks are units of continuous speech, not necessarily ended with a period, coma or other punctuation marks. You will listen to the excerpts from conversations and mark the chunks that speakers expressed by inserting a | right after the chunks you hear. Each excerpt will be repeated twice.*

### Instructions for participants in the prominence transcription experiment

Trong lời nói thông thường, người nói phát âm một từ hay nhiều từ nổi bật hơn các từ còn lại trong câu. Những từ này được gọi là có trọng âm và thường được nghe to hơn, rõ hơn, mạnh hơn và nổi bật hơn các từ khác trong câu. Quý vị sẽ lắng nghe các trích đoạn hội thoại và xác định âm tiết mang trọng âm mà người nói diễn đạt (nghe to hơn, rõ hơn, và

mạnh hơn) bằng cách gạch dưới âm tiết mà quý vị nghe được. Mỗi trích đoạn sẽ được đọc lại hai lần.

*In normal speech, speakers pronounce some word or words in a sentence with more prominence than others. These words are called “stressed” and often heard to be louder, clearer, stronger and more prominent than the other words in a sentence. You will listen to the excerpts from conversations and mark the stressed syllables that speakers expressed (they are heard louder, clearer and stronger) by underlining the syllable that you hear. Each excerpt will be repeated twice.*

### **Appendix 2: The transcription of the excerpts**

1. Lúc mới sang em cũng gặp những cái về khi thời gian ở nhà homestay thì em cũng có có trực trực với nhà đầu sau hai tuần thì họ chuyển đổi em sang nhà khác thì nhà khác thì rất là vui và thoải mái hơn
2. Việt Nam em cũng đi Đà Lạt Nha Trang Huế Đà Nẵng rồi thôi chứ em chưa ra Bắc ạ có em dạy tại chức ở Tiền Giang Huế Bình Dương nữa.
3. Thường em thì em thấy cũng học học trò cũng có nhiều khó khăn tại vì em dạy chỉ mới được có một hai học kỳ thôi nhưng mà em thấy em đưa ra yêu cầu học trò viết bài nhiều thì em đọc em cũng chỉ có một số ít chừng một phần sáu là viết được thôi còn lại là viết không được viết đọc không có hiểu rõ ý với lại câu cú rất yếu ạ
4. Lớp em ở lại được cũng nhiều cái năm đó lớp của em ở lại đến mười mười mấy người nhưng mà lúc đó là ở lại trong khoa thì ít nhưng mà về mấy trường khác trường Đại học Đại Cương
5. Bạn em có chung cùng khoá thì có Thắng Xuân Thắng qua đây học bổng UQ năm đầu tiên nữa ạ cùng khoá học đại học luôn khác lớp có hai lớp thì Thắng lớp A em lớp B
6. Thường thường thì em thích học à tùy những môn học có những môn học em thích học độc lập và có những môn học em thích học theo nhóm học theo nhóm thì em ở bạn em có thể giúp em a hiểu được một số vấn đề mà em ở chưa bắt kịp ở trên lớp
7. ở Úc này em ở cũng đi một số nơi ví dụ như là Melbourn nè Sydney nè a Gold Coast nè ạ hết rồi
8. ở Việt Nam em cũng đi chơi khá là nhiều a nhất là đi chơi xa ví dụ như là Nha Trang Hà Nội Huế Đà Nẵng và một số mấy tỉnh a gần Sài Gòn
9. Trong mấy nơi đó thì em thích nhất là Nha Trang tại vì Nha Trang là một thành phố biển rất là nhỏ và rất là đẹp ở ở đó có nhiều con đường chạy dọc theo biển rất là đẹp

10. Lúc mà rỗi rãi thì em thường đi shopping đi a câu cá đi a nhảy đầm dạ hết rồi
11. Nhìn chung thì ban thời ban đầu kỳ đầu tiên thì rất là khó khăn tại vì mới sang thì ngoại ngữ cũng chưa chưa tốt tập làm quen với phương pháp học mới cách thức học mới kiến thức cũ thì cũng khá hỏng phải a học lại từ đầu nói chung cũng khá vất vả trong cái thời kỳ học đầu tiên nhưng nói chung sau đó thì mọi thứ cũng được khắc phục
12. Tôi sang được à cũng một thời gian lâu lâu rồi cũng a một số năm tôi sang đây đi học để học ngành di truyền động vật đây là ngành mà tôi cảm thấy thích thú tại vì nó liên quan nhiều với với toán học sinh học đó là cái ngành mà tôi cảm thấy thích thú
13. à như tôi nói trước đây là đây là cái ngành mà tôi cảm thấy thích thú a tôi nghĩ rằng nó rất là hữu ích tại vì à cái thiện di truyền là một trong những a cái việc quan trọng để nâng cao năng suất và chất lượng các sản phẩm nông nghiệp
14. Có lẽ tôi nghĩ rằng Tasmania là một nơi đẹp nhất của Úc mà tôi đã từng đến không những về địa hình về khí hậu và về môi trường tôi cảm thấy rất là đẹp một cái gì đó khác xa với những thành phố khác của Úc nó mang nhiều cái nét tự nhiên
15. Đặc sản của Quảng Nam thì có rất nhiều món chẳng hạn như mì Quảng a bánh bèo cá cuốn cá tươi cá hấp cuốn với rau muống
16. ở Việt Nam cũng như ở đây thì tôi đều đầu tư thời gian để học tập và nghiên cứu và giảng dạy cho nên là cũng không có điều kiện để mà đi đâu xa ngoài Việt Nam cũng như không có điều kiện đi đâu xa ngoài cái thành phố mình đang ở đó là thành phố Đà Nẵng
17. Có thể đi ở đi ở nghe ca nhạc hoặc là có thể đi mua sắm loanh quanh ở các cái siêu thị ở Đà Nẵng còn nếu ban đêm thì có thể có có lẽ là đi a đi xem triển lãm hoặc là cũng có thể đi xem ca nhạc hoặc đi xem phim ảnh
18. Dưới chân cái ngọn núi Ngũ Hành Sơn này thì du khách có thể mua sắm được các cái thứ rất là nhiều các cái đồ đá hoặc là cái đồ chạm các thứ mà người ta có thể làm bằng tay
19. ở Việt Nam ở Đà Nẵng thì có một cái món đó là món mì Quảng và cái món này nó là món đặc trưng ở của thành phố Đà Nẵng so với những chỗ khác và nếu mà du khách có đến Đà Nẵng thì và nếu người ta có hỏi tôi món nào mà tôi sẽ giới thiệu thì tôi sẽ giới thiệu với họ đó là món mì Quảng của thành phố Đà Nẵng
20. Cái điều này cũng khó nói nó tùy thuộc vào sở thích ưa khẩu vị của mỗi người thế nhưng mà đa phần theo sự theo sự phản ánh của đa phần á đa số các khách hàng thì người ta có phản ánh là cái chỗ đó nó nấu ăn ngon và giá tiền cũng vừa phải thì có một lần là tôi được một người bạn giới thiệu đến thì cũng có ăn thử và cũng có thấy là tiếng đồn không sai
21. Về cá nhân thì tôi sẽ a sinh con cho nghề nghiệp thì tôi sẽ phụ trách giảng dạy cho các giáo viên đang học lớp cao học
22. Tôi nghĩ à phương pháp giảng dạy sẽ là một yếu tố để giúp cho các thông tin truyền đạt đến được với người học một cách hiệu quả nếu bạn có kiến thức mà cách truyền đạt

của bạn không tốt thì người học sẽ không tiếp nhận được gì cả do đó tôi cũng muốn thử làm quen với tất cả các phương pháp mà tôi đã được học ở bên đây

23. Tôi nghĩ họ có thể tìm các thông tin trên mạng bởi vì những thông tin trên mạng đều rất là hữu ích không thua gì những sách vở mà mình có với lại thư viện của ở của trường Đại Học Cần Thơ cũng được upgrade sách thường xuyên

24. Tôi chưa đi Melbourne mà giữa Sydney và Brisbane thì tôi cảm giác tôi thích không gian ở Brisbane hơn ở Sydney có vẻ cổ nó hơi cổ và tôi đến đó vào một thời điểm là mùa mưa và trời rất lạnh tôi không đi được nhiều chỗ

25. Tôi đi rất nhiều tôi đi a đến được các vùng biển vùng núi tôi đi Đà Lạt Nha Trang Vũng Tàu Hà Tiên hầu như khắp nơi tôi thích Nha Trang nhất vừa gần biển vừa gần núi

26. Cuối tuần thì à lâu lâu tổ chức tụ em cũng có tổ chức như là làm party mời mọi người cơ qua ăn thì có thể là ăn gỏi cuốn hay là ăn lẩu còn nếu mà chị em trong nhà thì thường nấu phở ăn hoặc là nấu bún bò gì đó những cái món mà nước á súp súp để mà ăn

27. Em thật ra thì xuống tới Melbourne em thấy cuộc sống của nó nhanh hơn nó đô thị hoá hơn mình ở trên đây nhưng mà nói thế thì em thích sống ở đây hơn vì em thấy nó hiền hoà hơn thanh bình hơn ở dưới đó có một cái gì đó nó cũng giống thành phố Hồ Chí Minh theo cảm giác của em là như vậy còn ở đây thì nói chung nhiều khi cảm thấy nó êm ả một cái gì đó dạ

28. Thường thì cuối tuần buổi tối thì tụ em thường tại vì ở đây thường có chiếu phim buổi tối cuối tuần hay thì buổi tối tụ em coi phim còn à thường cuối tuần tụ em đi chợ thì là thường cuối tuần được ăn cải thiện hơn ăn to hơn ăn ngon hơn

29. Em nghĩ chắc là Mỹ quá tại vì phim Mỹ ngoài cái việc mà nội dung nó còn có những cái chẳng hạn như là kỹ xảo á khả năng làm phim của họ thì cũng là chẳng hạn như vừa rồi em có coi phim Troy thì em thấy cái phim đó là mặc dù mình đã biết cốt truyện nhưng khi mình coi phim mình thực sự rất là cảm thấy là bị thuyết phục bởi cái sự hoành tráng của nó

30. ở Việt Nam á ở Việt Nam thì đi chơi cũng không nhiều nhưng mà em cũng được đi nhiều tỉnh thành phố trong miền Nam rồi bởi vì hồi lớp 11 may mắn là em có được cùng trường á đi ra Huế đi ra Huế mà tụ em đi xe đò