ACOUSTIC AND PERCEPTUAL PROPERTIES OF STRESS IN THE ETHNIC SUBVARIETIES OF SINGAPORE ENGLISH

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BrE British English

SE Singapore English

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SUMMARY

Most of the existing studies on SE stress focus on word stress placement, comparing the word stress patterns in SE to those in BrE. Using BrE as a guide, past researchers make two major assumptions about stress in SE – assumptions about the perceptual qualities and acoustic nature of stress in SE. On the perception of stress, researchers assume that SE speakers would perceive a higher pitched syllable as the prominent syllable. Acoustically, researchers assume that the stressed syllable in SE must surely be the syllable that has a higher pitch. There is a need to question if these assumptions are true.

This dissertation investigates the nature of stress in the three ethnic varieties of SE. Perceptual cues and the acoustic composition of stress in the Chinese, Malay and Indian varieties of SE form the basis of enquiry. Additionally, lexical stress placement in the three ethnic varieties of SE is also discussed.

Chapter Three presents the results of the experiment carried out to investigate the perceptual properties of stress in the Chinese, Malay and Indian varieties of SE. The experiment is intended to show to what extent each of the three parameters (pitch, intensity and duration) is, or may be responsible for the impressions identified by these Singaporean listeners as *stress*. Results show that all three groups of subjects have different perceptual cues for stress. Furthermore, there is a hierarchy in the dominance of the parameters of pitch, intensity and duration as perceptual cues for each group of speakers.

Chapter Four presents the results of the experiment carried out to investigate the acoustic properties of stress in the Chinese, Malay and Indian varieties of SE, in monosyllabic words. The experiment is intended to show if the three parameters (fundamental frequency, duration and amplitude) are different in the stressed, unstressed and

emphatically stressed words. The difference in the phonetic properties present in the stressed, emphatically stressed and unstressed syllables is the target of investigation. The findings show that the Chinese, Malay and Indian sub-varieties of SE have different acoustic correlates of stress. Acoustic correlates of emphatic stress are also found to be different between the three groups of speakers. Additionally, there is a hierarchy in the dominance of the parameters of pitch, intensity and duration as acoustic correlates of stress for each group of speakers. It is also observed that there is a correlation between the perception and the acoustic nature of stress for each group of speakers.

In Chapter Five, polysyllabic words are investigated, confirming that the acoustic correlates of stress for each group of speakers do not change with the number of syllables within the word. Lexical stress placement patterns, based on a small sample of polysyllabic words, are shown to be different between the three groups of speakers.

It is hoped that the groundwork for SE stress studies has been laid, so that future researchers of SE stress no longer need to look to a foreign variety to base their study on.

CHAPTER ONE

THE NATURE OF STRESS

1.1 Introduction

Singapore English has been described as an "exotic weed" (Gupta, 1998: 119). English has, from the time when Singapore was a colonial state to this post-colonial city-space of today, participated in a linguistic ecology of several indigenous languages. The English Language, in this tiny island in Southeast Asia, has flourished and evolved through the decades, and through contact with a myriad of other indigenous languages, has taken on a wholly unique and local flavour.

With Kachru's (1982, 1986) notion of nativisation – a process of acculturation of a language in a non-native culture and space that gives the language an independent linguistic and socio-cultural identity and existence – linguists, for the past two decades, have adopted the position that Singapore English (SE) is a distinctive and independent variety of English. There has been a surge of interest in describing the linguistic structure of SE in its own right, most of which are concentrated in the fields of lexicology, morphology and syntax. In the area of phonetics and phonology, research has tended to focus on the segmental rather than the suprasegmental aspects of SE (e.g. Tongue, 1979; Platt and Weber, 1980; Tay, 1982; Hung, 1995).

This concentration on the segmental features rather than the prosodic aspects of SE is an imbalance that needs to be addressed. As Brown (1991: 4) points out, though it is true that the segmental aspects of SE speech contribute to its distinctive identity, it is the suprasegmental aspects that contribute most to the unique character of SE. Furthermore, as

Tay (1978a) observes, it is the suprasegmental rather than the segmental aspects that interfere most with intelligibility:

> "What really makes the speech of some Chinese speakers hard to understand is not that they call a 'doctor' a 'loctor' or that they say 'solly, long lumber' instead of 'sorry, wrong number' but their 'strange' rhythm, stress and intonation."
>
> (1978a: 5)

This dissertation aims to contribute towards redressing this imbalance between the suprasegmental and segmental studies of SE by addressing one of the most important aspect of prosody, namely, stress[1].

Standard Southern British English has always been the yardstick used in SE research, and this is especially true in the research of the prosody of SE. Tongue (1979), Tay (1982) and Platt and Weber (1980), among many other works, are representative of this comparative approach to the study of SE prosody. This approach compares SE and British English (BrE), listing the differences between these two varieties. Such a method of analysis is what Mohanan (1992: 111) labels as the "parasitic approach" – an approach that describes features in SE as 'errors' or 'deviations' from the standard norm. This approach implicitly reinforces the view that SE is an imperfect or imprecise copy of the 'original'. Kachru (1979: 7) refers to this penchant for using an "unrealistic reference to a model" in the study of a new variety of English as a "sin of exhibiting language colonialism".

Many recent researchers (e.g. Deterding, 1994c; Low, 1994, 1998; Low and Grabe, 1999) embrace the idea that SE is an autonomous language. Their methodology of research, however, cannot escape a comparison between SE and BrE. This makes them look very much like "those who overtly reject colonialism and assert the independent status of non-

[1] The concept, *stress* and its theoretical implications will be discussed later in this chapter.

native system [but] are implicitly colonialist when it comes to linguistic descriptions of the structure of non-native varieties" (Mohanan, 1992: 113). In the description of the prosody of SE, few linguists have studied SE in its own right, without comparing and referring SE to the British variety. This dissertation seeks to break away from this comparative tradition in its investigation of stress in SE. It aims to look at stress from its own linguistic patternings and observations, without a presupposition of theories or assumptions that would allude to the British standard of understanding prosody.

Most of the existing studies on SE stress focus on word stress placement. Most of these studies work on comparing word stress patterns in SE to those in BrE (Tongue, 1979; Platt and Weber, 1980; Tay, 1982; Alsagoff, 1984; Ng, 1985; Chua, 1989; Sng, 1991; Deterding, 1994a; Deterding and Hvitfeldt, 1994; Bao, 1998; Low, 1998; Low and Grabe, 1999). While these researchers provide important information on how SE stress patterns differ or "deviate" from the British variety, the comparative approach does not show a picture of SE stress patterns as its own entity. Using BrE as a guide, these researchers also make two major assumptions about stress in SE – assumptions about the acoustic nature and the perceptual qualities of stress in SE that have never been tested or proven. In other words, the originary essence of what *is* stress in SE remains unaccounted for. Assuming that the acoustic and perceptual properties of stress are the same as those of BrE, then the analysis of the patternings of stress placement in SE could remain unquestioned. However, should these acoustic and perceptual properties of stress be different from that of the British variety, the subsequent results of their analyses on word stress placement in SE are therefore inclined to be erroneous. What makes *stress* in SE needs to be answered.

One of the assumptions these researchers make is that the acoustic correlate(s) of stress in SE is the same as that of BrE, namely, pitch. The biggest gap in these past studies is that the acoustic correlate(s) of stress in SE is not first determined before identifying the stressed syllables. Low (1998), investigating lexical stress placement in SE, assumes that a higher pitched syllable is a stressed syllable. Chua (1989) also assumes that pitch cues stress in SE, stating explicitly that she is following Bolinger's (1958) view that pitch is the acoustic correlate of stress in BrE. These researchers have neglected to take into account the fact that different languages have different acoustic correlates of stress, and that the acoustic correlates of stress in SE could well be different from that of BrE. Thus, it is inaccurate to assume that pitch is the acoustic correlate of stress simply because BrE has pitch as the phonetic property of stress.

In these past studies on SE stress, the findings on the stress patterns in SE are based on the researchers' own perceptions of stressed syllables. This is the second major assumption that these researchers of stress in SE are making, i.e. that the perception of stress in SE is the same as the perception of stress in BrE, and that BrE speakers would perceive stress in SE as how they would in BrE. Tongue (1979) and Platt and Weber (1980), for example, in their experiments, use their own judgements to determine the stressed syllables in their sample. It is important to note that researchers like Tongue and Platt and Weber are BrE speakers and therefore, the judgements of SE stress are based on BrE perceptions. As Tay (1982) points out, British listeners might perceive stress differently from SE listeners. A higher pitched syllable, while it might sound stressed to the BrE listener, might not be stressed for a SE listener. It is thus inappropriate to assume that SE speakers have the same perceptual cues for stress as those of BrE speakers.

Before an accurate analysis of SE stress patterns can be carried out, there is a need to go back to the basics, returning to question the original point: what *is* stress in SE? What makes a stressed syllable stressed in SE? What does a stressed syllable in SE consist of? The research on SE stress therefore sees two major gaps:

(1) the determination of the acoustic correlates of stress in SE – examining the acoustic properties present in a stressed syllable that are not present in unstressed syllables;

(2) the determination of the perceptual cues of SE – examining the properties present in a syllable that SE listeners would judge as stressed.

Another problem with the research on SE stress is that most of these researchers do not control ethnic group as a variable. For those who do, for example, Low (1998), Chinese speakers have always been taken as the representative sample of SE speakers. Ethnic differentiation in SE, however, still exists. Various studies, most of them identification tests and attitudinal studies (e.g. Ooi, 1986; H. Lim, 1989; C. Lim, 1989) have successfully shown that different ethnic groups of speakers can be distinguished. Work has also been done on the phonetic properties that distinguish the ethnic sub-varieties of SE (e.g. Tay, 1982; Sng, 1987; Anandi, 1997), focusing largely on the segmental features. On the suprasegmental features, Lim (1996) notes that the Malay speakers of SE have a different peak alignment with that of the Chinese and the Indian speakers. Tan (1999), also working on intonation, observes that the Chinese, Malay and Indian speakers of SE have characteristic tonal movements, as well as differences in pitch range and slope, all of which can be traced back to their respective substrate languages. It is evident, from these studies, that the different sub-varieties of SE have characteristic features. One therefore cannot readily assume that the acoustic correlates of stress in SE, or even lexical stress placement in SE, would be the same across the different sub-varieties. Taking the multi-ethnic nature of Singapore into account, it is felt that the ethnicity of the subjects needs to be controlled, and presenting the results of the three major subvarieties – the Chinese, Malay and Indian varieties of SE – would reflect a more accurate picture of the linguistic situation in Singapore.

This dissertation therefore aims to present a more representative study of stress in SE, and not merely a 'Chinese' account. This dissertation goes into the study of the nature of stress in SE by looking at the three communities – Chinese, Malay and Indian Singaporeans, separately, with aims to

(1) establish the acoustic correlate(s) of stress in the Chinese, Malay and Indian varieties of SE; and
(2) establish the perceptual cue(s) of stress in the Chinese, Malay and Indian varieties of SE.

The methodology and analyses in this study are carried out using modern speech analysis equipment and tools. Most past studies on SE stress, with the exception of Low (1998) and Low and Grabe (1999), have been largely impressionistic. Most of the researchers rely primarily on auditory analysis (e.g. Soh, 1969; Tongue, 1979; Platt and Weber, 1980; Tay, 1982). Some of the more recent researchers, however, have used instrumental documentation together with auditory analysis (e.g. Ayampillay, 1983; Yeow, 1987, Low, 1994; Deterding, 1995), but instrumental evidence on SE stress, on the whole, is still scarce. This study, based entirely on instrumental analysis, hopes to provide more acoustic evidence of SE stress, making this endeavour more scientifically verifiable.

1.2 What is *Stress*?

As highlighted in the previous section, this dissertation aims to look into the acoustic and perceptual properties of stress in SE. It becomes necessary therefore to elaborate on what *stress* is, its acoustic and perceptual components, and the different ways of discussing *stress*.

Stress is a linguistic concept discussed not only in phonetics, but also in general linguistics. The nature of stress can be considered from the phonetic standpoint, the phonological aspect, its morphological use, its syntactic function, its rhythmic distribution and its relationship with intonational structure. One would therefore expect, given the apparent importance of the role it plays in linguistic theories, that there would be a general agreement on the precise definition and use of the term, *stress*. Defining *stress*, or talking about *stress*, however, is by no means a straightforward affair, for as Lehiste asserts in the beginning of her discussion on stress, "of the three suprasegmental features,… stress for a long time has been the most elusive one" (1970: 106). And as Gimson succinctly points out, "the term 'stress' … is one which has come to be used with great laxity of definition" (1973: 94). With the vast literature on stress, linguists having different definitions defining of stress, presenting results of experimental work and analyses from various different perspectives, approaches to the treatment of this subject do not have a point of consensus. And perhaps, the only point of agreement among these linguists is that they regard *stress* as an "observable linguistic phenomena" (Ladefoged *et al*, 1958: 14). It is an "observable linguistic phenomena" because it can be measured, articulatorily, acoustically as well as perceptually. Phonologically, it can be predicted, and patterns can be derived.

Stress, as mentioned earlier, can be understood both phonetically and phonologically. The phonetic discussion of stress involves looking at its physical and/or perceptual manifestations. The biological mechanism for the production of stress, its acoustic manifestations and its perceptual qualities are the questions that would need to be answered in the understanding of phonetic stress. As opposed to phonetic stress, phonological stress is phonemic in nature. It is regarded as a phonological property of the syllable and is expressed and understood in terms of its underlying form. What is of more importance is a syllable's "potential for being stressed" (Lehiste, 1970: 150), for stressed syllables in phonological terms could possibly not show any phonetic signs of being stressed.

As this dissertation looks primarily at phonetic stress, heavy emphasis will be given to the description and discussion of stress from a phonetic standpoint. Phonological stress will also be discussed, but in less detail, concentrating on some of the key concepts that will have bearings on the experimental designs in the later chapters.

1.2.1 Phonetic Stress

A variety of phonetic criteria involving disparate notions such as emphasis, weight, intensity, sound pressure and so on (Crystal, 1969: 113) has been used to define stress. The diverse and different ways of understanding stress stem from the fact that stress has been described from different points of view. These different perspectives or descriptions of stress are however not contradictory, neither are they mutually exclusive.

Early assumptions of *stress* generally have it equated with *force* and/or *loudness*. Jones (1956: 245) for example, asserts that "stress may be described as the degree of force with which a sound or syllable is uttered". Stress is being measured by the strength of the articulation. Bloomfield (1957: 90), on the other hand, talks about stress using loudness as a gauge, defining stress as "speaking one of these syllables louder than the other or others". Force and loudness are not equitable, and Jones' and Bloomfield's definitions are not different ways of saying the same things. Jones is speaking from the speaker's point of view while Bloomfield is defining stress from the hearer's point of view. The reason for having both *loudness* and *force* in the definitions of stress is because "the points of view of the speaker and the hearer have often been confused" (Lehiste, 1970: 106).

To avoid such confusion, there needs to be a clear demarcation of categories when talking about stress. Stress can be understood systematically using Couper-Kuhlen's (1986: 7) dimensions of prosody. Couper-Kuhlen's three-dimensional characteristic of prosodic parameters is simple and apt and can be used in providing a skeletal framework upon which the discussion of stress will be based. Though Couper-Kuhlen applies this model to prosody, and not particularly to *stress*, this model provides for a systematic view of how phonetic stress can be understood and discussed. Thus, in phonetic terms, *stress* can be discussed in these three dimensions, namely, the articulatory, acoustic and auditory dimensions. The relationship between these three dimensions can be seen in Figure 1.1 below.

Figure 1.1: Dimensions of Prosody

Articulatory		*Acoustic*		*Auditory*
Vibration of vocal cords	———	Fundamental frequency (F_0)	——	Pitch
Physical effort	———————	Amplitude	——————————	Loudness (intensity)
Timing of articulatory movements	————	Time	—————————————	Duration

(Adapted from Couper-Kuhlen, 1986: 7)

In the following section, *stress* from the phonetic standpoint will be discussed by considering (i) the point of view of the speaker (articulatory dimension), (ii) what the instrumental measurements show (acoustic correlates) and (iii) the point of view of the hearer (auditory dimension).

1.2.1.1 The Articulatory Dimension: The Physiology of Stress

Early linguists generally believe that "stress is actually physiological stress" (Lehiste and Peterson, 1959: 429), and that "statements about stress are best regarded as statements about the speaker's muscular behaviour […] and differences in stress […] can be ordered more simply in terms of human behaviour producing them than in terms of the accompanying acoustic phenomena" (Ladefoged *et al*, 1958: 9). And it is the description of stress in physiological terms that holds the greatest contention because "there is no single mechanism to which the production of stress can be attributed in the same manner as the generation of fundamental frequency can be attributed to the vibration of the vocal cords" (Lehiste, 1970: 106).

Early linguists typically hold the belief that differences in stress are due to differences in physical effort, or the force of the utterance. Sweet (1906: 47) describes stress as "the effort by breath is expelled from the lungs […] acoustically, it produces the effect known as 'loudness' which is dependent on the size of the vibrations-waves which produce the sensation of sound". Jones (1956: 245) is also a strong advocate of this view, defining a stressed syllable as that which the speaker consciously utters with greater "degree of force" compared to other syllables in the same utterance. Lehiste (1970: 106) firmly states that "ultimately, differences in stress are due to differences in physical effort". While linguists believe that an increased effort is necessary to produce a stressed syllable, there are arguments as to which physiological component(s) of the human anatomy produces this effort.

Stetson (1951) is the pioneer in the research of the physiological correlates of stress. Not straying away from the general consensus that stress is caused by a greater effort, he, in addition pinpoints this 'effort' to that of the respiratory muscles. Stress, for Stetson, is defined as an increase in the intensity on a syllable caused by an extra effort in lung musculature leading to greater perceived loudness. Every syllable is accompanied by a ‘ballistic chest pulse’, which is caused by the increased activity of the expiratory muscles. Stressed syllables are the heavy strokes of the chest pulses, which are produced with the additional help from the abdominal muscles. His ‘chest pulse’ theory is developed using data obtained from kymograph recordings of the movements of the body wall, recordings of the air pressure in the trachea of tracheotomised subjects, and recordings of the pressure of the air in the lungs shown by variations in the pressure of an air-filled balloon in the stomach.

These methods of obtaining data however were found to be unsatisfactory with the advent of technology. Stetson’s chest pulse explanation was found to be inaccurate when direct evidence was provided by results from a series of experiments carried out by Ladefoged and his co-workers (Ladefoged, *et. al.*, 1958; Draper, *et. al.*, 1958, 1960; Ladefoged, 1960; Ladefoged and McKinney, 1963; Fromkin and Ladefoged, 1966) on the electromyograph. The electromyography was used to investigate four groups of muscles: the external intercostals; the internal intercostals; the latissimus dorsi, rectus addominis, internal and external obliques; and the diaphragm. The force exerted by these muscles was transmitted to the air in the lungs and thereby reflected in the subglottal pressure. The experiments showed no evidence for an identifiable chest pulse for every syllable. In fact, in words like *sport* and *stay*, it was found that there would sometimes be two separate bursts of activity, which would equate to two chest pulses in one syllable. While Stetson’s view cannot be substantiated, Ladefoged’s experiments instead led him to the conclusion that stressed syllables were caused by an increase in subglottal pressure, a phenomenon accompanied by an increase of muscular effort (Ladefoged, 1967). Ladefoged’s view was however challenged by Ohala (1977), whose experiments showed that except for emphatic stress, a strong expiratory pulse would not always accompany the production of stressed syllables. Instead, the variations in subglottal pressure were found to be dependent upon the action of the larynx, and not the pulmonic system, leading to the conclusion that the action of respiratory muscles was not a reliable cue to physiological stress.

The investigation of the physiological correlates of stress, as discussed so far, was generally reserved for languages such as English, Russian and German, believed to have "expiratory accent", different from the "pitch accent" found in languages such as Chinese, Swedish and Serbo-Croatian (Ohala, 1977: 145). Languages with 'pitch accent' were therefore excluded from these experiments. In addition, with experiments carried out by Fry and his colleagues (1955, 1958, 1965) to investigate the perceptual correlates of stress, there was, at that time, a growing recognition that pitch should also be considered in defining stress. Ladefoged's view on effort being correlated to subglottal pressure was again contested by Lieberman (1967), who showed that changes in subglottal pressure (pulmonary activity) correspond to changes in F_0. This view caused a new debate on whether F_0 changes were caused by laryngeal or pulmonary muscles. Fuelled also by the need to consider pitch in defining stress, more experiments were carried out in the vein of Lieberman's proposition (Öhman and Lindqvist, 1966; Vanderslice, 1967; Ohala, 1977). The experiments show that the increase in subglottal pressure was only a negligible contributory factor to a rise in F_0, leading to the conclusion that it was the larynx and not the lungs (as Lieberman claims) that caused changes in F_0. Thus, should stress be defined in terms of pitch, it would then be the larynx that is the articulatory device. Further, Peterson's (from Lehiste, 1970: 109 - 110) description of a paralysed patient affirmed this view. The paralysed patient had normal control of the larynx, but did not have control of her respiratory muscles and had to breathe entirely with a respirator. She could however speak in a way that "closely resembles normal conversational speech in all aspects". It was therefore concluded that breath pulses, which this patient could not produce, were not obligatory in normal speech, implying that a significant part of the control of stress could be related to laryngeal and articulatory processes rather than subglottal pressures, refuting the Stetson/Ladefoged view.

1.2.1.2 The Auditory Dimension: The Perception of Stress

As mentioned earlier, one of the early assumptions of stress, when taken from the point of view of the listener, is that a stressed syllable is louder than the unstressed syllable. This view is popularly held by linguists such as Malmberg, who believes that *stress* involves "variations of the sound intensity" and that "it is a question of […] loudness" (1963: 83).

It is also in the dealing of stress from the perceptual point of view that the concept, *prominence* is introduced, albeit with differing views among the linguists. Pike (1947) introduces the concept *prominence*, specifically to mean loudness. For Pike, *stress* is "a degree of intensity upon some syllable which makes it more prominent or louder than unstressed syllables" (1947: 250). The term is used to refer to the manifestation of *stress*. Kingdon (1958) for example, defines *stress* as "the force employed in uttering a syllable" (1958: ix), and this force gives the syllable "a certain degree of prominence" (*ibid.*). *Stress* is used, in this case, to refer to the point of production, and *prominence* is used when the listener's point of view is considered.

Prominence is used, also in relation, but different from *stress*. Jones (1956) also distinguishes between *stress* and *prominence*. According to Jones, the prominence of a syllable is its general degree of distinctness, and this is produced by the combined effect of the timbre, length and stress of the syllable. *Prominence* is merely "an effect perceived by the hearer" (Jones, 1950: 137). As Roach summarises, "stressed syllables are recognised as stressed because they are more prominent than unstressed syllables" (1991: 86). *Prominence* is a generic term referring to the distinctiveness of a particular syllable in relation to other surrounding syllables, making it stand out. Thus, a syllable can be prominent, i.e. distinctive, even if it is not stressed.

For Fry (1955, 1958, 1965), the perception of stress denotes a complex of perceptual physical dimensions. He believes that there are four physical factors that are important in influencing one's judgement of stress. The listener perceives stress objectively by relying the factors, namely, (1) the length of syllables, (2) the loudness of the syllables, (3) the pitch of the syllables and (4) the vowel qualities of the syllables.

As there is no one-to-one correspondence between stress and a single acoustic correlate (Lehiste, 1970:110), there is therefore also no single straightforward way for a hearer to perceive and identify stressed syllables. Fry's (1955, 1958, 1965) series of experiments sparked off a string of other similar works on different languages, contributing tremendously to the understanding of the perceptual nature of stress.

Fry (1955, 1958, 1965) aims to determine the relative importance of the four acoustic parameters of stress, namely, duration, amplitude, F_0 and vowel formant structure as perceptual cues for stress. In the classic 1955 experiment, using the Haskins Pattern-Playback synthesiser, and producing test words like *object, digest, permit* and *convert*, he systematically varied the duration and amplitude of both syllables. His 100 subjects to whom the listening test was administered all agreed that when the syllable was long and of high amplitude, the syllable was judged to strongly stressed. When the syllable was short and of low amplitude, the syllable was judged to be weakly stressed. Studying further the effects of duration and amplitude independently, Fry concludes that duration is the dominant cue for stress, compared to amplitude.

In the 1958 experiment, Fry went further and tested three parameters – amplitude, duration and F_0. Using the Haskins Pattern-Playback synthesiser again, the test materials were synthesised at 120 Hz. In this experiment, two parameters were explored at the same time. Duration changes were combined with step changes in F_0, while amplitude was held constant. It is found that both duration and amplitude act as cues in stress judgements, but it is duration that produces greater overall fluctuations in judgements, confirming the 1955 study. He also finds that the direction of step change of F_0 has strong influence on stress judgements, but the magnitude of F_0 change has no marked effect. He concludes that there is a tendency for higher pitched syllables to be heard as stressed when compared to a lower pitched syllable. The change in F_0 differs from the change in duration and intensity in that it tends to produce, what he calls, a "all-or-none effect". This means that the magnitude of F_0 change is unimportant, but the fact that a F_0 change has taken place is all-important, suggesting that F_0 is the overriding factor in the determination of prominence, outweighing duration as a perceptual cue.

Fry, in a similar experiment in 1965, this time manipulating vowel quality, the fourth perceptual cue, systematically varied the first and second formant frequencies of the synthesised word pairs in his test materials. The fundamental frequency of the vowels was kept at 120 Hz, and maximum intensity in the two syllables of the test word was kept equal, but the difference between the two formants was maintained throughout. Variations in vowel duration were also introduced. It is shown from the experiment that formant structure is not an effective perceptual cue. Duration is found to be more effective than the formant structure as a perceptual cue. In fact, it appears that, as a perceptual cue, the formant structure is even less effective than intensity. Putting the experiments together, he therefore concludes that intensity, as a perceptual cue, ranks below duration, which in turn ranks below fundamental frequency. Fry's experiments and results suggest that the traditional belief that loudness is stress or prominence needs to be reconsidered.

Other similar studies, for example, Bolinger (1958), using both natural and artificial speech, concludes that the primary cue to stress is pitch. While he regards duration as an equally important perceptual cue, he rejects the notion that amplitude has a crucial role to play as an effective perceptual cue.

Morton and Jassem (1965), using nonsense words, /sisi/, /sɔsɔ/ and /sasa/ as test items, synthesised and varied the acoustic parameters of F_0, amplitude and duration in the same systematic manner as Fry did. They note that a raised F_0 is more effective as a perceptual cue than a lowered one, and that the more intense and longer a syllable is, the more likely it is to be marked as stressed. The most important finding is that variations in F_0 produce far greater effects in the listeners' judgements than duration or amplitude, seemingly showing the importance of pitch as the dominant perceptual cue for stress. The results of Morton and Jassem confirm the "all-or-none" effect of fundamental frequency as observed by Fry (1958).

In an extension of Fry's paradigm, Isenberg and Gay (1978) find that duration, fundamental frequency, intensity and vowel reduction are all effective cues for the perception of stress, but only in an isolated synthetic disyllable.

Research on other languages also find F_0 to be the overriding perceptual cue for stress. Jassem (1959), Jassem *et al* (1968) and Awedyk (1986) conclude from their experiments that Polish listeners take F_0 to be the dominant perceptual cue for stress. Janota (1979) notes that in Czech, changes in F_0 are predominant factors in the listeners' perceptions of stressed syllables. Westin *et al*'s (1966) study on Southern Swedish also finds F_0 to be the main perceptual cue for stress. For the Estonians, the findings are the same, as reported by Eek (1987). For the Russians however, as Eek (1987) reports, duration, not F_0, serves as the leading parameter. In Japanese, duration plays no role in stress production or perception because a quantity opposition in vowel length is phonemic (Mitsuya and Sugito, 1978; Beckman, 1986). Amplitude, believed to be an important acoustic cue, is later shown to have little influence in stress perception in Japanese (Weitzman, 1969; Beckman, 1986; Beckman and Pierrehumbert; 1986; Hasegawa and Hata, 1992). It seems, therefore, that in Japanese, F_0 is also the overriding perceptual cue for stress.

1.2.1.3 The Acoustic Correlates of Stress

According to Lehiste and Peterson, "stress…is reflected in at least four acoustic parameters: speech power, fundamental voice frequency, phonetic quality and duration" (1959: 428). Besides the perception of stress, the determination of the acoustic properties present in stressed syllables is also an area in stress research that has been studied by various researchers.

Lieberman (1960), in the investigation of the acoustic correlates of stress in American English, used 25 verb-noun pairs as test materials. He notes that the stressed syllable has a higher F_0 than the unstressed syllable. It is in this same study that he introduces AI (amplitude integral). The integrals of the amplitude and duration of the stressed and unstressed syllables of the same word were computed and compared. The results show that the AI is the most robust acoustic correlate of stress, while peak amplitude is a weak correlate. This finding is also supported by Lea (1977). The reliability of AI as an acoustic correlate of stress must however be evaluated, as the AI measure is a combination of two parameters of stress – amplitude and duration – and it is therefore not surprising that the AI is found to be an important acoustic correlate of stress, compared to the single correlate of peak amplitude. On the same note, should peak amplitude be combined with, for example, duration, into an integral, the results could possibly show this integral to be a strong acoustic correlate compared to that of amplitude. The basis of comparison is not a fair one.

In other languages like Polish (Jassem, 1959), it is also found that, like English, the stressed syllables are higher pitched than the unstressed ones. Jassem further finds that Polish stressed vowels tend to be longer than the same vowels in unstressed syllables. At times, an increased intensity is noted in stressed syllables. There is however no correlation found between stress and vowel quality.

Not all languages however have the same acoustic properties for stress. In Danish, for example, it is found that stressed syllables are longer and louder, and in contrast to the above examples, have lower F_0. In Hungarian, Fónagy (1966) notes that an unstressed syllable is longer, has higher F_0 and amplitude than that of a stressed syllable, which is counter-intuitive, and has yet to have reached any unambiguous conclusion.

Different varieties of the same language can also have different phonetic properties for stress. In the English spoken in Southern England, the stressed syllables are "louder, longer and higher" (Lass, 1987: 108) than unstressed syllables. In Northern Irish English however, stressed syllables are louder, longer but lower than unstressed syllables (*ibid.*).

Thus, it is clear from the experiments that the acoustic correlates of stress, their relative importance and their effectiveness as perceptual cues vary from language to language.

1.2.1.4 A Note about 'Accent' and 'Stress'

Many linguists have found it necessary to make a distinction between *accent* and *stress*, and the reasons are of two broad types: 1) to distinguish between the phonetic and phonemic, and 2) to differentiate between the different ways of which prominence or salience are produced.

From the results of the experiments as described in the earlier sections, especially from Fry (1955, 1958, 1965), Bolinger (1958) and Lieberman (1960), one is tempted to infer that the relevant feature of stress, at least in English, is pitch. It is precisely from these experiments that the term *accent*, or *pitch accent*, to be more specific, is introduced. Bolinger (1958) argues that since fundamental frequency is a more effective perceptual cue than intensity or duration, pitch must itself be stress. He replaces the term *stress* with *pitch accent*, defining it as "prominence due to configurations of pitches" (1958: 36). He further makes a distinction between *stress* and *accent*, suggesting that at the level of utterances, it is better to speak of *pitch accent* than of *stress*. The term, *stress*, should be restricted to the phonemic domain, i.e., *stress* is the potential for a syllable being made prominent. Phonetically, a syllable that is prominent is *accented*. For linguists like Bolinger, there is a need to use two different terms to make the distinction between the phonetic and the phonemic domains.

Abercrombie (1991b) also makes a distinction between *stress* and *accent*. Not unlike Bolinger, he asserts that one term should be used in phonetic discussion, and the other in discussions involving the phonology of stress. The difference here however is that Abercrombie uses the term *stress* for "*general phonetic* discussions" (1991b: 81). For him, *stress* is a reinforcement of a breath-pulse, a muscular action which produces a higher sub-glottal air-pressure. *Accent*, on the other hand, "exists only at the lexical level" (1991b: 82). *Accent* is what is "indicated by 'stress marks' in… dictionaries" (1991b: 83). *Accent*, in Abercrombie's terms, is phonemic, while *stress* is phonetic. The syllable that receives the accent is the "salient syllable" (*ibid.*), and *accent*, being phonemic, is "a *potentiality for salience*" and salient syllables are prominent.

Linguists like O'Connor and Arnold (1961) and Malmberg (1963: 83) use *stress* and *accent* to make a distinction of how prominence is being achieved. *Accent*, according to Malmberg, is defined as "variations in pitch", and *stress* is defined as "variations in loudness" (*ibid.*). For Lehiste (1976), *stress* is used specifically to refer to prominence produced by means of respiratory effort. The term *accent* is used when prominence is achieved by other phonetic means in place of, or in addition to respiratory effort.

In this dissertation, there is no special need to make this distinction. As this research is concerned primarily on the phonetic level, the phonological aspects of stress will not be dealt with, with which the confusion or the need to demarcate the two levels is made unnecessary. Furthermore, this dissertation does not make any prior assumptions about how prominence or salience is produced, the adoption of the terms *stress* and *accent* in accordance to O'Connor and Arnold, Malmberg and Lehiste becomes unwieldy.

1.2.2 Phonological Stress

As opposed to phonetic stress, which, as mentioned earlier, can be described in terms of phonetic properties, phonological stress is phonemic in nature. It is regarded as a phonological property of the syllable and is expressed and understood in terms of its underlying form, the abstract quality. The concern in phonological stress is not with the articulatory, acoustic or auditory qualities of stress, as with phonetic stress. What is of more importance is a syllable's "potential for being stressed" The positions and placement of stress on syllables or words are predictable by sets of rules and principles based on morphological, lexical or syntactic criteria.

When dealing with phonological stress, two important issues require attention. As outlined by Lehiste (1976: 235), in considering the linguistic function of stress, it is useful to treat separately (i) the question of stress type and (ii) stress position or placement. The discussion on the former issue will concentrate on differentiating types of stress such as *word stress*, *sentence stress*, *emphatic stress*, *fixed stress* and *free stress*, as well as the various degrees of stress. The distinction between these different types of stress will be pertinent to the experiments later in the dissertation. Stress placement will also be discussed, from both the structuralist and functionalist perspectives.

1.2.2.1 Types of Stress

The question concerning types of stress can be looked at on two levels: word-level and sentence-level. On the word-level, stress serves to divide the speech chain into units, and has an articulatory function. On the sentential level, stress is determined by morphological-lexical criteria, and the occurrence and distribution of stress is to be described with these in mind.

The term *word-stress* presupposes the domain of stress to be restricted to the word. Laver defines *word-stress* as "the placement of phonological stress on a particular syllable within a word", and which is also "a defining property of that word" (1994: 511). In languages like French, Finnish, Hungarian, Polish and Latin, the location of stress within the word is fixed. Languages of this type are said to have *fixed stress*, i.e., the place of the stress is fixed once and for all, and determined automatically by the phonetic structure of the group. In French and Polish, it is always the last syllable that is stressed. In Hungarian, Finnish and Czech, it is the first syllable that is stressed. In Latin, the stress is on the penultimate or the antepenultimate, depending on the quantity of the penultimate.

In contrast, languages like English and Russian have *free stress* (Lehiste, 1970). The placement of stress within the word is independent of the phonetic structure of the word. In one word, it may occur on the first syllable, in another on the second and so on. For example, in Russian, the stress can fall on the first syllable in [`pravdə] ('truth') and on the second syllable in [da`rogə] ('road'). In such languages, unlike the fixed-stress languages, it is sometimes possible to change the meaning of a word or a form by changing the location of the stress. This means that the placement of the stress consequently plays a linguistic role and therefore is a distinctive phenomenon that has semantic roles. In English, the location of word stress distinguishes word class. For example, *per`mit* with the stress on the second syllable is a verb; while *`permit* which has the stress on the first syllable is a noun. In Spanish, *`canto* with the stress on the first syllable means 'I sing', while *can`to*, with the stress on the second syllable, means 'he sang'. In Swedish, [`ja:pan] ('Japan') is opposed to [ja`pa:n] ('Japanese').

The function of word-stress is not the same for all languages, which is why Lehiste (1970) finds it necessary to distinguish between two different types of word-stress, and they are *phonemic stress* and *constructive stress*.

According to Lehiste, when the definition of a word does not depend on a criterion involving stress, the word stress that is involved here is called *phonemic stress.* In English for example, the word *teacher* would not change in meaning or in morphemic structure whether it is stressed on the first or the second syllable, though stressing it on the second syllable might sound unnatural and odd. While phonemic stress does not affect the morphological or semantics of the word, it does however conform to rules of stress placement depending on the phonological structure of the language.

Constructive stress on the other hand affects the morphological structure of a word. This type of stress "serves to combine a sequence of morphemes into a stress construction in which the morphemes stand in a fixed stress relationship to each other" (Lehiste, 1970: 148). For example, in English, certain noun phrases may be distinguished from compounds by the use of stress appropriate for compound nouns, the difference between *'blackboard* and *black'board* is an example.

Within word stress, problems with the degree of stress also surface. Jones (1956) posits two degrees of stress, weak and strong, which serve to make distinctions between words. Degrees between the strong and weak stress are, according to Jones, degrees of prominence due to other factors (pitch, vowel quality and duration) other than intensity, which, as discussed in the earlier section, is defined as *stress*. Jones asserts that in languages like German and English, it is only at the sentential level or in compound words where one can find more than two degrees of stress, in which case, it is beyond word-level phonology.

Trager and Smith's (1951) postulation of four distinctive degrees of stress in English is probably the most popular and widely followed view. The four degrees of stress are *primary, secondary, tertiary* and *weak stress*. According to them, all significant contrasts in English can be sufficiently and adequately expressed and explained with these four degrees of stress. However, the phonetic reality behind these four degrees of stress is questionable. One wonders if there is a genuine need for these different levels of stress. In languages like Hungarian, for example, there is only one main stress (no secondary or tertiary stress) regardless of the number of syllables the word has, or if the word is simple or derived (Varga, 2002). One wonders too if the four degrees of stress could really be clearly distinguished, both articulatorily and auditorily. In fact, Chomsky and Halle (1968) proceed to use these four degrees of stress and give an elaborate account of stress rules in English without first determining the phonetic differences between them. Given that word-stress is itself an abstract quality, since it is merely a potential for being stressed, it is therefore not surprising, and perhaps not to be expected, that the phonetic differences between the gradations of stress cannot be ascertained phonetically.

Laver (1994) makes a distinction between three degrees of stress, *primary, secondary* and *unstressed*. According to Laver, these degrees of stress point to the graded differences of prominence that characterise individual syllables within a word. For example, in *ˌsyste'matic*, *-ma-* will have primary stress, *-sys-* secondary stress, and *-te-* and *-tic-* are unstressed.

In the domain of *sentence stress*, similar to *word stress*, different degrees and types of stress can be distinguished. *Sentence stress*, as opposed to *word stress*, is the stress that functions within the domain of a sentence. Sentence stress does not change the meaning of any lexical item, but only increases the prominence of one or more of the items.

Bierwisch (1966, from Lehiste, 1970: 150) makes a distinction between three kinds of sentence stress – *primary stress*, *contrastive stress* and *emphatic stress*. According to Bierwisch, each sentence has a *primary stress*, which simply refers to the prominence of a lexical item in a sentence. Lehiste (1970) refers to it as *nonemphatic sentence stress*. Szwedek (1986) labels stress of this kind as *neutral stress*.

Bierwisch further breaks down sentence stress into *contrastive stress* and *emphatic stress. Contrastive stress* is defined as stress that "occurs in sequences of sentences with parallel constituents that are filled with different morphemes" (Lehiste, 1970: 151). For example, in the sentence, *I want the pear, not the bear*, the word *pear* is stressed to contrast it with the noun in the negation phrase.

Emphatic stress on the other hand is "to call the listener's attention to a given syllable or word with greater insistence than is afforded merely by neutral patterns of intonation or lexical stress" (Laver, 1994: 515). Emphatic stress can be used to give special prominence in the case *The dog ate the 'biscuit* as opposed to a neutrally stressed one in *The dog ate the 'biscuit.*

While Bierwisch sees a difference between *contrastive stress* and *emphatic stress,* Laver (1994) and Szwedek (1986) do not make such a distinction. To a very large extent, these two types of stress are indistinguishable for as Lehiste (1970) points out, not all languages need such a distinction. However, it remains necessary to keep in mind the differences, for it appears that in Hungarian, emphasis affects word order, while contrastive stress is phonologically significant (Kiefer, 1967), in which case, the distinction becomes theoretically important.

1.2.2.2 Stress Placement

Theories concerning stress placement can be divided into two camps, the structuralist approach and the functionalist approach. The debate has focused on the question of whether stress placement is determined by syntactic rules and principles (e.g. Pike, 1945; Chomsky and Halle, 1968; Bresnan, 1971, 1972) – the structural argument; or if semantic, pragmatic or discoursal factors come into play (e.g. Halliday, 1967b; Daneš, 1974; Bolinger, 1972a; Chafe, 1974, 1976; Schmerling, 1976; Jackendoff, 1972; Ladd, 1996) – the functionalist point of view.

The Structural Approach

In the analysis of stress from the structuralist approach, the distribution of stress is one of its major concerns. One characteristic of the structuralist approach is its limitation of investigation to the domain of the sentence. With its emphasis on the distribution of stress, semantic and pragmatic considerations are excluded to a very large extent. Therefore, analysis of stress from this approach is a purely syntactic endeavour. As this dissertation does not presuppose stress placement based on syntactic principles, much of the discussion here will not be in detail, and would only aim contrast it with the functionalist approach, which, in some way, the experiment designs in the later chapter depend on.

One of the issues discussed is the relationship between category membership and stress. Pike (1945: 63-64) divides words into two main categories: the innately stressed and the innately without stress. In general, nouns, main verbs, adjectives, interjections, interrogatives, adverbs of time, place and manner belong to the innately stressed. On the other hand, personal pronouns, auxiliary verbs and adverbs of degree are innately without stress.

Pike's idea is not new. Jones (1956) also proposes a theory of stress placement that stipulates that the relative stress of words depends on their relative importance. In fact, this idea can be traced all the way back to John Hart (1551, from Danielsson, 1955), whose description of stress is also in terms of the importance of the words that carry them. He makes a distinction between the strong-stressed words and the weak-stressed ones: the more important a word is, the stronger its stress. According to Hart, the most important words are usually the nouns, adjectives, demonstratives and interrogative pronouns, principle verbs and adverbs. Therefore, as a rule, these words are strong-stressed. Weak-stressed words are articles, auxiliary verbs and pronouns.

In Chomsky and Halle (1968) and their proposition of stress in the field of transformational-generative theory, obligatory rules and principles determine stress placement, the shape and degree of a stress contour. These rules include the Main Stress Rule, Alternating Stress Rule and Stress Adjustment Rule which apply to stress on the word-level. These rules will determine and yield the maximum of one syllable with primary stress. On the sentence-level, Compound Stress Rule and Nuclear Stress Rule will determine the placement of stress. In the attempt to account for examples that Chomsky and Halle could not explain with their rules, Bresnan (1971, 1972), Berman and Szamosi (1972) and Lakoff (1972) made modifications to their proposal. Though not completely at ease with Chomsky and Halle's principles, what they all have in common in the analysis of stress is their apparent lack for semantic and pragmatic considerations.

Though not quite syntactic in nature, the Metrical Theorists (e.g., Liberman, 1975; Liberman & Prince, 1977; Hayes, 1995) hold true to the principle that stress can be predicted, and like the Structuralists, have no consideration for semantic and pragmatic issues. The central argument of Metrical Theory is that stress is the linguistic manifestation of rhythmic structure and that there is a cross-linguistic correlation between rhythm type and duration. According to the Metrical Theorists, stress patterns can be analysed and predicted based on the concept of feet, and that the rhythmic structure and feet inventories can provide for a universal account of stress analysis.

The functional linguists, on the other hand, believe in understanding stress from a semantic and pragmatic point of view. The next section will be a discussion on the Functionalist approach to stress placement, showing how these theorists focus primarily on semantic and pragmatic considerations and the relationship with sentence stress.

The Functionalist Approach

Adherents of the functionalist approach assume that the aim of language within the frame of the act of communication is the conveyance of information. Thus, utterances should not be examined from the syntactic structure, but more from its content, context and the organisation of given and new information. While the structural approach comes purely from a syntactic vein, the functionalists take to semantic and pragmatic concerns. Bolinger (1972a) for example argues against and rejects the syntactic approach advocated by the structuralists like Chomsky and Halle (1968). He claims that "the distribution of sentence stress is not determined by syntactic structure but by the semantic and emotional highlighting" (1972a: 644).

In the discussion of stress, in particular sentence stress, information structure of the sentence is of great importance, for information structure is "signalled by or at least intimately connected with sentence stress" (Szwedek, 1986: 60). Thus, in this section, the main focus of discussion will be the relationship between sentence stress and information structure, concentrating particularly on the distinction between new/given information.

This is particularly pertinent to the experiment design in the investigation of the acoustic correlates of stress in Chapters 4 and 5.

Halliday (1967b) makes a clear distinction between new and given information. What is particularly important to note is that this distinction is dependent on the speaker. According to Halliday, 'new' information is the "information focus" which "reflects the speaker's decision as to where the main burden of the message lies" (1967b: 204). The information focus is a kind of emphasis, and this emphasis is what the speaker wishes to mark out as informative. This 'new information' is 'new' not because it has never been previously mentioned in the discourse, but more so because the speaker presents it "as being new, textually (and situationally) non-derivable information" (1967a: 205). On the other hand, 'given' information is "offered as recoverable anaphorically or situationally" (1967a: 211). Whether the information is new or given, he believes that these are options "on the part of the speaker, not determined by the textual or situational environment; what is new is… what the speaker chooses to present as new" (1967b: 211). With this new/given distinction, Halliday concludes that stress will be assigned to new information, while given information will not be stressed.

Bolinger (1972a) accepts the new/given dichotomy, and like Halliday, anchors it to the choice of the speaker. For Bolinger, where the main stress will fall is dependent upon "the speaker's invention" (1972a: 638). He strongly insists that sentence stress is independent of syntax. Using the sentence *I have a clock to clean and oil* as an example, he remarks that the accent can fall on *clean* and *oil*, and not necessarily on *clock*. This example, he claims "can show probabilities, rarely certainties" (1972a: 635), arguing against the Structuralists' attachment of stress using rules.

Most linguists take on the dichotomy but choose slightly different ways to express it. Chafe (1974, 1976) for example believes that new/given information is linked to the speaker's consciousness and thus chooses to adopt terms like 'already activated' and 'newly activated'. Dahl (1976), on the other hand uses terms like 'on-stage'/'off-stage' to label new/given information. Moving along the same lines, Jackendoff (1972) also takes into the account the role of the addressee and makes a distinction between 'focus' and 'presupposition', the latter of which is the information that is "assumed by the speaker to be shared by him and the hearer" (1972: 230).

The functional linguists, for all their different terminology and theories have a common thrust. The perspective they come from stems from a semantic and pragmatic consideration, and thus, any discussion of stress invariably depends on the analysis of semantic and pragmatic considerations. Stress becomes for the functionalists a signalling tool for new/given information in an utterance. Unlike the structural approach, stress from this point of view cannot be predicted but depends ultimately on the information structure, context and the interlocutors.

Reconciliation: The 'Focus-to-Accent' Approach

While the debate between the functional viewpoint and the structural approach seems opposing and irreconcilable, Ladd (1980, 1996) highlights the common ground between these two strictly dichotomous positions.

The Structuralists' main preoccupation is with what Ladd (1980, 1996) refers to as *normal stress*. Normal stress, according to Ladd, has no meaning or function. Normal stress, for the Structuralists, can be predicted by phonological rules on syntactic structures. *Contrastive* stress, on the other hand, is unpredictable, and is beyond the scope of what the rules can explain. The functional linguists, however, put forth the argument that words can be highlighted or brought into salience to convey new information or contrast. This, the Functionalists argue, is not a matter of phonological rules and grammar, but rather what the speakers are trying to say in a specific context.

According to Ladd, both approaches make use of the common assumption that there is a distinction between what is normal and what is contrastive. He goes on further to state that while the syntactic approach postulates rules that account for normal stress, contrastive stress is not taken care of. This lack of consideration for contrastive stress, Ladd suggests, can be redressed if normal stress is reinterpreted as part of the 'focus', or more specifically, 'broad focus'. 'Broad focus' essentially refers to focus on whole constituents or sentences rather than individual words. In this case therefore, when the focus is broad, the Structuralists' stress rules can be applied and seen as a description of where the main stress is placed. This does not go against the Functionalists' point of view. Ladd proposes the view that while one looks at the information structure of the sentence to determine stress, in the case where no special informational focus is highlighted by the speaker, stress is then determined by syntactic principles. This brings us to the '*focus-to-accent'* theory.

The '*focus-to-accent'* (FTA) approach has been discussed and accepted, in various versions, by researchers working on sentence-level stress and prominence. In general terms, following Gussenhoven's (1983) definition, the FTA theory states that words and constituents in utterances can be focused for various reasons, and that these focused words and constituents are marked by pitch accents. Ladd's (1980, 1996) version of the FTA is what he calls the 'structure-based' account. According to Ladd, within a sentence, the speaker can place stress or "narrow focus" (Ladd, 1996: 164) on any word, and this is subject to all kinds of contextual influences. However, once the focused part of the utterance is specified, the stress placement patterns can more or less be predicted by the Structuralists' 'normal stress' rules. In a sentence like *John painted the shed*, the speaker, could, for different contextual reasons have narrow focus on any word within the utterance, for example, *shed*, yielding the pattern *John painted the SHED*. The absence of stress on *painted* however does not mean that this word is not stressed, but rather, it is part of a larger constituent, in this case, the sentence, that has the main stress somewhere else, *viz*. on the object.

1.3 What Stress? Which Theory?

This chapter has discussed stress in phonetic and phonological terms, distinguished the different types of stress, and presented its correlation with semantics and pragmatics. With the theoretical issues clarified, bearing in mind the large scope of the subject matter involved, it seems timely to determine the terms, uses, definitions and theoretical slant this dissertation is to adopt.

Morton and Jassem (1965: 161) define stress as "a general term to describe a structurally significant phonetic entity, identifiable and definable at any level of speech communication". This definition, compared to the various approaches and definitions outlined in the previous sections, does not seem to say anything very much at all, and is so general the description could well fit another phonetic feature. However, it is perhaps the best way to approach stress, at least in this dissertation. As the focus of the dissertation is to investigate the acoustic correlates and perceptual cues of stress, one cannot have any assumptions about what stress is composed of acoustically. Neither can one assume how stress is being perceived. To take either the intensity/loudness definition of stress (e.g. Pike, 1947; Jones, 1956; Malmberg, 1963) or pitch is stress definition (e.g. Bolinger, 1958) would be to make unjust assumptions about the nature of stress in SE. As mentioned earlier, there will be no distinction made between the term *accent* and *stress*. Linguists make this distinction to either make a clear differentiation between the phonetic and phonemic level, or to make a distinction between how prominence is produced. As this research is concerned primarily on the phonetic level, and the phonological aspects of stress not dealt with, there is no need to demarcate the two levels. Furthermore, this dissertation does not make any prior assumptions about how prominence or salience is produced, the distinction between the terms *stress* and *accent* becomes unnecessary. The term *accent* thus is of no relevance here and will not be used.

Stress, as Laver would describe, "is one way of making a syllable perceptually more prominent" (1994: 156). As Couper-Kuhlen succinctly puts it, "*stress* … refers to nothing more than the fact that in a succession of spoken syllables or words some will be perceived as more salient or prominent than others" (1986: 19). The term *stress*, in this dissertation, "is used in a more general, less specified way" (Cruttenden, 1997: 13). A syllable is stressed if it is prominent, salient, striking or conspicuous, in comparison to other syllables.

Three types of stress will be investigated in this dissertation, and for the sake of simplicity and to avoid alluding to any theoretical assumptions, syllables will simply be labelled *stressed*, *unstressed* or *emphatically stressed* (when emphasis, beyond what is normally stressed, is placed on a word). Though it is common practice to use the terms *stressed* and *unstressed* to refer to word-level stress, these terms are used in this dissertation to indicate stress on the sentential level. Word-level stress will be referred to as *lexical stress*.

Stress, in this dissertation, will be studied on the sentential level. In a normal, simple statement, the most important and relevant lexical item, i.e., new information or the information focus will be stressed. Ladd's structure-based FTA theory will be adopted, with the 'accent' in his theory modified to refer to 'stress', as used in this dissertation. Thus, the focus is the item that receives the main stress, and the focus within the sentence is determined by semantic considerations, rather than syntactic principles.

1.4 Outline of Chapters

This dissertation comprises six chapters. The first two chapters provide the essential background, both theoretical and socio-linguistic to the next three chapters, which are the experimental and analysis chapters. Chapters 3, 4 and 5 present the experimental method, data and analyses focusing on the perceptual cues of prominence, the acoustic correlates of stress and word stress placement in the three ethnic varieties of SE. Chapter 6 concludes the dissertation, containing a summary of this dissertation, a discussion on the findings, the implications and suggestions for further research.

Chapter 1 provided an introduction to the dissertation. It gave an overview of the motivation for this research. It also summarised the key issues and the theoretical bases for the concept *stress*. A discussion of the different approaches to stress analysis was also given.

Chapter 2 provides the sociolinguistic background of Singapore. In addition, it also reviews the previous studies on SE stress, and details the relevant research on SE prosodic research of those mentioned briefly in Chapter 1. The specific research aims of this dissertation are also presented.

Chapter 3 focuses on the perceptual cues of prominence in the three ethnic varieties of SE. The experimental procedure and analyses of the data will be presented in detail.

Chapter 4 presents experimental results of the acoustic correlates of stress in the three ethnic varieties of SE. In addition, the differences in acoustic correlates of stressed syllables and emphatically stressed syllables will also be investigated. This chapter investigates only monosyllabic words.

Chapter 5 focuses on the analysis of polysyllabic words of the Chinese, Malay and Indian speakers. Having established the acoustic correlates of stress of the three ethnic varieties of SE for monosyllabic words in the previous chapter, this chapter seeks to determine the phonetic properties of stress in two- and three- syllable words. Differences in lexical stress placement between the three ethnic varieties will also be investigated.

Chapter 6 summarises and discusses the findings. The implications and suggestions for future research are explored.

CHAPTER TWO

THE SOCIOLINGUISTIC SITUATION & PAST RESEARCH ON SINGAPORE ENGLISH

2.1 The Sociolinguistic Situation in Singapore

Since its founding in 1819, the burgeoning of trade and commerce drew people of various climes to Singapore, creating, as Tham (1990: 1) aptly remarks, "a veritable socio-linguistic pot-pourri".

Singapore presents one with a unique ethnic and linguistic situation. Singapore has a population of 4 million, 76.8% of whom are ethnically classified as Chinese, 13.9% as Malay, 7.9% as Indian and 1.4% as "Others", according to the 2000 Singapore Census of Population. These ethnic classifications however do not reflect the linguistic situation. Chinese languages like Hokkien, Teochew, Hakka, Hainanese, Foochow and Cantonese are spoken within the Chinese community, though Mandarin is increasingly being used as a dominant Chinese language, at home as well as within the community. While Malay is the predominant language spoken within the Malay community, languages like Javanese and Boyanese are still spoken. Within the Indian community, the Indian languages used include Tamil, Malayalam, Punjabi, Bengali, Telugu, Gujarati and Hindi.

English, Mandarin, Malay and Tamil are the four official languages in this country, with English as the language of administration and government.

2.1.1 The English Language in Singapore

English is the *lingua franca* in modern Singapore. This situation is not so much a result of the legacy of the British colonialists, but more an effect of the post-independence policies made by the Singapore government.

With the coming to power of the People's Action Party (PAP) government in 1965, English was made an official language in Singapore. The role of English as an official language was based on the twin ideologies of "pragmatism" and "neutrality" (Ho and Alsagoff, 1998). The first is the belief that Singapore depends on English for survival in the global marketplace, giving Singapore an access to scientific, technological and economic information, enabling development and modernisation. The ideology of neutrality resides in the belief that English is not an Asian language and is not the mother tongue of any of the ethnic groups and therefore is an appropriate common language for inter-ethnic communication. It also serves to express the "supra-ethnic national identity" (Kuo and Jernudd, 1994: 29) and national consciousness in one unified tongue.

Due to its importance in serving Singapore's economic concerns as well as forging a national identity that transcends ethnic boundaries, English is institutionalised as a compulsory language in schools. English is also delegated the important roles of being the language of government, law, legislation, science and technology, education, international communication and diplomacy. English is the primary working language in Singapore, the *de facto* national language (Llamzon, 1977). The use of English is so widespread that, according to the 2000 Singapore Census of Population, 71% of the resident population aged 15 years and over is literate in English, an increase from 63% in 1990. This also explains why English is the *lingua franca* for inter-ethnic communication, especially among the younger generation of Singaporeans. Bazaar Malay and Hokkien, the languages of inter-ethnic communication in the past, are now used only by the older generation of Singaporeans, and confined only to non-formal areas of discourse.

English in Singapore has gone beyond the six characteristic uses as described by Tay (1978b), namely, as an official language, a language of education, a working language, a language of inter- and intra-ethnic communication, a language for the expression of national identity, and an international language. English is also increasingly, in recent years, used as a home language. As Platt and Weber (1980) observe, English is not only used in the public domains, but also in the more private domains of family and friendship. According to the 2000 Singapore Census of Population, there is a general increase of households citing English as the most frequently used language at home. 23.9% of Chinese Singaporeans use English as the predominant home language, an increase from 19.3% in 1990. For the Malays, 7.9% of them claim to use English most frequently at home, also an increase from 6.1% in 1990. For the Indians, a high 35.6% of them communicate in English in the home domain, a 3% increase from the 32.3% reported in the 1990 Singapore Census of Population. It is no surprise therefore, that, as Newbrook states, “Singapore is, in fact, well on the way towards becoming a largely English-speaking society” (1987: 12). In fact, there is a growing pool of English users, especially the younger Singaporeans, who can be said to be “native speakers” of the language, assuming that a native speaker is a fluent speaker of the language, typically after having learnt the language as a child (Pakir, 1993a: 24).

2.1.2 Ethnic Groups and Mother Tongue

As mentioned in the earlier paragraphs, the Chinese, Malays and Indians are considered the three main ethnic groups in Singapore. It is necessary to elaborate on the concepts of ethnicity and the related linguistic issue of ‘Mother Tongue’ in this section, especially on what these concepts mean in the Singapore context.

Fishman (1997: 329) starts his discussion on ethnicity by claiming that defining *ethnicity* is a "struggle" and that there lacks "an intellectual tradition with respect to this topic". It is not the object of this section to delve into an in-depth discussion of this complex topic, and thus, it would suffice to understand this concept from a "general orientational level" (1997: 330). Ethnicity is a social construct. It is, according to Fishman, both the sense and the expression of "collective, intergenerational cultural continuity" (*ibid.*). In other words, it is the sensing and expressing of links to "one's own kind". It is the belonging to a cultural collectivity, and this collectivity involves the sharing of a common history, putative ancestral origins, gifts, responsibilities, rights and obligations, encompassing an experience of sharing the same physical, behavioural and phenomenological components.

The definition of *ethnicity* in Singapore does not follow the above criteria. The Singapore population is simply conveniently grouped into the Chinese, Malay and Indian categories, despite the fact that not everyone within each group shares the same cultural collectivity. One example would be that of Chinese with ancestors who were migrants from China, and the Straits-born Chinese, known as the Peranakans, who have ancestral origins in the Straits – both of whom, while culturally different, are labelled 'Chinese' in this system. Similarly, Singaporeans of Pakistani origin, Sri Lankan origin, or Indian ancestry would all be labelled as 'Indian' in Singapore. Singaporeans who cannot be "categorised" under these three groups would simply be labelled 'Others', and they typically include the Arabs and Eurasians.

While there is no inherent link between ethnicity and language, it remains true that language is an important or even necessary component of ethnic-group membership. As Trudgill (1974: 59) remarks, "linguistic characteristics may be the most important *defining* criteria for ethnic-group membership". Trudgill (1974: 60-61) further elaborates that the separate identity of ethnic groups can be signalled by different varieties of the same language, with characteristic linguistic features functioning as important group-identification tools. The linguistic features characterising the ethnic groups are of particular interest in this research.

Corresponding to the three ethnic classifications is the ‘Mother Tongue’ of each ethnic group. Mandarin, Malay and Tamil are the designated ‘mother tongues’ of the three ethnic groups, Chinese, Malay and Indian respectively.

The concept ‘mother tongue’ needs to be addressed, especially in a multilingual society such as Singapore. According to Skutnabb-Kangas and Phillipson (1989: 452-453), ‘mother tongue’ is defined by (1) origin, which is the language(s) one learned first; (2) competence, i.e., the language(s) one knows best; (3) function, which is the language(s) one uses most; and (4) identification, which is the language(s) one identifies with as well as the language(s) one is identified as a native speaker by others. By these criteria, Skutnabb-Kangas and Phillipson further state that one can have several mother tongues. The same person can also have different mother tongues, depending on which definition is used. A person’s mother tongue can also change during one’s life-time, according to the definition of competence, function and identification.

The ‘mother tongue’ in the Singapore context, however, is not defined by Skutnabb-Kangas and Phillipson’s criteria of origin, competence, function and identification. In Singapore, the Mother Tongue is the “superordinate language” (Gupta, 1998: 117) of one’s official ethnic group. The official languages of Mandarin, Malay and Tamil are assigned to the official ethnic groups correspondingly. Therefore, if one is ethnically classified as ‘Chinese’, then one’s Mother Tongue is deemed to be Mandarin, that of a ‘Malay’, Malay and that of an Indian, ‘Tamil’ (1998: 117). The term ‘Mother Tongue’ in Singapore therefore does not reflect the linguistic reality. Very often, especially for the Chinese and Indian speakers, the assigned ‘Mother Tongue’ is not their actual ‘mother tongue’. Mandarin, for example, while not the mother tongue for a large majority of the Chinese population, is the language chosen to represent the Chinese community, owing to historical and political reasons. The ‘Speak Mandarin’ Campaign, launched in 1979, is an effort on the part of the government to promote the use of Mandarin in place of the other Chinese languages like Hokkien and Cantonese, the two most widely spoken Chinese languages in Singapore. Similarly for the Indians, Tamil is the language chosen to represent the Indian community, though at best only half of the Indian population speak the language, for the sole purpose of providing a common link between the different Indian groups. Pakir (1993a: 23) suggests that, in the Singapore context, the term, ‘ethnic mother tongue’ would be perhaps be more appropriate.

Language in Singapore, as observed by Gupta, is “highly politicised” (1998: 117). The post-independence language and education policies, described as a policy of “pragmatic multilingualism” (Kuo and Jernudd, 1994: 28) have a huge impact in promoting the use of languages in various domains.

English and the Mother Tongue are compulsory languages to be learnt in school. English is officially known as the *first language*, which is defined as the main medium of education. This is different from the linguistic definition of *first language* as the language that a child learns before learning any other languages. The ‘Mother Tongue’ is officially known as the *second language,* which is defined simply as the other language studied, apart from English. Again, this definition differs from the linguistic definition of *second language*, which is normally used to refer to the language that is not an individual’s native language, but is used in one's daily life. The rationale offered by the Singapore Government for making the 'Mother Tongue' a compulsory language to be learnt in school is that learning one's 'Mother Tongue' would give pupils "an anchor in their ethnic and cultural traditions" (Gopinathan, 1997: 67). The 'Mother Tongue' is believed to be able to act as a cultural ballast, preserving one's Asian heritage, beliefs and traditions. It also acts as a shield against the undesirable Western influences that come with the use of English. All students therefore, for the first ten years of their formal education, have to take both the 'First Language' (English) and the 'Second Language', in which case, is the official assigned Mother Tongue. Most Singaporeans born after 1965 are therefore bilinguals of English and their "designated" Mother Tongues. This is, according to Pakir (1991: 111-20), a phenomenon known as "English-knowing bilingualism", and 'bilingualism', in the Singapore context, is peculiarly defined as proficiency in English and in one other official language of the country (Tay, 1983: 176). According to the 2000 Singapore Census of Population, 48.3% of the Chinese Singaporeans, 76.7% of the Malay population and 54.9% of the Indian population, notable are those aged 15 and above, are literate in both English and their respective Mother Tongues.

As mentioned in the earlier section, English is increasingly being used as a home language, in addition to being a language of administration and inter-ethnic communication. There is, however, still a large number of Singaporeans using their designated Mother Tongues as a home language. Census data from the 2000 Singapore Census of Population shows that 45.1% of Chinese households use Mandarin as a home language, and 30.7% of them use other Chinese languages, such as Hokkien, Teochew, Cantonese and Hainanese as the predominant language at home. Malay is used very frequently and is spoken by almost every Malay Singaporean in the community, with 91.6% of the Malay households using it as the primary language at home. For the Indian community, 42.9% of Indian Singaporeans report that Tamil is the predominant language used at home.

The focus of this research therefore is on the three groups of 'English-knowing' bilinguals who are effectively adept in both English and the respective 'Mother Tongues', using the 'Mother Tongue' in the private domain of family and friends, and English in the public domains of work, study and administration.

2.1.3 Singapore English

Singapore English is the product of a successful educational system with English as the language of instruction. Nevertheless, as local languages continue to be used and spoken, Singapore English exhibits features which arise through language contact. Given this multi-lingual and multi-ethnic context in Singapore, it is hardly surprising therefore that the variety of English spoken here is distinctive and varied, showing major influences from the other languages used on this island.

Singapore English exists on a continuum, and has been commonly classified into three basic categories – the basilect, the mesolect and the acrolect (Platt and Weber, 1980). The basilectal variety of Singapore English is spoken by the less educated Singaporeans, as well as the educated Singaporean speaker in informal situations. This variety of Singapore English, is also commonly referred to as *Singlish*, a term used to refer to the local colloquial form of English spoken in Singapore. The mesolectal variety is between the basilectal and acrolectal varieties. The acrolectal variety is the highest variety, and is commonly known as Standard Singapore English. It is the variety that is spoken by educated Singaporeans, in formal situations such as education, government and administration, and is considered to be the high prestige variety. The term, *Singapore*

English, as used in this dissertation, refers to this standard, educated variety of English spoken in Singapore.

Linguists like Gupta (1994a, 1994b) refrain from using the lectal continuum which is very closely correlated to education level and socioeconomic status. Instead, she makes a distinction between the High variety (Singapore Standard English) and the Low variety (Singapore Colloquial English), and describes it from a behavioural perspective. This form of diglossic behaviour, she notes, is very commonly found in the English-speaking community in Singapore, especially among the young speakers, who can frequently and systematically switch between the High variety and Low variety, depending on the context and situation. This High variety is "the norm in formal circumstances, in education, and in all writing except some representations of dialogue" (Gupta, 1994a: 7). She further adds that the difference between Standard Singapore English and other Standard Englishes are principally differences in phonological features. The Low variety, on the other hand, differs sharply from the High variety, especially in the areas of syntax and morphology. This is the kind of English used in the home and in casual situations, among friends and family.

In this next section, a detailed discussion of past research of Singapore English stress will follow. This review will define the scope of the present study.

2.2 Review of Past Research

As introduced in Chapter One, past research on stress in Singapore English (SE) has tended to focus on the description of word stress patterns, often in comparison with BrE. Another common feature of these studies is that they do not control ethnic group as a variable. In fact, for most studies in SE prosody, ethnic differentiation is an area that is very rarely investigated.

This review will concentrate on these two areas: discussing and summarising the findings of research done on SE stress as well as providing an overview of some work done in the area of ethnic differentiation in SE.

2.2.1 Studies on Stress in SE

All the studies done on SE stress focus on word stress (e.g. Tongue, 1979; Platt and Weber, 1980; Tay, 1982; Alsagoff, 1984; Ng, 1985; Chua, 1989; Sng, 1991; Deterding, 1994a; Deterding and Hvitfeldt, 1994; Bao, 1998; Low, 1998; Low and Grabe, 1999). Most of these studies are concerned primarily with word stress placement, and more significantly, in comparison to lexical stress placement in BrE. Except for a few early researchers who study the mesolectal variety of Singapore English, most of the studies on SE stress to be reviewed in the following sections have Standard Singapore English as the target of investigation.

The early works of Tongue (1974: 20) and Platt and Weber (1980), studying the mesolectal variety of Singapore English, report that there is a perception of prominence in the final syllable of a word in SE. They suggest that the prominence of final syllables could be a result of the lengthening of the syllable occurring in the phrase-final position. Platt and Weber (1980) also add that there is not only an increased length in this final syllable, but that there appears to be also an increase in loudness and a change in vowel quality. Platt *et al* (1984: 134) observe that stress patterns differ from “the more established varieties of English”, especially for words with three or more syllables. They note that the syllable appears to be stressed because of length, in particular vowel length.

For example, SE speakers would use the longer vowel [i:] in place of the BrE [ɪ]. They further elaborate that vowel quality is different between the two varieties. SE speakers have a preference for using the open [ɜ:], especially if it is in the final syllable, compared to BrE speakers, who use the short centralised [ə]. They also note that the pitch movement in SE is different from that of BrE. The BrE speakers utter the word, *educated* with a higher pitch on -*ca*-, differing from the typical pitch movement in SE.

Tongue (1974, 1979), Platt and Weber (1980) and Tay (1982) report that there is a rightward shift of stress on words, which, in BrE, have initial syllable stress. Platt and Weber report that in their sample of 210 polysyllabic words, nearly half "deviated" (1980: 55) from Received Pronunciation in primary stress. For instance, for the word *educated*, the British speakers pronounce it *e-du-ca-ted*, with the primary lexical stress on the first syllable. The SE speakers however, tend to shift this stress to the right, thus having *e-du-ca-ted*. Similarly, the SE speakers would say *cri-ti-ci-sm* instead of *cri-ti-ci-sm*.

This observation is also noted by other researchers. Sng (1991), studying Standard SE, reports that in polysyllabic words, the stress moves away from the initial syllable. However, in three-syllable words, the primary lexical stress shifts to the initial syllable, which is contrary to what Platt and Weber (1980) have found.

Alsagoff (1984), using teachers of English Language as her subjects, notes that words with suffixes in SE behave differently from that in BrE. She observes that in suffixed words, there is a shift of stress to the word-initial syllable. Bao (1998) also observes that stress placement in suffixed words in SE is different from that of BrE. He is however more specific, dealing only with the suffixes -*logy* and -*ic*. In BrE, stress is assigned to the syllable before -*logy*, for example, *tech-no-lo-gy*. In SE however, stress is placed on the first syllable of the suffix, as seen in *tech-no-lo-gy*. For words with the suffix *-ic*, differences between SE and BrE are also noted. For BrE, words with the *-ic* suffix attract stress placement on the syllable immediately preceding it. For example, for the word *academic*, British speakers will say *a-ca-de-mic*. In SE however, the same word will have the main stress placed on the second syllable, as in *a-ca-de-mic*, retaining the stress allocation as with that of *a-ca-de-my*.

Alsagoff (1984), in her investigation of word-accentuation patterns in SE concludes that stress is not used to demarcate parts of speech in SE. For example, while British speakers would use *in-crease* to refer to a noun, and *in-crease* to refer to a verb, SE speakers would use *in-crease* to refer to both noun and verb. This is a finding also made by Tay (1982) and Sng (1991).

The use of compound and phrasal stress in SE is also noted to be different from that of BrE. In BrE, stress placement is used to make a distinction between compounds and phrases. When a word like *blackboard* has stress falling on the first syllable, it is taken to be a compound, having compound stress. When the stress falls on the second syllable, as in *black board*, it is taken to be a phrase, and has phrasal stress. In this case, *board*, being the head of the noun phrase, is assigned the primary stress. SE speakers, however, do not make such a distinction, as noted by researchers (e.g. Tongue, 1974; Platt and Weber, 1980; Deterding, 1994b). Compounds in SE are also assigned phrasal stress. Thus, the SE speaker would say *blackboard* regardless of whether the lexical item in question is a compound or a noun phrase.

Low (1998, 2000b), using experimental and instrumental methods, confirms the claim that SE speakers do not make a distinction between compound stress and phrasal stress.

Making a comparison between BrE speakers and SE speakers, she measured the duration and fundamental frequency of the vowels in the test materials she designed. It is found that the fundamental frequency in compounds and phrases differ for BE speakers, but no such difference is noted for the SE speakers. As F_0 is considered to be a primary cue for stress in the nuclear position, the findings indicate that BrE speakers distinguish between compounds and phrases, while the SE speakers do not. She also notes that no difference is found in duration between the compounds and phrases, for both groups of speakers. She therefore concludes that stress placement in compounds and phrases differ between SE and BrE, and this acoustic difference is in pitch, not duration.

Alsagoff also adds that SE speakers do not reduce their vowels, and with the association of stress with heavy syllables, the supposedly ‘unstressed’ syllables in BrE become stressed in SE. On the same note, Sng also concludes that the more syllables a word has, the more it deviates from the stress pattern of BrE.

As with Alsagoff and Sng, Ng (1985) and Chua (1989) also conclude that word stress in SE is different from word stress in BrE. Using Chomsky and Halle’s (1968) Main Stress Rule and Fudge’s (1984) Suffix Rules, Ng and Chua find that SE speakers do not follow these rules, thus implying that SE is different from BrE, even though Chomsky and Halle's rules were not set up to account for BrE.

In another experiment based on nonsense words, Chua finds that SE speakers tend to stress low rather than high vowels. She also adds that syllables with vowels followed by two or more consonants are also more likely to be stressed. Ng, on the other hand concludes that the stressing of nonsense words by and large follow the Main Stress Rule.

Bao (1998), though not denying that there are differences in the word-accentuation patterns of SE compared to that of BrE, claims that SE deviates only in a few cases. Using these past studies as a base, he systematically and neatly captures the differences by three rules, which he claims would account for the word accentuation patterns in SE. His rules state that all heavy syllables are stressed, and that stress occurs on alternate syllables. For words with more than one stressed syllable, the last syllable carries the main stress.

As highlighted in the previous chapter, stress is cued by duration, amplitude, pitch, spectral reduction or a combination of these features (e.g. Fry, 1955; Lieberman, 1960, 1967; Lindblom, 1963; Brown and McGlone, 1974; Gay, 1978). As discussed in Chapter One, stress in different languages has different acoustic correlates. What is apparent in these studies on word stress patterns in SE is that these researchers perceive stress in SE without first establishing how stress is perceived in SE. These researchers have therefore identified stressed syllables in SE without a prior knowledge of what the acoustic properties of a stressed syllable are in SE.

One of the biggest flaws in these past studies is that the findings on the stress patterns in SE are based on the researcher's own perceptions of stressed syllables. Tongue (1974) and Platt and Weber (1980), in their experiments, use their own judgements to determine the stressed syllables in their sample. It is important to note that researchers like Tongue, Platt and Weber are BrE speakers and therefore, the judgements of SE stress are based on BrE perceptions. As Tay (1982) points out, British listeners might perceive stress differently from SE listeners. Since pitch is the acoustic correlate of stress in BrE (Bolinger, 1958), then what these researchers have heard in SE, which they think is stress, might just turn out to be simply an increase in pitch which does not serve any function for prominence. It could also turn out that stress placement between SE and BrE is not different, but rather, stress is simply cued differently for these two varieties. Another possibility could be that it is indeed a difference in lexical stress placement between the two varieties that is being observed. In either case, neither of these two possibilities has been seriously considered nor investigated. As Tay (1982) further asserts, speakers of SE might use duration or amplitude to mark stress. If this is the case, then using pitch as a cue for stress will lead to the wrong judgements of stress placement. Bao (1998) indicates, almost in passing, that stress in SE is cued by duration and amplitude. However, no phonetic evidence is provided to support his hypothesis. With a largely auditory and impressionistic account of stress, with no acoustic evidence to substantiate these claims, these observations need to be re-investigated and re-examined in greater detail.

Without any evidence as to what the acoustic correlates of stress are in SE, it is extremely difficult to identify, with any amount of certainty, what the stressed syllables are in SE. Yeow (1985) comparing the rhythmic patterns of SE and BrE speakers is the first researcher to explicitly point out the difficulty in determining stress in SE. With 3 SE speakers and 3 BrE speakers reading the text, "Arthur and the Rat", Yeow notes that it is not easy establishing a rhythmic pattern in SE as "much difficulty had been encountered in determining the stressed syllables of the readers" (1985: 23). Using stress rules commonly applied to BrE, he soon discovers that the rules are "seriously inadequate because of the scores of exceptions" (*ibid*.).

Despite the difficulty he faces, he makes several observations. He notes that the difference in pitch movements between the SE and the BrE speakers is what is causing the complication in the determination of stressed syllables. He elaborates further, noticing that the BrE speakers have a tendency to use a higher pitch on the accented syllables compared to the following unaccented ones. The SE speakers however, have a tendency to do the reverse. In other words, they realise a lower pitch on the accented syllable rather than on the following unaccented one.

He also notes that for the SE speakers, there are “numerous utterances in which the stressed syllables could not be distinguished from the unstressed” (1985: 15). Without any past research establishing the acoustic correlates of stress in SE, Yeow admits that the determination of the stressed syllables is done with “some arbitrariness” (1985: 16), without any systematic application of the criteria of what makes a syllable stressed.

Yeow (1987), working on intonation, stress and rhythm in SE, devotes an entire section, not making observations about stress in SE, but rather talking about the difficulty of stress determination in SE. He says that stress is not investigated in much detail as he has problems “identifying stress” (1987: 115). Learning from his research in 1985, he believes that a study on SE stress is not possible unless a detailed analysis of what constitutes stress in SE is first established. The study of stress in SE, he claims, “is not as straightforward as simply adopting the cues and correlates of stress identified for another accent of English” (1987: 115). In his discussion on this difficult endeavour, he further asks, “to whom do they sound most prominent? To the native speaker, who is considered to take a higher pitch or a pitch change as the chief perceptual cue? Or to the non-native speaker, who we are not at all sure has the concept of syllable prominence ingrained in his linguistic competence?” (*ibid*.). These questions are indicative of what is sorely lacking in the research on stress in SE. There is a need to seriously investigate the concept of prominence in SE, and how SE speakers perceive prominence. Yeow, with his questions, has shown that in this investigation of prominence in SE, it is imperative that SE has to be studied in its own right, without any reference to the British variety of English.

Most of the other researchers on SE stress studies have a similar problem identifying the stressed syllables in SE. However, instead of acknowledging the difficulty, they simply assume that the acoustic correlate of stress in SE is pitch. In the determination of the stressed syllables in their investigation of word stress placement, they conveniently adopt the position that pitch, being the acoustic correlate of stress in BrE, is the acoustic correlate of stress in SE. Low (1998) in investigating lexical stress placement in SE assumes that a higher pitched syllable is a stressed syllable. Chua (1989) also assumes that pitch cues stress in SE, stately explicitly that she is following Bolinger's (1958) view that pitch is the acoustic correlate of stress in BrE. For researchers like Sng (1991), who indicates that she does not use pitch, uses length and loudness as primary cues. However, she uses pitch, in addition to length and loudness when there is an indecision as to which syllable is stressed. In other words, depending on the speaker and the test item, different cues for stress are being used at different times. This inconsistent and almost idiosyncratic method of analysing stress placement makes for erroneous judgements as well as inaccurate findings with regard to stress placement in SE.

Harcharan (1994) is the only work so far that investigates the acoustic properties of stress in SE, with word stress being the main focus of study. She recorded a pool of 5 speakers; variables of ethnicity and gender were not controlled. Her test material was made up of 56 words, and the word list was made up of three main groups of words. The first group consisted of words that were identical but differing in grammatical category, which could only be determined by a shift of stress. Word pairs like *re<u>bel</u>* (verb) and *<u>re</u>-bel* (noun) were included in this group. The second group of words consisted of morphologically related words, with a base form, and suffixes attached. *Metal* and *metallic* are examples of word-pairs belonging to this group. The third group was made up of words with similar segmental make-up, but differing in stress placement. Word-pairs like *<u>phy</u>sics* and *physique* belong to this group. Her methodology involves getting her subjects to read the words in the word list, in which all the words were given in random order. For words belonging to the Noun-Verb pairs, no grammatical category was indicated for each word. She then asked her subjects to listen to their own recordings, instructing them to indicate the syllables that they have stressed. Measuring the stressed syllable and unstressed syllable for duration, amplitude and fundamental frequency, she compared the stressed and unstressed syllables in each word, with the stressed and unstressed syllables in the corresponding word belonging to the word pair. Using a formula that she formulated, the formula would give a ratio of for example, the duration of the stressed syllable to the duration of the unstressed syllable. A value of 1.5 was taken to suggest that there is a clear difference between the stressed and unstressed syllable. An example of how the formula is applied is as follows:

$$\frac{\text{Duration of stressed syllable in } \textit{rapid} \times \text{Duration of stressed syllable in } \textit{rapidity}}{\text{Duration of unstressed syllable in } \textit{rapid} \times \text{Duration of unstressed syllable in } \textit{rapidity}}$$

(adapted, 1994:21)

This piece of work, while significant because it is the first in the research on the acoustic correlates of SE stress, is however very problematic. The test material is not suited for use for SE speakers, and the findings resulting from this choice of experimental design is prone to error.

The researcher assumes that the "actual stress" will fall on the syllables that are believed to be stressed. The researcher's Group One test items, consisting of Noun-Verb pairs, rest on this assumption. Early researchers (e.g. Alsagoff, 1984; Tay, 1982; Platt and Weber, 1980) however observe that SE speakers do not make a distinction between noun-verb pairs. If it is true that the speakers do not make such a distinction, then no measurement can be made to compare between the stressed syllable in the noun, and the counterpart unstressed syllable in the verb. In which case then, the acoustic correlate of stress cannot be determined, as no value can be put into her formula to derive the ratio. Assuming that the speakers in the study do make a distinction between the noun-verb pairs, then one must conclude that either her speakers belong to a minority of SE speakers, or her speakers were attempting to pronounce the words the 'correct' way. Either way, the data does not present a representative or even true picture of stress in SE.

Another apparent flaw is that the test items were given to the subjects in no particular order and with no context given. This is especially problematic for the noun-verb pairs. Since no context was given, and no grammatical category was indicated, one wonders how the subjects say each word at each instance. Would they say, for example, *re-bel* for every single instance of this token, or would they say *re-bel* each time the word comes up? Another possibility could be that a mixture of both was said. Given this situation, one could see that the tokens recorded were not controlled. One can end up with a range of different '*rebel*'s said in a variety of ways, with no clear number of times each speaker said it. This lack of control makes for inaccurate analysis, especially in statistical analysis.

There are also several problems with the formula she employed. The syllables taken for comparison have different phonetic environments. The *-ra-* in *rapid* is different from the *-ra-* in *rapidity*. The number of syllables, for one, is different between the two words, which could have an influence on the duration of a syllable. The speaker could have pronounced the *-ra-* in *rapidity* as [rə], in which case, will not be comparable with the [ræ] in *rapid*. The *-pid-* in *rapid* is at a word final position, which will be subject to factors like word-final lengthening. The *-pid-* in *rapidity* is however not in the same position, but is followed by other segments, which could have some effect on the length of the syllable.

As can be seen therefore, the syllables used in this formulation are not comparable, and thus, the extent to which the results are reliable scientifically and realistically, needs to be more seriously evaluated.

As mentioned earlier, a value of 1.5 was taken to be the benchmark of whether or not the feature in question is an acoustic correlate of stress in SE. This value is an arbitrary one, and does not have any statistical significance.

Further, Harcharan determines the stressed syllables in her research by asking the subjects to mark out the syllables they themselves have stressed. Using the results of this ‘perception test’, she concludes that there is a correlation between the production and perception of stressed syllables. However, this test is not objective. It could turn out that the subjects have marked out what they think they have stressed, or what they think should be stressed, but not what they have actually stressed.

Harcharan, using the experiment and formula that was described earlier, concludes that duration and amplitude are the acoustic correlates of stress in SE. Her conclusions are drawn from the basis that three out of her five subjects use duration and amplitude. With the problems and flaws in her methodology and experimental design, one has to take these conclusions with much reservation. Though problematic in nature, it is nevertheless an important starting point for research focusing on the acoustic correlates of stress in SE.

Low and Grabe (1999) is another important piece of research that has to be given due mention. The focus of their research is to investigate if SE and BrE differ in lexical stress placement or if it is the acoustic correlate of stress that differs between these two varieties.

They conclude it is not the location of stress that differs in the two varieties, but the acoustic realisation of stress that is different.

10 SE and 10 BrE speakers were used as subjects in their experiment. The subjects were asked to produce polysyllabic words which were placed in nuclear, intonation phrase-final position (*He did it flawlessly)* and in non-nuclear, intonation phrase-medial position (*He flawlessly defied the aggressive official*). Duration and F_0 measurements were taken.

The results show that in phrase-final position, the SE test items exhibit a longer length compared to the BrE test items. In phrase-medial position however, the syllable length between the BrE and SE speakers are comparable. Since this difference in stress placement for polysyllabic words is only noted in nuclear, intonation phrase-final position, manifested by the increase in length of the vowels in this position, this may be a result of the intonational boundary phenomenon, and may not constitute an example of a difference in stress placement. Therefore in SE, a phrase-final syllable is more obvious than in BrE as it is to signal a phrase-final boundary rather than lexical stress placement

In terms of F_0, in the phrase-final position, it is noted that while BrE exhibits a clear step-down in F_0 between the initial syllable and the following two syllables, SE is characterised by a more gradual fall in F_0 between the initial syllable and the following two syllables. In BrE, the prominence distinction between the nuclear syllable and the following unstressed syllables is made by an F_0 obtrusion on the nuclear syllable and a sharp drop in F_0 on the following syllables. In SE however, such a comparable drop does not happen. Rather, there is a lack of "deprominencing" (1999: 49) of postnuclear syllables, and this lack of deprominencing contributes further to the impression that the relatively longer final syllable of the word is stressed in SE.

They therefore conclude that the apparent word-final stress is not a result of lexical stress placement. Rather, it is the combination of substantial lengthening on the final syllable of the words in phrase-final position, combined with the lack of de-prominencing of unstressed syllables in F_0 that lead to the impression that the final syllables are stressed. With these results, the researchers conclude that it is not that SE and BrE differ in lexical stress placement, but rather, it is the phonetic realisation of stress that is different.

The conclusion however, does not follow from the results in their study. With the results of the study, one can say with a certain amount of confidence that SE speakers use duration phrase-finally, and BrE use pitch. However, it does not follow that BrE and SE speakers use different acoustic correlates to mark stress, more specifically, BrE speakers using pitch and SE speakers, duration. Low and Grabe's experiment is based on the assumption that BrE and SE have the same lexical stress placement. This assumption is not tested, and could very well be erroneous. It is possible that F_0 is indeed the acoustic correlate of stress in SE, but does not manifest itself phrase-finally because the stress is placed on another lexical item. Duration will then not be an acoustic correlate of stress in SE, simply because the stress is not in that position. It seems therefore that the researchers are begging the question.

As Low (1994) has noted, it is very difficult to make use of the British model of intonation in the analysis of SE, for the identification of the nucleus is almost impossible. Thus, one cannot readily assume that the SE and BrE speakers in Low and Grabe's experiment share the same intonational boundaries. The supposed "nuclear" syllable in BrE might not be a nuclear syllable for the SE speakers.

While F_0 and duration measurements were taken, noticeably missing from Low and Grabe's experiment is the measurement of amplitude. Amplitude, one of the possible correlates of stress in SE, if measured, could possibly provide some insight into the stress placement in SE, which would lead to a different conclusion.

Quite notable from the research done on stress of SE so far, all of them focus primarily on word stress, especially word stress placement. Sentence stress, or emphatic stress in SE are areas that have not been worked on at all. Besides Harcharan, all the studies have investigated stress in SE without first determining what the acoustic correlates of stress in SE are, and they have, in a sense, missed out on a very crucial grounding to base their studies on. Harcharan's research, incidentally also only investigating word stress, though noting the importance of determining acoustic correlates of stress in SE, has left much room for more rigorous research.

2.2.2 Studies on Ethnic Differentiation

The studies on SE stress, as reviewed in the earlier section, have one thing in common, and it is that SE is taken as a homogenous entity. Most of the researchers do not control ethnic group as a variable. For those who do, the Chinese population, which is the largest ethnic group in Singapore, is taken as a representative of the Singaporean population.

While these researchers maintain the point of view that SE has its own identity, and should be described in its own right, it does not entail that differences, especially along ethnic lines, do not exist within SE itself. As Deterding and Poedjosoedarmo (2000: 1) points out, "it would … be extremely naïve to assume that young Singaporeans all sound alike when they speak English". It would not be surprising if young Singaporeans, while having phonetic features that distinguish them from others as distinctively Singaporean, would also have some unique phonetic features which mark them out as Chinese, Malay or Indian. In other words, ethnic differentiation still exists, though for the most part, it cannot be denied that the SE spoken by different ethnic groups are largely similar. This implies that, within SE, there is a myriad of distinct sub-varieties of the language.

With natural cultural assimilation and national policies that seek to forge a supra-ethnic national identity, researchers have tended to see a unified Singaporean English as an inevitable consequence. Platt and Weber, for instance, find:

> "… the increasing similarity of Singaporean English as spoken by those of different ethnic backgrounds. … Some speakers of English who have had a Chinese-medium, Malay-medium, or Tamil-medium education can still be distinguished from the speakers of the typical SE variety… but these cases are becoming rarer, particularly among the younger generation."
>
> (1980: 46)

Platt *et al* (1984: 6) further affirms his claim, stating that his test on telephone switchboard operators shows that these operators could not identify the ethnicity of young Singaporeans beyond the fact that they were Singaporean.

Despite such views however, various studies, most of them identification tests and attitudinal studies (e.g. Ooi, 1986; H. Lim, 1989; C. Lim, 1989), have successfully shown that different ethnic groups of speakers can be distinguished.

Seah's (1988) and H. Lim's (1989) attitudinal tests show that Singaporeans could identify a speaker's ethnicity through the SE that he spoke fairly accurately. Most of the respondents in Lim's test could correctly identify the ethnic group of the speaker, with more than 80% of correct identification. Lim's test further reveals that the ethnic group of the speakers can be identified from the segmental and suprasegmental features alone. Ooi's (1986) perception tests also show that the speakers from the three ethnic groups can be recognised with a high success rate, and this is especially true for the Chinese and Indians. More than 90% of the Singapore speakers were perceived as sounding 'local' in his experiment.

Lim (1996: 64), using Chinese, Malay and Indian speakers as well as listeners of all three groups, finds that the success rate for ethnic identification is very high. The accuracy rate was 80% for the Chinese speakers, 75% for the Malay speakers and 65% for the Indian speakers. When asked what features were used in identifying the ethnic groups of the speakers, most of the listeners chose 'intonation', from a list of other options including 'sound', 'word', 'grammar', 'content', 'speed' and so on. This is indicative that ethnic group differentiation is perhaps most marked in the prosodic features.

The most recent identification test carried out by Deterding and Poedjosoedarmo (2000) also confirms that the accuracy rate for ethnic identification is very high, and this is especially so in more informal contexts.

Despite the fact that identification tests have shown that ethnic differentiation does exist in SE, descriptive studies pinning down the phonetic features that contribute to this differentiation in SE are few. Most of the descriptive studies done so far focus on the segmental features of SE that are characteristic of each ethnic group. Tay (1982) claims that some features like the absence of /v/-/w/ distinction in Indians and some other characteristic segmental features in Malay and Chinese are features distinguishing the three varieties of SE. Sng (1987) and Anandi (1997), concentrating on the consonants of

SE, have identified, for instance, the retroflexion of alveolar stops and lateral approximants in the SE spoken by Tamil speakers. Though all these researchers find some features that are distinctive in each ethnic group, they conclude that there appears to be a general homogeneity in the SE spoken by the different ethnic groups.

Lim (1996) is probably the first to look into ethnic differences in the prosody of SE. Investigating several aspects of SE prosody like rhythm and intonation, she finds that the intonation patterns of SE spoken by the different ethnic groups are different, the most significant difference being the peak alignment. This is in line with Tay's observation that "it is also intonation which sets apart Malay, Chinese and Indian varieties of Singapore English" (1982: 61).

Tan (1999) also investigating ethnic differences in the intonation of SE further finds that each ethnic variety has its own unique global curve and tonal melodies. Using auditory and instrumental analyses, Tan notes that the pitch range, slopes and sizes of rises and falls between the different ethnic varieties of SE are also significantly different. Peak alignment, contrary to Lim's findings, does not show significant difference between the different groups. In addition, analysing the Mandarin, Malay and Tamil spoken by the same group of subjects, she finds that the unique features found in each ethnic variety of SE can be traced back to the Mother Tongue directly, showing a strong case of substrate influence.

Sng (1991) attempts to find ethnic differences in the word-accentuation patterns of SE. However, she notes that no differences can be found. As can be seen, descriptive studies on ethnic differentiation in the prosody of SE are very scarce. While Lim and Tan worked on intonation in some detail, there has been virtually no work done on stress, especially in the area of the perceptual and acoustic correlates of stress in the ethnic varieties of SE.

It is perhaps appropriate and necessary to mention an early work by Ramish (1969) which purportedly investigated ethnic differences in the segmental as well as suprasegmental aspects of English in Singapore. Ramish's work however is of quite a different orientation from that of Lim (1996) and Tan (1999). Ramish did not carry out experiments on actual SE speakers. Predictions of how English ought to be pronounced in Singapore were made, in place of an actual observation of the linguistic features of English in Singapore. Ramish, in investigating influences from the substrate languages to English, provided published descriptions of sound systems of the substrate languages which were not quite relevant, for example Beijing Mandarin, which is not the same as the Mandarin spoken in Singapore. She then tested her predictions against recordings of her subjects, who came from a mixture of linguistic backgrounds, for example, a Beijing student learning English as a second language and an Indian national who learnt English in school. All of them were different from Singaporeans who have grown up in this unique linguistic environment. Using those non-native speakers of SE, she then concluded that SE, or the different ethnic varieties of SE, would sound as how she predicted. Ramish was not investigating SE, which did not exist for her. Her study was rooted in, and was meant for a time very different from now.

2.3 Motivations

As highlighted in the review so far, it can be noted that work has to be done to determine the perceptual and acoustic properties of stress in SE before any study on SE stress can be done on a more concrete basis. There are striking gaps to be found in the past research. The gaps, as summarised, are:

1) no one has worked on the acoustic correlates of stress in SE, particularly that of sentence stress or emphatic stress;
2) no work has been done to investigate the differences in the acoustic correlates of stress between the three ethnic varieties of SE;
3) no study has investigated the perceptual cues of stress in SE;
4) no study has determined if the speakers of the three ethnic groups perceive stress differently from one another;
5) no work has attempted to investigate if there are differences in stress placement between the different ethnic varieties of SE.

This research is motivated from the gaps found in the past research in this area and aims to fill these gaps.

2.4 Aims

This dissertation thus aims to fulfil the following goals:

1) To determine the perceptual cues of stress in the ethnic sub-varieties of SE.
2) To determine the acoustic correlates of stress in the ethnic sub-varieties of SE, focusing on sentence stress and emphatic stress.
3) To investigate lexical stress placement in the ethnic subvarieties of SE.

In the next few chapters, the analyses and the findings will be presented and discussed.

CHAPTER THREE

PERCEPTUAL CUES OF STRESS

3.1 Introduction

As introduced earlier in the first chapter, the perception of stress denotes a complex of perceptual physical dimensions and they are (1) the length of the syllables, (2) the loudness of the syllables, (3) the pitch of the syllables and (4) the vowel qualities of the syllables (Fry, 1955, 1958, 1965).

Fry's (1955, 1958, 1965) series of experiments lead him to the conclusion that fundamental frequency is the most important perceptual cue in English, followed by duration, and lastly, intensity. Researchers like Bolinger (1958), and Morton and Jassem (1965) confirm Fry's findings. The same experiments were carried out with other speakers and listeners of other languages. The researchers of these experiments also conclude that F_0 is the overriding perceptual cue for stress. Jassem (1959), Jassem *et al* (1968) and Awedyk (1986) on Polish, conclude that Polish listeners take F_0 to be the dominant perceptual cue for stress. The same conclusion is also reached for languages like Czech (Janota, 1979), Southern Swedish (Westin *et al*'s, 1966), Estonian (Eek, 1987) and Japanese (Weitzman, 1969; Beckman, 1986; Beckman and Pierrehumbert; 1986; Hasegawa and Hata, 1992). For the Russians however, as Eek (1987) reports, duration, not F_0, serves as the leading parameter. These studies show that the perception of stress is different for different languages.

In Chapter Two, it was mentioned that one of the biggest flaws in the studies on word stress patterns in SE is that researchers perceive stress in SE without first establishing how stress is perceived in SE. The findings on the stress patterns in SE are always based on the researcher's own perceptions of stressed syllables (e.g. Tongue, 1974; Platt and Weber, 1980), using pitch as the perceptual cue. However, as Tay (1982) asserts, speakers of SE might use duration or amplitude to mark stress and if this is the case, then using pitch as a perceptual cue will lead to the wrong judgements of stress placement.

This chapter attempts to address the issue of the perception of stress in SE. The perceptual cues of stress of SE will be the targets of investigation. The following sections present the experiment and the findings.

3.2 The Experiment

3.2.1 Aim

The experiment is intended to show to what extent each of the three parameters (fundamental frequency, duration and amplitude) is, or may be responsible for the impressions identified by these listeners as *stress*.

The experiment is in two main parts. For the first part, the main purpose is to determine if the Chinese, Malay and Indian subjects use higher or lower pitch, greater or less intensity and shorter or longer vowel duration to determine stress.

Having established that, the second part of the experiment concentrates on determining the relative strengths of the perceptual cues. In other words, when faced with a choice between two syllables, one of which is longer and the other, louder, for example, which syllable the subjects would choose as the more prominent one. The analysis will also investigate if there are differences in the judgements of the Chinese, Malay and Indian subjects.

3.2.2 The Structure of the Experiment

The experiment consists of sentences that are of the form: *N V N N/Adv*. All the sentences consist of four words. The second and the third words are the target words. These two target words have exactly the same segmental and suprasegmental composition. In other words, not only do they have the same sounds, they also have the same values for fundamental frequency, length and amplitude, and it can be seen as follows:

Word-1	Target word	Target word	Word-4
↓	↓	↓	↓
F_0 = 98 Hz	F_0 = 120 Hz	F_0 = 120 Hz	F_0 = 98 Hz
Amplitude = 60 dB	Amplitude = 70 dB	Amplitude = 70 dB	Amplitude = 60 dB
Vowel length = 0.08 sec	Vowel length = 0.2 sec	Vowel length = 0.2 sec	Vowel length = 0.08 sec

For the first part of the analysis, when the main aim is to determine if the Chinese, Malay and Indian subjects use higher or lower pitch, greater or less intensity and shorter or longer vowel duration to determine stress, the second target word will be manipulated in four different step manipulations, one parameter at a time, with two parameters kept constant at the same time. The following is an illustration of the manipulation of duration, for example:

Word-1	Target word	Target word (manipulated)	Word-4
↓	↓	↓	↓
F_0 = 98 Hz	F_0 = 120 Hz	F_0 = 120 Hz	F_0 = 98 Hz
Amplitude = 60 dB	Amplitude = 70 dB	Amplitude = 70 dB	Amplitude = 60 dB
Vowel length = 0.08 sec	Vowel length = 0.2 sec	**Vowel length = 0.3 sec**	Vowel length = 0.08 sec

The comparison therefore is now between a shorter (first target word) and a longer (second target word).

For the second part of the analysis, when the purpose is to determine the relative strengths of the perceptual cues, both target words will be manipulated at the same time, one parameter in each target word. For example, when one wants to compare the relative strengths of amplitude and F_0, the sentence and its component words will have the following values:

Word-1	Target word (manipulated)	Target word (manipulated)	Word-4
↓	↓	↓	↓
F_0 = 98 Hz	**F_0 = 140 Hz**	F_0 = 120 Hz	F_0 = 98 Hz
Amplitude = 60 dB	Amplitude = 70 dB	**Amplitude = 80 dB**	Amplitude = 60 dB
Vowel length = 0.08 sec	Vowel length = 0.2 sec	Vowel length = 0.3 sec	Vowel length = 0.08 sec

The comparison is now between a higher but softer (first target word) and a lower but louder (second target word).

3.2.3 Materials

The materials consist of three utterances. They are:

(1) I **see sea** creatures.

(2) I **saw saw** blades.

(3) He'll **sue Sue** later.

The key words or syllables, in bold above, can be transcribed as [si:si:], [sɔ:sɔ:] and [su:su:]. The choice of these phonetic segments is based on the following considerations:

(1) The same vowel is used in both syllables. As vowels of different qualities might have intrinsically different qualities in terms of pitch, intensity and duration (Lehiste and Peterson, 1959), having the same vowel in both syllables removes this unnecessary complication. This control is necessary so as to ensure that there are no other phonetic considerations that can influence the subjects' choice besides the acoustic correlates themselves.

(2) The syllables have the same structure, [CV]. The same consonant is used in all the syllables to avoid the possibility of different consonants affecting the intrinsic phonetic properties present in the following vowel.

(3) Three different vowels are chosen to determine if the perceptual cues would change depending on the spectral properties of the vowels.

(4) As much as possible, "extreme" vowels are chosen. The choice of [ɔ:] was to replace [a:], which could not be used in this case, as [sa:] is not a word in English.

(5) The syllables/ words tested are sounds and sound sequences that can be found in English. This is to make sure that the test stimuli are as close to real speech situation as possible.

The sentences in the test materials have also been carefully designed. The following considerations are:

(1) The syllables/words tested are situated within a sentence.

(2) Each test word is monosyllabic. This is because the basic acoustic unit of speech perception (and production) is roughly syllabic length (Ladefoged, 1967).

(3) The sentence is kept as simple as possible to avoid distraction from the main test words.

(4) All three sentences contain four words, with the test words/syllables placed between the first and the fourth word. This is to make sure that there is no sentence-initial or sentence-final effect on the test words.

(5) To keep it as controlled as possible, the first word in the sentence only contains one syllable.

(6) The sentences are all the in the form: N V N N/Adv (for *later*). The two test words are all Verb, followed by Noun.

(7) It is a deliberate decision not to have two nouns for the test words. This is because the use of compound and phrasal stress in SE is also noted to be different from that of BrE. In BrE, stress placement is used to make a distinction between compounds and phrases. When a word like *blackboard* has stress falling on the first syllable, it is taken to be a compound, having compound stress. The same word, with the stress falling on the second syllable, as in *black board*, is taken to be a phrase, and has phrasal stress. In this case, *board*, being the head of the noun phrase, is assigned the primary stress. SE speakers, however, do not make such a distinction, as noted by researchers (e.g. Tongue, 1974; Platt and Weber, 1980; Deterding, 1994b). Compounds in SE are also assigned phrasal stress. Thus, the SE speaker would say *blackboard* regardless of whether the lexical item in question is a compound or a noun phrase. In this case, if both the test words were nouns, there is a chance that the SE subjects would pick the second noun anyway, regardless of the phonetic properties in the word.

3.2.4 Synthesis

3.2.4.1 The Original Stimulus

The three test sentences in the test material were 'spoken' by a computer-generated speech synthesis program. This original stimulus was taken from *The Festival Speech Synthesis System: University of Edinburgh*, a web-based synthesis tool that can be accessed online (www.cstr.ed.ac.uk/projects/festival/).

The *Festival Speech Synthesis System* produces words based on the accents of several varieties of English in the United Kingdom as well as Spanish spoken in different regions. For the purpose of this research, the 'speaker' that speaks Standard Southern British

English is chosen as the provider of the utterances. The advantage of using this system is that the speech is machine-generated, so it is much easier to control the utterances, as compared to getting humans to read the utterance.

This ‘speaker’ was made to say the test-words in the test stimuli in exactly the same way, something that is impossible for the human speaker. While there is concern that the ‘British’ accent might interfere with the subjects’ perceptions of stress, much of the British accent was lost after the synthesis and manipulation, due to the level intonation and strict control on pauses and time.

The other reason for choosing this ‘British’ speaker is because it is a neutral ‘speaker’, not belonging to any of the three ethnic groups whose judgements are being elicited. Obtaining the original stimulus from any Singaporean speaker would create problems for the accountability of the subjects’ judgements. If a Chinese speaker’s speech was used, for example, the Chinese subjects’ response could possibly be influenced not just by the acoustic correlates of pitch, duration and intensity in the test materials, but by other factors such as a mutual understanding of the “Chinese” accent, for example. Even for the Malay and Indian subjects, their responses could also be due to a preconceived notion of how the Chinese speaks, rather than the actual test materials itself. In other words, getting any Singaporean speaker, Chinese, Malay or Indian to provide this original stimulus would not be a fair test.

Another drawback of getting the speech of a Singaporean speaker as the original stimulus is that the speech would have to be taken from a ‘live’ person. There is to date no speech synthesis tool based on Singapore English, or Singaporean speakers. Furthermore, as mentioned earlier, it is necessary to control, to the minutest detail every single phonetic property in the test materials. Having a 'live' person's speech would make it difficult to control the acoustic properties in the speech produced, thus making it unsuitable for further synthesis and manipulation.

3.2.4.2 The Synthesis Procedure

The 'speaker' was made to say each word separately, so as to avoid any intonation or rhythmic pattern interfering with the test stimuli. The words were later put together using Praat Version 3.0 (www.praat.org), with each word being put at an equal length to the next. This is to make sure that no unnecessary pauses or breaks would interfere with the perception of these sentences. Praat is a speech analysis programme that also allows for speech synthesis and manipulations.

The test syllables were synthesised on Praat, with a predetermined set of individual parameters. The vowel, not the whole syllable was synthesised. As mentioned earlier, though the syllable is the basic unit of perception (Ladefoged, 1967), it is the vowel that takes the bulk of the suprasegmental load (Studdert-Kennedy, 1976: 270). This is because the vowel is "relatively stable, high in energy, and spectrally compact", and it allows the speaker to display variations in fundamental frequency, duration and intensity to "offer possible contrasts in stress and intonation" (*ibid*.).

The average values for F_0 in conversational speech in European languages are approximately 120 Hz for men (Fant, 1956). Normal conversation is conducted at about 70 dB (Moore, 1982: 8). Bearing these in mind, the basic values of fundamental frequency, amplitude and duration for each vowel are 120 Hz, 70 dB and 0.2 sec respectively, as they are the closest to natural speech (of an average man), spoken in a relatively quiet environment, and at a relatively normal speed. The vowels in the two words wrapping the test words, i.e. the first and the last word in the sentence have the following values:

I	(test word) (test word) *creatures.*
I	(test word) (test word) *blades*.
He'll	(test word) (test word) *later*.

F_0 = 98 Hz	F_0 = 98 Hz
Amplitude = 60 dB	Amplitude = 60 dB
Vowel length = 0.08 sec	Vowel length = 0.08 sec

(both vowels in polysyllabic words)

This is to make sure that these non-test words do not have values of F_0, vowel length and amplitude higher than that of the test words', so that the subjects would concentrate solely on the test words.

The just-noticeable difference for pitch perception is about 1 Hz, in the span of F_0 from 80 to 160 Hz (Flanagan, 1957: 534). The just-noticeable difference in intensity has a value of about 0.5 - 1 dB (Rodenburg, 1972) within the range of 20 dB to 100 dB (Miller, 1947). The just-noticable difference in duration between two sounds is about 10 - 40 msec (Lehiste, 1976: 226), which is 0.01 - 0.04 sec. These values serve as an important starting point to which the variations in the parameters are decided and manipulated. However, as they are values for just-noticeable differences, the values chosen for the variations must invariably be larger than these differences, so as to ensure that the listeners would be able to clearly distinguish the differences between the sounds they hear.

The first task was to determine the values for the step manipulations. A test involving 6 listeners was run prior to the execution of this experiment to get at a set of values that, when two test items were compared, they were audibly distinguishable. The vowels in the words, *see*, *saw* and *sue* were manipulated at the following values:

F_0 (Hz)	amplitude (dB)	vowel length (sec)
90	50	0.05
95	52	0.08
100	55	0.10
105	58	0.12
110	60	0.15
115	62	0.18
120	65	0.20
125	68	0.23
127	70	0.25
130	73	0.27
133	75	0.30
135	78	0.32
138	80	0.35
140	82	0.38
145	85	0.40

Table 3.1: The values for F_0, amplitude and vowel length used in pilot test in the determination of values for step manipulations.

When manipulating each parameter, the other two parameters were kept constant. For fundamental frequency, the lowest F_0 played was 90 Hz, the highest, 145 Hz, with difference between each manipulation as small as 2 Hz (125 Hz and 127 Hz). For amplitude, the lowest was 50 dB, and the highest, 85 dB, and the difference between each manipulation as small as 2 dB. Vowel length ranged from 0.05 sec to 0.40 sec, and similarly, the difference between the step manipulation as 0.02 sec.

Each subject was played all the manipulations, and was asked to compare 2 sounds, with different step manipulations. For example, the word *see* at 130 Hz was compared with the same word at 125 Hz, 127 Hz, 133 Hz, 135 Hz, 138 Hz and 140 Hz. The same went for amplitude and vowel length.

2 subjects were given the manipulations of the word *see*, 2 subjects were asked to listen to *saw* and the other 2 subjects, *sue*. Each subject was interviewed individually. Each interview session lasted 45 minutes.

Based on the responses of the 6 subjects, it was observed that a difference of 10 Hz for F_0, 5 dB for amplitude and 0.05 sec for vowel length were the smallest possible difference for the subjects to hear a distinction between two manipulations. Thus, the values chosen for the step manipulations are:

F_0 : 100 Hz, 110 Hz, 130 Hz and 140 Hz.

Amplitude : 60 dB, 65 dB, 75 dB and 80 dB.

Vowel length : 0.10 sec, 0.15 sec, 0.25 sec and 0.30 sec.

For 36 utterances (12 utterances per vowel set), the first test syllable was kept at the basic form (120 Hz, 70 dB, 0.2 sec), and the second test syllable had one parameter being manipulated at one time, with the other two parameters being held constant. The following shows the manipulation of the F_0, amplitude and length of the vowels:

Labels of the manipulations	**V1** (the vowel in the 1st test word)			**V2** (the vowel in the 2nd test word)		
F1	120 Hz	70 dB	0.20 sec	**100 Hz**	70 dB	0.20 sec
F2	120 Hz	70 dB	0.20 sec	**110 Hz**	70 dB	0.20 sec
F3	120 Hz	70 dB	0.20 sec	**130 Hz**	70 dB	0.20 sec
F4	120 Hz	70 dB	0.20 sec	**140 Hz**	70 dB	0.20 sec
I1	120 Hz	70 dB	0.20 sec	120 Hz	**60 dB**	0.20 sec
I2	120 Hz	70 dB	0.20 sec	120 Hz	**65 dB**	0.20 sec
I3	120 Hz	70 dB	0.20 sec	120 Hz	**75 dB**	0.20 sec
I4	120 Hz	70 dB	0.20 sec	120 Hz	**80 dB**	0.20 sec
D1	120 Hz	70 dB	0.20 sec	120 Hz	70 dB	**0.10 sec**
D2	120 Hz	70 dB	0.20 sec	120 Hz	70 dB	**0.15 sec**
D3	120 Hz	70 dB	0.20 sec	120 Hz	70 dB	**0.25 sec**
D4	120 Hz	70 dB	0.20 sec	120 Hz	70 dB	**0.30 sec**

Table 3.2: Values of the parameters manipulated for synthesis, manipulating 1 parameter at a time.

In the investigation of the relative strengths of the parameters, 36 utterances, similarly 12 utterances per vowel set were synthesised, this time, having two parameters manipulated at the same time, with both the first and the second vowel each having one parameter manipulated, and the remaining parameter kept constant. The following shows the manipulation of the F_0, amplitude and duration of the vowels:

Labels of the manipulations	V1			V2		
I1-F1	120 Hz	**60** dB	0.20 sec	**100 Hz**	70 dB	0.20 sec
F2-I2	**110** Hz	70 dB	0.20 sec	120 Hz	**65 dB**	0.20 sec
I3-F3	120 Hz	**75 dB**	0.20 sec	**130 Hz**	70 dB	0.20 sec
F4-I4	**140 Hz**	70 dB	0.20 sec	120 Hz	**80 dB**	0.20 sec
F1-D1	**100 Hz**	70 dB	0.20 sec	120 Hz	70 dB	**0.10 sec**
D2-F2	120 Hz	70 dB	**0.15 sec**	**110 Hz**	70 dB	0.20 sec
F3-D3	**130 Hz**	70 dB	0.20 sec	120 Hz	70 dB	**0.25 sec**
D4-F4	120 Hz	70 dB	**0.30 sec**	**140 Hz**	70 dB	0.20 sec
D1-I1	120 Hz	70 dB	**0.10 sec**	120 Hz	**60 dB**	0.20 sec
I2-D2	120 Hz	**65 dB**	0.20 sec	120 Hz	70 dB	**0.15 sec**
D3-I3	120 Hz	70 dB	**0.25 sec**	120 Hz	**75 dB**	0.20 sec
I4-D4	120 Hz	**80 dB**	0.20 sec	120 Hz	70 dB	**0.30 sec**

Table 3.3: Values of the parameters manipulated for synthesis, manipulating 2 parameters at one time.

Due to the constraint of time and energy, as well as the need to keep the listening test short for the subjects, not all possible permutations of the variations for each parameter were done. The manipulation was kept as systematic as possible, with each step manipulation of each parameter paired with the same for another parameter, for example, *D1* (duration manipulated to 0.1 sec) in the first vowel and *F1* (F_0 manipulated to 100 Hz). Different permutations of the parameters, for example *F1* (F_0 manipulated to 100 Hz) with *D4* (duration manipulated to 0.3 sec) may lead to different results from what is to be presented in the analysis later. The large number of permutations however makes it an impossible task for this research. This research therefore aims to provide a starting point for future research in this area.

All 72 utterances were randomised, and together with 8 filler utterances placed at the beginning, middle and end, the set of 80 utterances was recorded into a cassette tape.

3.2.5 Subjects

150 undergraduates with normal hearing from the National University of Singapore, aged between 19-27, partook in this experiment. There were 50 Chinese, 50 Malays and 50 Indians. Gender was not controlled.

The subjects were given a questionnaire which asked about the subject's linguistic profile before they were played the perception test (see Appendix I for questionnaire). This was to make sure that the subjects were native Singaporean speakers, and were bilingual speakers of English and their respective Mother Tongue (Mandarin for the Chinese subjects, Malay for the Malay subjects and Tamil for the Indian subjects).

All 150 subjects who took the perception test are Singaporean, and never lived abroad for more than 5 years. They are all bilingual in both English and their respective Mother Tongues. For the Chinese subjects, besides Mandarin, some can also speak other Chinese languages like Teochew, Hokkien, and Cantonese. For the Indian subjects, only those who speak Tamil as their Mother Tongue were asked to participate in this experiment. All the Malay subjects have Malay as their Mother Tongue. For all three groups of subjects, all of them use their respective Mother Tongue at least 50% of the time.

3.2.6 Listening Procedure

The subjects listened to the tapes in groups or individually. Each listening session had not more than 6 people at one time. The test was held in the sound-proof Phonetics Laboratory in the National University of Singapore. The tape was played to them using a good quality tape recorder.

They were given instructions in the questionnaire to listen to the tape carefully, and to tick the word in the sentence they felt was *prominent* (see Appendix I for response sheet). They were also given the choice to leave the option blank if they could not decide which word was the more prominent one. Each sentence was played twice. The whole listening test lasted 10 minutes.

3.2.7 Measurements and Analysis

The main concern of the analysis is to establish the percentage of listeners in their judgements of prominent syllables. The following section will discuss $F_{0,}$ amplitude, and duration as perceptual cues. All three vowel sets will be discussed to determine if spectral changes bring about effects in the perceptual cues of a particular parameter.

3.3 RESULTS

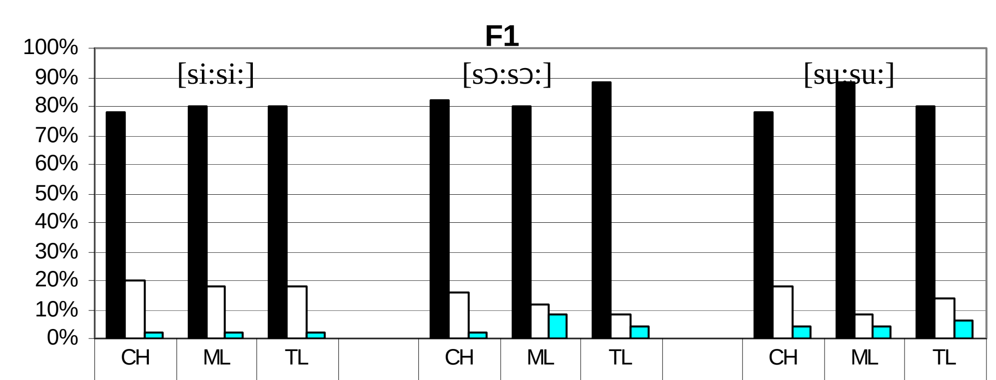
3.3.1 F_0 as a Perceptual Cue

The following section, sub-sectioned as *F1*, *F2*, *F3* and *F4* respectively, describes the four manipulations of fundamental frequency in one of the two vowels in each set of test words, [si:si:], [sɔ:sɔ:] and [su:su:]. The Chinese, Malay and Indian subjects' choice of the more prominent vowel is dependent upon a difference in fundamental frequency. Amplitude and duration are kept at the same value of 70 dB and 0.2 sec respectively for both vowels in each set of test words, in all four steps of manipulation. The following outlines in detail the percentages of the subjects' choice of the test word which they feel is more prominent.

F1: {V1 = 120 Hz, 70 dB, 0.2 sec and V2 = <u>100 Hz</u>, 70 dB, 0.2 sec}

In this manipulation, for all three vowel sets, [si:si:], [sɔ:sɔ:] and [su:su:], the difference between the first and the second test word in each set is 20 Hz. The vowel in the first test word has an F_0 at 120 Hz, and the second one has a lower F_0, at 100 Hz. Amplitude and duration are constant at 70 dB and 0.2 sec respectively.

Figure 3.1 shows the judgements of the Chinese, Malay and Indian subjects for all three vowel sets, [si:si:], [sɔ:sɔ:] and [su:su:] with F_0 as the only parameter manipulated in this first step manipulation.



	CH	ML	TL		CH	ML	TL		CH	ML	TL
■ V1	78%	80%	80%		82%	80%	88%		78%	88%	80%
□ V2	20%	18%	18%		16%	12%	8%		18%	8%	14%
□ NIL	2%	2%	2%		2%	8%	4%		4%	4%	6%

Fig. 3.1: Judgements of the Chinese, Malay and Indian subjects when V2 has F_0 = 100 Hz and V1 has F_0 = 120 Hz; length and amplitude constant at 0.2 sec and 70 dB.

As can be seen from Figure 3.1, all three groups of subjects consistently choose the test word containing the vowel with the higher F_0 as the more prominent item.

The majority of the Chinese subjects choose the higher pitched syllable as the stressed syllable. 78% of the Chinese subjects feel that the higher pitched [si:] and [su:] is more prominent than their lower pitched counterparts. The higher pitched [sɔ:] has as high as 82% of the Chinese subjects choosing it as the more prominent syllable. The percentages of the Chinese subjects choosing the lower pitched syllable as the more prominent item range remains below 20% in general. The percentages of neutral votes are at a low of 2% for [si:] and [sɔ:] and 4% for [su:].

For the Malay subjects, for all three sets of test words, more than 80% of them choose the higher pitched syllable as the more prominent item. 80% of the Malay subjects choose the higher pitched [si:] and [sɔ:] over their lower pitched counterparts as the more prominent syllable. The higher pitched [su:] even has up to 88% of the Malay subjects choosing it as the more prominent syllable. The percentages of the Malay subjects choosing the lower pitched syllable as the stressed syllable are generally low, falling below 18%. The percentages of neutral votes remain below 10%.

Similar to the Malay subjects, more than 80% of the Indian subjects, for all three sets of test words, choose the higher pitched test word as the more prominent item. 80% of the Indian subjects choose the higher pitched [si:] and [su:] as the more prominent syllable. The higher pitched [sɔ:] has up to 88% of the Indian subjects' vote as the more prominent item. The percentages of the Indian subjects choosing the lower pitched syllable fall below 20% across the three sets of test words. The percentages of neutral votes remain low, with 6% for [su:], 4% for [sɔ:] and a low of 2% of [si:].

F2: { V1 = 120 Hz, 70 dB, 0.2 sec and V2 = <u>110 Hz</u>, 70 dB, 0.2 sec}

In this manipulation, for all three sets of test words, the difference between vowel in the first test word and the vowel in the second test word in each set is 10 Hz. The vowel in the first test word has the F_0 at 120 Hz, and the second one has a lower F_0, at 110 Hz.

Figure 3.2 shows the judgements of the Chinese, Malay and Indian subjects for all three vowel sets, [si:si:], [sɔ:sɔ:] and [su:su:] in this second manipulation of F_0.

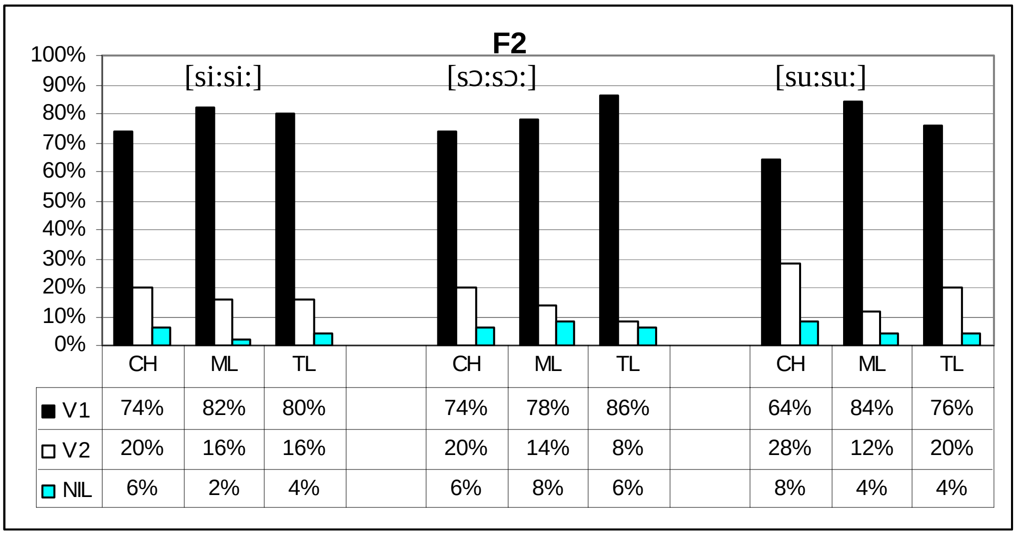


Fig. 3.2: Judgements of the Chinese, Malay and Indian subjects when V2 has F_0 = 110 Hz and V1 has F_0 = 120 Hz; length and amplitude constant at 0.2 sec and 70 dB.

When the difference in F_0 between the vowels in the two test words is only 10 Hz, as in this case, the situation begins to show a slight variation. As can be seen from Figure 3.2, while the majority of Malay and Indian subjects choose the higher pitched test word as the more prominent item, the percentages of the Chinese subjects making the same judgement are significantly lower. Across all three sets of test words, less than 75% of the Chinese subjects choose the higher pitched test words as the more prominent syllable.

Unlike what is seen in *F1*, the percentages of Chinese subjects choosing the higher pitched syllable as the stressed syllable is generally lower. 74% of the Chinese subjects feel that the higher pitched [si:] and [sɔ:] is more prominent than their lower pitched counterparts. However, less than two-thirds of the Chinese subjects feel that the higher pitched [su:] is more prominent, with only 64% of the Chinese subjects choosing it as the more prominent syllable. The percentages of the Chinese subjects choosing the lower pitched syllable as the more prominent syllable range from 20% for [si:] and [sɔ:] to a high of 28% for [su:]. The percentages of neutral votes however remain below 10%, with 6% for [si:] and [sɔ:] and 8% for [su:].

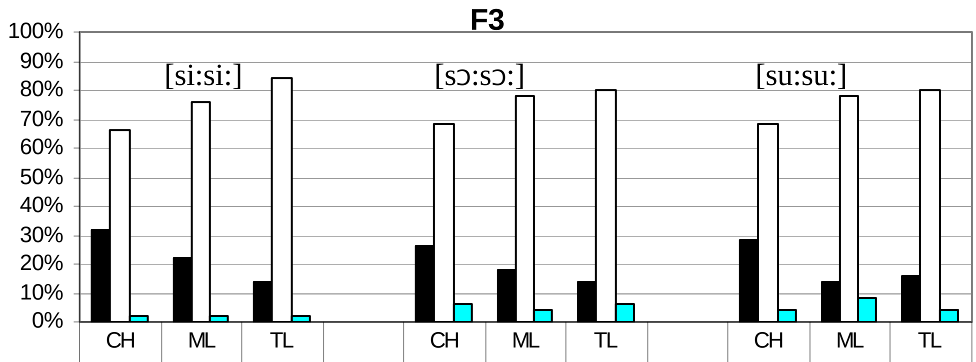
Similar to what is seen in *F1*, the majority of the Malay subjects remain true to judgement that the higher pitched syllable is the more prominent syllable. 78% of the Malay subjects choose the higher pitched [sɔ:] over its lower pitched counterpart as the more prominent syllable. The higher pitched [si:] has 82% of the subjects choosing it as the more prominent syllable. The higher pitched [su:] even has up to 84% of the Malay subjects choosing it as the stressed syllable. The percentages of the Malay subjects choosing the lower pitched syllable are generally low, with less than 20% across all three sets of test words. The percentages of neutral votes, across all three groups of test words, remain below 10%.

Similar to the Malay subjects, more than three-quarters of the Indian subjects, for all three sets of test words, choose the higher pitched test word as the more prominent syllable. 76% of the Indian subjects choose the higher pitched [su:] as the more prominent syllable. The higher pitched [si:] has 80% of the subjects choosing it as the more prominent syllable. The higher pitched [sɔ:] has up to 86% of the Indian subjects' vote as the more prominent syllable. The percentages of the Indian subjects choosing the lower pitched syllable in general, are below 20%. Just like the other two groups, the percentages of neutral votes remain low, with 6% for [sɔ:], and 4% for [si:] and [su:].

F3: { V1 = 120 Hz, 70 dB, 0.2 sec and V2 = <u>130 Hz</u>, 70 dB, 0.2 sec}

In this manipulation, for all three sets of test words, the difference between the vowel in the first test word and the vowel in the second test word in each set is 10 Hz. The vowel in the first test word has an F_0 at 120 Hz, and the second one has a higher F_0, at 130 Hz.

The judgements of the Chinese, Malay and Indian subjects for all three vowel sets, [si:si:], [sɔ:sɔ:] and [su:su:] in this third manipulation of F_0 is presented in Figure 3.3.



	CH	ML	TL		CH	ML	TL		CH	ML	TL
■ V1	32%	22%	14%		26%	18%	14%		28%	14%	16%
□ V2	66%	76%	84%		68%	78%	80%		68%	78%	80%
NIL	2%	2%	2%		6%	4%	6%		4%	8%	4%

Fig. 3.3: Judgements of the Chinese, Malay and Indian subjects when V2 has F_0 = 130 Hz and V1 has F_0 = 120 Hz; length and amplitude constant at 0.2 sec and 70 dB.

Similar to what is seen in *F2*, when the difference in F_0 between the vowels in the two test words is only 10 Hz, as in this case, the situation shows a slight variation away from what is seen in *F1*, especially for the Chinese subjects. As can be seen in Figure 3.3, while the Malay and Indian subjects still have more than 75% of the subjects choosing the higher pitched test words as the more prominent syllable, the percentages of the Chinese subjects making the same judgement are significantly lower, and it is even more so here, compared to what is seen in *F2*. Across all three vowel sets, less than 70% of the Chinese subjects choose the higher pitched test word as the more prominent syllable.

Only 68% of the Chinese subjects feel that the higher pitched [sɔ:] and [su:] is more prominent than their lower pitched counterparts and only 66% of the Chinese subjects choose the higher pitched [si:] as the more prominent syllable. The percentages of the Chinese subjects choosing the lower pitched syllable as the more prominent syllable range are high, compared to what is seen in *F1* and *F2*. 26% of the Chinese subjects choose the lower pitched [sɔ:] as the more prominent syllable. 28% of them choose the lower pitched [su:] as the more prominent syllable, and a high 32% choose the lower pitched [si:] as the prominent syllable. The percentages of neutral votes remain low, with 6% for [sɔ:], 4% for [su:] and only 2% for [si:].

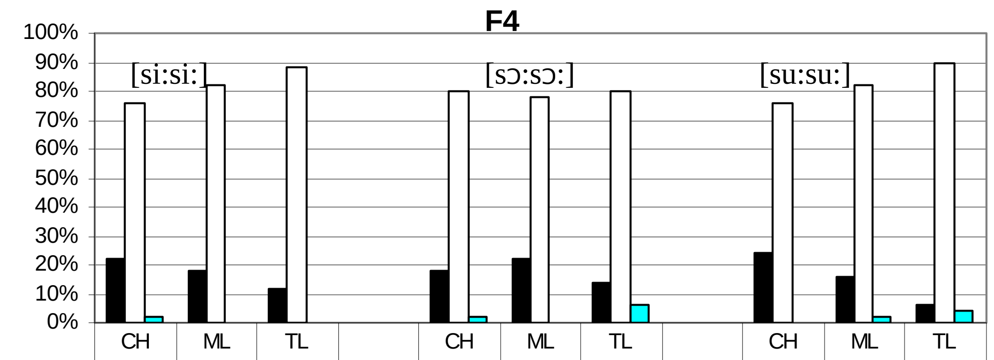
The majority of the Malay subjects, consistent with what is observed in *F1* and *F2*, choose the higher pitched test word as the more prominent syllable, regardless of the vowel. 78% of the Malay subjects choose the higher pitched [sɔ:] and [su:] over their lower pitched counterparts as the more prominent syllable. The higher pitched [si:] has 76% of the subjects choosing it as the more prominent syllable. Less than a quarter of the Malay subjects choose the lower pitched syllable as the more prominent item. The percentages of neutral votes remain below 10%, from 2% for [si:], 4% for [sɔ:] and 8% for [su:].

For the Indian subjects, in this instance, their choices are more marked than those of the Chinese and Malay subjects. More than 80% of the Indian subjects, consistently, for all three sets of test words, choose the higher pitched test word as the more prominent syllable. 80% of the Indian subjects choose the higher pitched [sɔ:] and [su:] as the more prominent syllable. The higher pitched [si:] has up to 84% of the Indian subjects' vote as the more prominent syllable. The percentages of the Indian subjects choosing the lower pitched syllable as the more prominent item are below 20% across all three sets of test words. The percentages of neutral votes are range around the 5% mark.

F4: {V1 = 120 Hz, 70 dB, 0.2 sec and V2 = 140 Hz, 70 dB, 0.2 sec}

In this manipulation, for all three sets of test words, the difference between the vowel in the first test word and the vowel in the second test word in each set is 20 Hz. The vowel in the first test word has the F_0 at 120 Hz, and the second one has a higher F_0, at 140 Hz.

Figure 3.4 shows the judgements of the Chinese, Malay and Indian subjects for all three vowel sets, [si:si:], [sɔ:sɔ:] and [su:su:] in this fourth step manipulation of F_0.



	CH	ML	TL		CH	ML	TL		CH	ML	TL
V1	22%	18%	12%		18%	22%	14%		24%	16%	6%
V2	76%	82%	88%		80%	78%	80%		76%	82%	90%
NIL	2%	0%	0%		2%	0%	6%		0%	2%	4%

Fig. 3.4: Judgements of the Chinese, Malay and Indian subjects when V2 has F_0 = 140 Hz and V1 has F_0 = 120 Hz; length and amplitude constant at 0.2 sec and 70 dB.

From Figure 3.4, it can be observed that all three groups of subjects consistently choose the test word containing the vowel with the higher F_0 as the more prominent item. All three groups of subjects, for all three sets of test words, similar to what is seen in *F1*, have over 75% of the subjects choosing the test word containing the vowel with the higher F_0 as the more prominent item.

Just like what is observed in *F1*, more than three-quarters of the Chinese subjects choose the higher pitched syllable as the stressed syllable. 76% of the Chinese subjects feel that the higher pitched [si:] and [su:] are more prominent than their lower pitched counterparts. The higher pitched [sɔ:] has as high as 80% of the Chinese subjects choosing it as the more prominent syllable. The percentages of the Chinese subjects choosing the lower pitched syllable as the more prominent item are generally low, compared to what is seen in *F2* and *F3*. Across all three sets of test items, less than a quarter of the Chinese subjects choose the lower syllable as the more prominent syllable. The percentage of neutral votes is almost negligible.

For the Malay subjects, for all the three sets of test words, more than 75% of them choose the higher pitched test word as the more prominent syllable. 76% of the Malay subjects choose the higher pitched [si:] over its lower pitched counterpart as the more prominent syllable. The higher pitched [sɔ:] and [su:] has even has up to 82% of the Malay subjects choosing it as the more prominent syllable. The percentages of the Malay subjects choosing the lower pitched syllable as the more prominent item are generally low. 22% of the Malay subjects choose the lower pitched [sɔ:] as the prominent syllable. 18% of the Malay subjects choose the lower pitched [si:] as the more prominent syllable, and 16% of them choosing the lower pitched [su:] as the more prominent syllable. The percentages of neutral votes are low, with 2% for [su:] and 0% for [si:] and [sɔ:].

For the Indian subjects, in this instance, their choices are more marked than those of the Chinese and Malay subjects. More than 80% of the Indian subjects, for all three sets of test words, consistently choose the higher pitched test word as the more prominent syllable. 80% of the Indian subjects choose the higher pitched [sɔ:] as the more prominent syllable. The higher pitched [si:] has up to 88% of the Indian subjects' vote as the more prominent syllable, and the higher pitched [su:] has a high 90% of the Indian subjects choosing it as the more prominent syllable. The percentages of the Indian subjects choosing the lower pitched syllable as the more prominent item are below 15% across the three sets of test words. Just like the other two groups, the percentages of neutral votes remain low, with 6% for [sɔ:], 4% for [su:] and 0% for [si:].

Higher or lower pitch?

As can be seen, all three groups of subjects, when faced between a choice between a higher pitched and lower pitched syllable, consistently feel that the higher pitched syllable is the more prominent item. The only difference is that while more than 75% of the Malay and Indian subjects choose the higher pitched syllable as the more prominent one, the Chinese subjects are more divided in their judgements. When the difference in the F_0 between the two test words is 20 Hz, more than 75% of the Chinese subjects would choose the higher pitched syllable as the more prominent one. However, when the difference in the F_0 between the two test words is reduced to only 10 Hz, the percentage of Chinese subjects choosing the higher pitched syllable drops to as low as 66%. This is not to say that the Chinese subjects use lower pitch to determine stress. Rather, the reason for the slight swing of judgement of stress for the lower pitched syllables is probably because, for some of the Chinese subjects, a difference of 10 Hz does not signal a difference in prominence. In this case, their choice of stress could be determined by their expectations of where the stress should be, from memory, or simply, guesswork, since amplitude and duration are exactly the same between the two test words. It is interesting that the results of the Chinese subjects are as such, for, Mandarin, being a tone language, and the Chinese subjects, having a tone language as Mother Tongue, should be even more aware and perhaps have a more acute sense of pitch differences. Yet, it may be precisely because the Chinese subjects speak a tone language, that when the difference in pitch is only 10 Hz, they hear it simply as a difference in tone, and not intonation. It may be because of this that this difference in pitch is not considered salient enough for them to perceive it as stress, compared to the speakers of the other two groups.

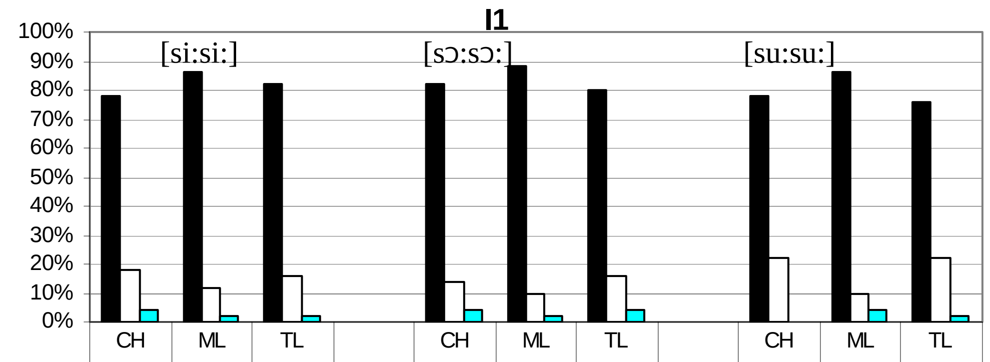
3.3.2 Intensity as a Perceptual Cue

The following section, sub-sectioned as *I1*, *I2*, *I3* and *I4* respectively, describes the four manipulations of amplitude in one of the two vowels in each set of test words, [si:si:], [sɔ:sɔ:] and [su:su:]. The Chinese, Malay and Indian subjects' choice of the more prominent vowel is dependent upon a difference in amplitude. Fundamental frequency and length are kept at the same value of 120 Hz and 0.2 sec respectively for both vowels in each set of test words, in all four steps of manipulation. The following outlines in detail the percentages of the subjects' choice of the test word which they feel is more prominent.

I1: { V1 = 70 dB, 0.2 sec, 120 Hz and V2 = <u>60 dB</u>, 0.2 sec, 120 Hz}

In this manipulation, for all three sets of test words, [si:si:], [sɔ:sɔ:] and [su:su:], the difference between the vowel in the first test word and the vowel in the second test word in each set is 10 dB. The first vowel has an amplitude of 70 dB, and the second one has a lower amplitude, at 60 dB. Fundamental frequency and duration are held constant at 120 Hz and 0.2 sec respectively.

Figure 3.5 shows the judgements of the Chinese, Malay and Indian subjects for all three vowel sets, [si:si:], [sɔ:sɔ:] and [su:su:] when amplitude is different between the vowels in the two target words.



	CH	ML	TL		CH	ML	TL		CH	ML	TL
■ V1	78%	86%	82%		82%	88%	80%		78%	86%	76%
□ V2	18%	12%	16%		14%	10%	16%		22%	10%	22%
□ NIL	4%	2%	2%		4%	2%	4%		0%	4%	2%

Fig. 3.5: Judgements of the Chinese, Malay and Indian subjects when V2 has amplitude = 60 dB and V1 has amplitude = 70 dB; length and F_0 constant at 0.2 sec and 120 Hz.

As can be seen from Figure 3.5, all three groups of subjects consistently choose the test word containing the vowel with the higher amplitude as the more prominent item.

The majority of the Chinese subjects use loudness to determine stress. 78% of the Chinese subjects feel that the louder [si:] and [su:] is more prominent than their softer counterparts. The louder [sɔ:] has as high as 82% of the Chinese subjects choosing it as the more prominent syllable. The percentages of the Chinese subjects choosing the softer syllable as the more prominent syllable range from 14% for [sɔ:], to 18% for [si:] and 22% for [su:]. The percentages of neutral votes are low, with 4% for [si:] and [sɔ:], and 0% for [su:].

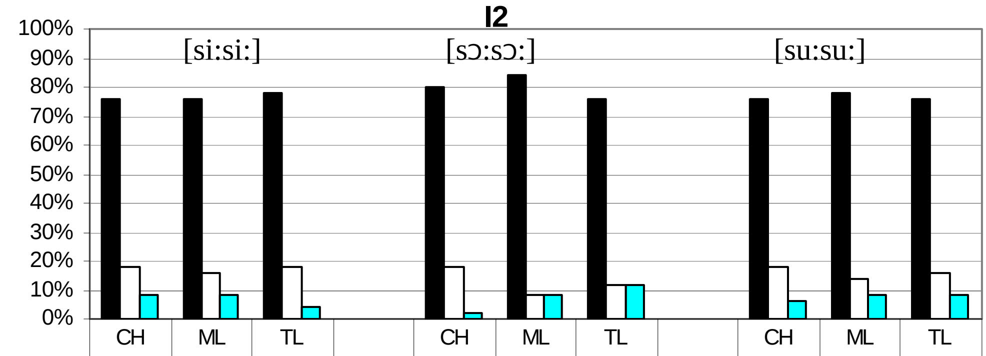
More than 85% of the Malay subjects consistently choose the louder test word as the more prominent syllable, for all the three sets of test words. 86% of the Malay subjects choose the louder [si:] and [su:] over their softer counterparts as the more prominent syllable. The louder [sɔ:] even has up to 88% of the Malay subjects choosing it as the more prominent syllable. The percentages of the Malay subjects choosing the softer syllable as the more prominent item are low, with less than 15% across all three sets of test words. The percentage of neutral votes is below 5%.

Similar to the other two groups of subjects, the Indian subjects consistently, across all three sets of test words, choose the louder syllable as the more prominent syllable. 76% of the Indian subjects choose the louder [su:] as the more prominent syllable and 80% of them choose the louder [sɔ:] as the more prominent syllable. The louder [si:] has 82% of the Indian subjects' vote as the more prominent syllable. The percentage of the Indian subjects choosing the softer syllable as the more prominent item is low, with 16% choosing the lower pitched [si:] and [sɔ:], and 22% choosing the lower pitched [su:] as the more prominent syllable. The percentage of neutral votes is below 5%.

I2: { V1 = 70 dB, 0.2 sec, 120 Hz and V2 = 65 dB, 0.2 sec, 120 Hz}

In this manipulation, for all three sets of test words, the difference between the vowel in the first test word and the vowel in the second test word in each set is 5 dB. The vowel in the first test word has an amplitude of 70 dB, and the vowel in the second test word has a lower amplitude, at 65 dB.

Figure 3.6 shows the judgements of the Chinese, Malay and Indian subjects for all three vowel sets, [si:si:], [sɔ: sɔ:] and [su:su:] in this second step manipulation of amplitude.



	[si:si:] CH	[si:si:] ML	[si:si:] TL		[sɔ:sɔ:] CH	[sɔ:sɔ:] ML	[sɔ:sɔ:] TL		[su:su:] CH	[su:su:] ML	[su:su:] TL
■ V1	76%	76%	78%		80%	84%	76%		76%	78%	76%
□ V2	18%	16%	18%		18%	8%	12%		18%	14%	16%
NIL	8%	8%	4%		2%	8%	12%		6%	8%	8%

Fig. 3.6: Judgements of the Chinese, Malay and Indian subjects when V2 has amplitude = 65 dB and V1 has amplitude = 70 dB; length and F_0 constant at 0.2 sec and 120 Hz.

Similar to what is seen in *I1*, all three groups of subjects consistently choose the test word containing the vowel with the higher amplitude as the more prominent item, even though the difference in amplitude between the vowels in the two test words is now reduced to 5 dB. This can be observed from Figure 3.6.

Similar to what is observed in *I1*, the majority of the Chinese subjects use loudness to determine stress. 76% of the Chinese subjects feel that the louder [si:] and [su:] is more prominent than their softer counterparts. The louder [sɔ:] has as high as 80% of the Chinese subjects choosing it as the more prominent syllable. The percentage of the Chinese subjects choosing the softer syllable as the more prominent syllable is 18% for all three sets of test words. The percentage of neutral votes is generally below 10%.

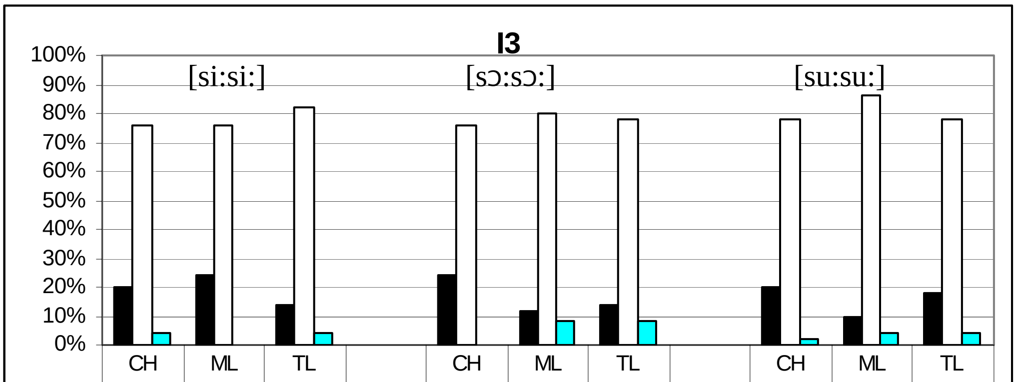
More than 85% of the Malay subjects, for all the three sets of test words, choose the louder test word as the more prominent syllable. 76% of the Malay subjects choose the louder [si:] over its softer counterpart as the more prominent syllable. 78% of the Malay subjects feel that the louder [su:] is the more prominent syllable. The louder [sɔ:] has up to 84% of the Malay subjects choosing it as the more prominent syllable. Less than 20% of the Malay subjects choose the softer syllable as the more prominent syllable. The percentage of neutral votes is 8% for all three sets of test words.

Similar to the other two groups of subjects, the Indian subjects consistently, across all three sets of test words, choose the louder syllable as the more prominent syllable. 76% of the Indian subjects choose the louder [sɔ:] and [su:] as the more prominent syllable and 78% of them choose the louder [si:] as the more prominent syllable. Less than 20% of the Indian subjects choose the softer syllable as the more prominent item. Unlike the other two groups though, the percentage of neutral votes is relatively high, compared to what is seen earlier in the previous sections, with up to 12%.

I3: { V1 = 70 dB, 0.2 sec, 120 Hz and V2 = 75 dB, 0.2 sec, 120 Hz}

In this manipulation, for all three sets of test words, the difference between the vowel in the first test word and the vowel in the second test word in each set is 5 dB. The vowel in the first test word has an amplitude of 70 dB, and the vowel in the second test word has a higher amplitude, at 75 dB.

Figure 3.7 shows the judgements of the Chinese, Malay and Indian subjects for all three vowel sets, [si:si:], [sɔ:sɔ:] and [su:su:] in this third step manipulation of amplitude.



	CH	ML	TL		CH	ML	TL		CH	ML	TL
■ V1	20%	24%	14%		24%	12%	14%		20%	10%	18%
□ V2	76%	76%	82%		76%	80%	78%		78%	86%	78%
NIL	4%	0%	4%		0%	8%	8%		2%	4%	4%

Fig. 3.7: Judgements of the Chinese, Malay and Indian subjects when V2 has amplitude = 75 dB and V1 has amplitude = 70 dB; length and F_0 constant at 0.2 sec and 120 Hz.

Similar to what is seen in *I1* and *I2*, all three groups of subjects consistently choose the test word containing the vowel with the higher amplitude as the more prominent item, as can be seen in Figure 3.7.

More than 75% of the Chinese subjects choose the louder syllable as the stressed syllable. 76% of the Chinese subjects feel that the louder [si:] and [sɔ:] are more prominent than their softer counterparts. 78% of the Chinese subjects choose the louder [su:] as the more prominent syllable. The percentage of the Chinese subjects choosing the softer syllable as the more prominent syllable is relatively high compared to what is seen in *I1* and *I2*, with slightly more than 20% of them making this judgement across all three sets of test words. The percentages of neutral votes are however low, at below 5% across all three sets of test words.

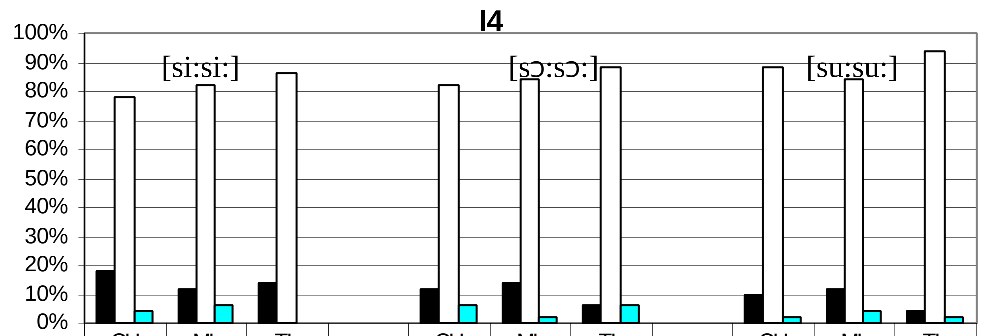
For the Malay subjects, for all the three sets of test words, more than 75% of them choose the louder test word as the more prominent syllable. 76% of the Malay subjects choose the louder [si:] over its softer counterpart as the more prominent syllable. 80% of the Malay subjects feel that the louder [sɔ:] is the more prominent syllable. The louder [su:] even has up to 86% of the Malay subjects choosing it as the more prominent syllable. The percentages of the Malay subjects choosing the softer syllable as the more prominent syllable range from 10% for [su:], 12% for [sɔ:] and a high of 24% for [si:]. The percentage of neutral votes is below 10% across all three sets of test words.

Similar to the other two groups of subjects, more than 75% of the Indian subjects consistently, across all three sets of test words, choose the louder syllable as the more prominent syllable. 78% of the Indian subjects choose the louder [sɔ:] and [su:] as the more prominent syllable and 82% of them choose the louder [si:] as the more prominent syllable. The percentage of the Indian subjects choosing the softer syllable is generally low, with less than 20% across the three sets of test words. The percentage of neutral votes is below 10% across all three sets of test words.

I4: {V1 = 70 dB, 0.2 sec, 120 Hz and V2 = 80 dB, 0.2 sec, 120 Hz}

In this manipulation, for all three sets of test words, the difference between the vowel in the first test word and the vowel in the second test word in each set is 10 dB. The vowel in the first test word has an amplitude of 70 dB, and the vowel in the second test word has a higher amplitude, at 80 dB.

Figure 3.8 shows the judgements of the Chinese, Malay and Indian subjects for all three vowel sets, [si:si:], [sɔ:sɔ:] and [su:su:] in this fourth step manipulation of amplitude.



	CH	ML	TL		CH	ML	TL		CH	ML	TL
V1	18%	12%	14%		12%	14%	6%		10%	12%	4%
V2	78%	82%	86%		82%	84%	88%		88%	84%	94%
NIL	4%	6%	0%		6%	2%	6%		2%	4%	2%

Fig. 3.8: Judgements of the Chinese, Malay and Indian subjects when V2 has amplitude = 80 dB and V1 has amplitude = 70 dB; length and F_0 constant at 0.2 sec and 120 Hz.

Similar to what is seen in *I1*, *I2* and *I3,* all three groups of subjects consistently choose the test word containing the vowel with the higher amplitude as the more prominent item. This can be seen in Figure 3.8.

A large majority of the Chinese subjects use loudness to determine stress. 78% of the Chinese subjects feel that the louder [si:] is more prominent than its softer counterpart. 82% of the Chinese subjects feel that the louder [sɔ:] is the more prominent syllable. The louder [su:] has up to 88% of the Chinese subjects choosing it as the more prominent syllable. The percentage of the Chinese subjects choosing the softer syllable as the more prominent syllable is below 20% across all three sets of test words. The percentages of neutral votes are however low, at below 10% across all three sets of test words.

More than 80% of the Malay subjects choose the louder test word as the more prominent syllable. 82% of the Malay subjects choose the louder [si:] over its softer counterpart as the more prominent syllable. The louder [sɔ:] and [su:] even has up to 84% of the Malay subjects choosing it as the more prominent syllable. The percentages of the Malay subjects choosing the softer syllable as the more prominent syllable are low, at below 15% across all three sets of test words. The percentage of neutral votes is below 10% across all three sets of test words, with 6% for [si:], 4% for [su:] and 2% for [sɔ:].

For the Indian subjects, in this instance, their choices are more marked than those of the Chinese and Malay subjects. More than 85% of the Indian subjects consistently, across all three sets of test words, choose the louder syllable as the more prominent syllable. 86% of the Indian subjects choose the louder [si:] as the more prominent syllable and 88% of them choose the louder [sɔ:] as the more prominent syllable. The louder [su:] even has up to a high of 94% of the Indian subjects choosing it as the more prominent syllable. The percentage of the Indian subjects choosing the softer syllable is generally low, ranging from 14% for [si:], 6% for [sɔ:] and a low of 4% for [su:]. Less than 10% of the Indian speakers choose to remain neutral.

Louder or Softer?

As can be seen, it is consistent across all three groups of subjects that the test word containing the louder vowel is perceived as the more prominent item, and this is so across the four different manipulations. Though for all the instances, the test word containing the louder vowel is perceived as the more prominent one, there is a suggestion that when the difference in amplitude between the two vowels is only 5 dB, the choice becomes more difficult to make, as can be seen in the slight increase in the percentage of neutral votes in these cases.

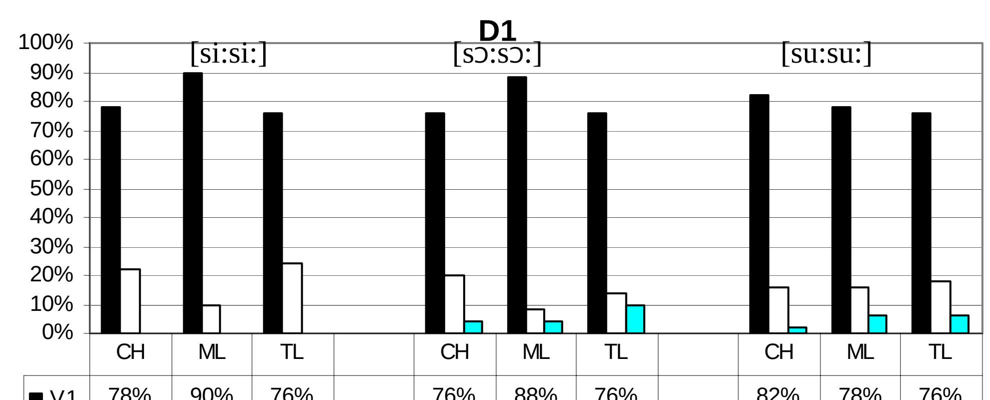
3.3.3 Duration as a Perceptual Cue

The following section, sub-sectioned as *D1*, *D2*, *D3* and *D4* respectively, describes the four manipulations of length in one of the two vowels in each set of test words, [si:si:], [sɔ:sɔ:] and [su:su:]. The Chinese, Malay and Indian subjects' choice of the more prominent vowel is dependant upon a difference in length. Amplitude and fundamental frequency are kept at the same value of 70 dB and 120 Hz respectively for both vowels in each set of test words, in all four steps of manipulation. The following outlines in detail the percentages of the subjects' choice of the test word which they feel is more prominent.

D1: { V1 = 0.2 sec, 70dB, 120 Hz and V2 = <u>0.1 sec</u>, 70 dB, 120 Hz}

In this manipulation, for all three sets of test words, [si:si:], [sɔ:sɔ:] and [su:su:], the difference in the vowel lengths of the first test word and the second test word in each set is 0.1 sec. The first vowel has a length of 0.2 sec, and the second one is shorter, at 0.1 sec. Fundamental frequency and amplitude are held constant at 120 Hz and 70 dB respectively.

Figure 3.9 shows the judgements of the Chinese, Malay and Indian subjects for all three vowel sets, [si:si:], [sɔ:sɔ:] and [su:su:] when vowel length is manipulated in this first step manipulation.



	CH	ML	TL		CH	ML	TL		CH	ML	TL
■ V1	78%	90%	76%		76%	88%	76%		82%	78%	76%
□ V2	22%	10%	24%		20%	8%	14%		16%	16%	18%
□ NIL	0%	0%	0%		4%	4%	10%		2%	6%	6%

Fig. 3.9: Judgements of the Chinese, Malay and Indian subjects when V2 has length = 0.1 sec and V1 has length = 0.2 sec; amplitude and F_0 constant at 70 dB and 120 Hz.

As can be seen in Figure 3.9, all three groups of subjects consistently choose the test word containing the longer vowel as the more prominent item.

More than three-quarters of the Chinese subjects use length to determine stress. 76% of the Chinese subjects feel that the longer [sɔ:] is more prominent than its shorter counterpart. 78% of the Chinese subjects choose the longer [si:] as the more prominent syllable. The longer [su:] has as high as 82% of the Chinese subjects choosing it as the more prominent syllable. The percentage of the Chinese subjects choosing the shorter syllable as the more prominent syllable ranges from 16% for [su:], to 20% for [sɔ:] and 22% for [si:]. The percentage of neutral votes is below 5%.

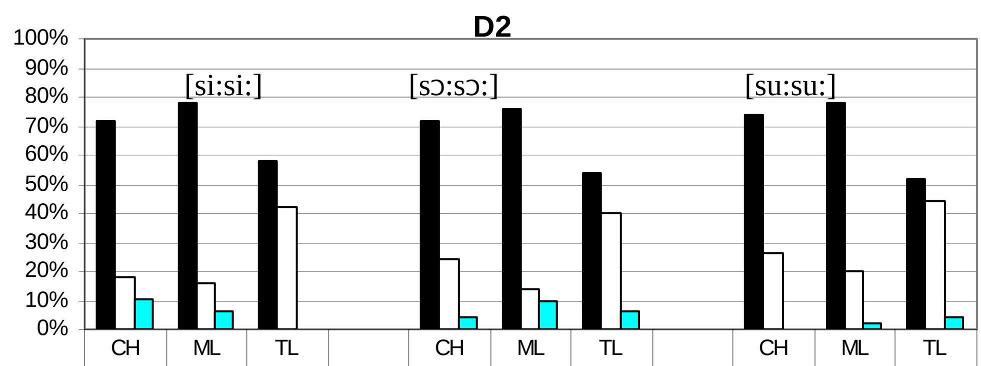
For the Malay subjects, for all the three sets of test words, more than 75% of them consistently choose the longer vowel as the more prominent syllable. 78% of the Malay subjects choose the longer [su:] over its shorter counterpart as the more prominent syllable. 88% of the Malay subjects choose the longer [sɔ:] as the more prominent syllable. The longer [si:] even has up to a high of 90% of the Malay subjects choosing it as the more prominent syllable. The percentage of the Malay subjects choosing the shorter syllable as the more prominent item is low, with less than 20% across all three sets of test words. The percentage of neutral votes remains below 10%.

Similar to the other two groups of subjects, the Indian subjects consistently, across all three sets of test words, choose the longer syllable as the more prominent syllable. 76% of the Indian subjects choose the longer test word as the more prominent syllable across the three sets of test words. Less than 25% of the Indian subjects choose the shorter syllable as the more prominent. Similar to the other two groups, the percentage of neutral votes is below 10%.

D2: {V1 = 0.2 sec, 70dB, 120 Hz and V2 = 0.15 sec, 70 dB, 120 Hz}

In this manipulation, for all three sets of test words, the difference in the vowel lengths of the first test word and the second test word in each set is 0.05 sec. The vowel in the first test word has a length of 0.2 sec, and the vowel in the second test word is shorter, at 0.15 sec.

Figure 3.10 shows the judgements of the Chinese, Malay and Indian subjects for all three vowel sets, [si:si:], [sɔ:sɔ:] and [su:su:] in this second step manipulation of vowel lengths in the two words.



	CH	ML	TL		CH	ML	TL		CH	ML	TL
■ V1	72%	78%	58%		72%	76%	54%		74%	78%	52%
□ V2	18%	16%	42%		24%	14%	40%		26%	20%	44%
NIL	10%	6%	0%		4%	10%	6%		0%	2%	4%

Fig. 3.10: Judgements of the Chinese, Malay and Indian subjects when V2 has length = 0.15 sec and V1 has length = 0.2 sec; amplitude and F_0 constant at 70 dB and 120 Hz.

When the difference in length between the vowels in the two test words is only 0.05 sec, as in this case, the situation begins to show a variation. As can be seen in Figure 3.10, while the Malay subjects still have more than 75% of the subjects choosing the longer test word as the more prominent item, the percentage of the Chinese subjects making the same judgement falls below 75%. Across all three sets of test words, less than 75% of the Chinese subjects choose the higher pitched test words as the more prominent syllable. For the Indian subjects, the drop in percentage is even more drastic. In fact, in this set of test materials, the percentage of Indian subjects choosing the longer test word drops below 60%.

As compared to what is seen in *D1*, the percentage of Chinese subjects choosing the longer test word has dropped, falling below 75% across the three sets of test words. 74% of the Chinese subjects feel that the longer [su:] is more prominent than its shorter counterpart. Only 72% of the Chinese subjects choose the longer [si:] and [sɔ:] as the more prominent syllable. The percentage of the Chinese subjects choosing the shorter syllable as the more prominent syllable has also increased from what is seen in *D1*, ranging from 18% for [si:], to 24% for [sɔ:] and a high of 26% for [su:]. The percentage of neutral votes, similar to the case in *D1*, is below 10%.

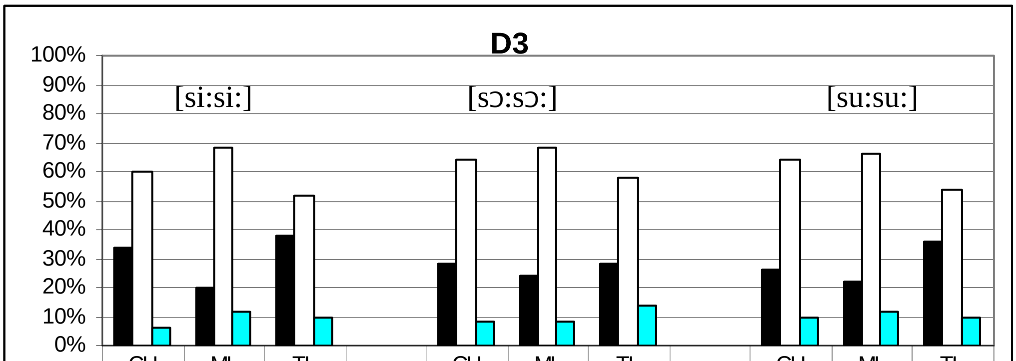
For the Malay subjects, for all the three sets of test words, similar to what is seen in *D1*, more than 75% of them choose the longer vowel as the more prominent syllable. 78% of the Malay subjects choose the longer [si:] and [su:] over their shorter counterparts as the more prominent syllable. 76% of the Malay subjects choose the longer [sɔ:] as the more prominent syllable. In general, less than 20% of the Malay subjects choose the shorter syllable as the more prominent item. The percentage of neutral votes is low, at around 10%.

As compared to what is seen in *D1*, the percentage of Indian subjects choosing the longer test word has dropped drastically, falling below 60% across the three sets of test words. Only 58% of the Indian subjects choose the longer [si:] as the more prominent syllable, and 54% of them choose the longer [sɔ:] as the more prominent item. A low 52% of the Indian subjects choose the longer [su:] as the more prominent item. As expected, the percentage of the Indian subjects choosing the shorter syllable as the more prominent item is high with slightly less than half of the Indian subjects choosing the shorter test words as the more prominent word, as compared to their longer counterparts. 40% of the Indian subjects feel that the shorter [sɔ:] is more prominent, and 42% of them feel that a shorter [si:] is more prominent. A high 44% of the Indian subjects feel that the shorter [su:] is the more prominent item. Similar to what is observed in the other two groups, the percentage of neutral votes is below 10%.

D3: { V1 = 0.2 sec, 70dB, 120 Hz and V2 = <u>0.25 sec</u>, 70 dB, 120 Hz}

In this manipulation, for all three sets of test words, the difference in the vowel lengths of the first test word and the second test word in each set is 0.05 sec. The vowel in the first test word has a length of 0.2 sec, and the vowel in the second test word is longer, at 0.25 sec.

Figure 3.11 shows the judgements of the Chinese, Malay and Indian subjects for all three vowel sets, [si:si:], [sɔ:sɔ:] and [su:su:] in this third step manipulation of vowel length.



	CH	ML	TL		CH	ML	TL		CH	ML	TL
■ V1	34%	20%	38%		28%	24%	28%		26%	22%	36%
□ V2	60%	68%	52%		64%	68%	58%		64%	66%	54%
■ NIL	6%	12%	10%		8%	8%	14%		10%	12%	10%

Fig. 3.11: Judgements of the Chinese, Malay and Indian subjects when V2 has length = 0.25 sec and V1 has length = 0.2 sec; amplitude and F_0 constant at 70 dB and 120 Hz.

In this set of test materials, the test word containing the longer vowel is in the second position, and the difference in vowel length between the two test words is 0.05 sec. While this difference in length is similar to that as seen in *D2*, the change in the position of the test words seem to have an impact on the judgements of the subjects, especially for the Chinese and Malay subjects. As can be seen in Figure 3.11, less than 60% of the Indian subjects choose the longer test word as the more prominent item, not unlike the situation in *D2*. For the Chinese subjects however, the percentage of Chinese subjects choosing the test word containing the longer vowel as the more prominent item drops below 65%, a slight fall from the 70% range as seen in *D2*. The drop for the Malay subjects is the most dramatic, with less than 70% of the Malay subjects choosing the longer test word as the more prominent syllable, a significant fall from the above 75% range in as seen in *D2*.

As compared to what is seen in *D1* and *D2*, the percentage of Chinese subjects choosing the longer test word has dropped, falling below 65% across the three sets of test words. 64% of the Chinese subjects feel that the longer [sɔ:] and [su:] are more prominent than their shorter counterparts. Only 60% of the Chinese subjects choose the longer [si:] as the more prominent syllable. The percentage of the Chinese subjects choosing the shorter syllable as the more prominent syllable, as expected, has also increased from what is seen in *D1* and *D2*, ranging from 26% for [su:], to 28% for [sɔ:] and a high of 34% for [si:]. The percentage of neutral votes remains low, at about 10%.

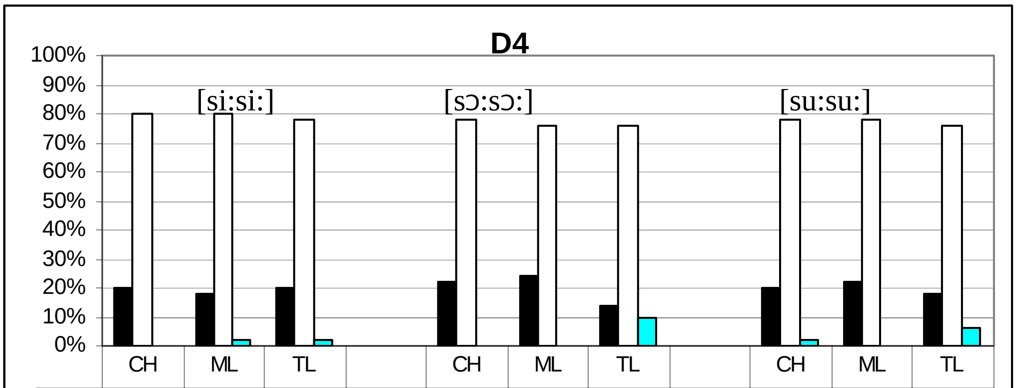
For the Malay subjects, for all the three sets of test words, unlike what is seen in *D1* and *D2*, has less than 70% of them choosing the longer vowel as the more prominent syllable. Only 68% of the Malay subjects choose the longer [si:] and [sɔ:] over their shorter counterparts as the more prominent syllable. A low 66% of the Malay subjects choose the longer [su:] as the more prominent syllable. The percentage of the Malay subjects choosing the shorter syllable as the more prominent item, as expected, has also increased, and they range from 20% for [si:], 22% for [su:] and 24% for [sɔ:]. The percentage of neutral votes has also increased slightly, hitting 12%.

Similar to what is seen in *D2*, the percentage of Indian subjects choosing the longer test word remains below 60% across the three sets of test words. Only 58% of the Indian subjects choose the longer [sɔ:] as the more prominent syllable, and 54% of them choose the longer [su:] as the more prominent item. A low 52% of the Indian subjects choose the longer [si:] as the more prominent item. As expected, the percentage of the Indian subjects choosing the shorter syllable as the more prominent item is high with 38% of them choosing the shorter [si:], 36% choosing a shorter [su:] and 28% choosing the shorter [sɔ:] is the more prominent item. The percentage of neutral votes is also at a relatively high 15%.

D4: { V1 = 0.2 sec, 70dB, 120 Hz and V2 = 0.3 sec, 70 dB, 120 Hz}

In this manipulation, for all three sets of test words, the difference in the vowel lengths of the first test word and the second test word in each set is 0.1 sec. The vowel in the first test word has a length of 0.2 sec, and the vowel in the second test word is longer, at 0.3 sec.

Figure 3.12 shows the judgements of the Chinese, Malay and Indian subjects for all three vowel sets, [si:si:], [sɔ:sɔ:] and [su:su:] in this fourth step manipulation of vowel length.



	CH	ML	TL		CH	ML	TL		CH	ML	TL
■ V1	20%	18%	20%		22%	24%	14%		20%	22%	18%
□ V2	80%	80%	78%		78%	76%	76%		78%	78%	76%
□ NIL	0%	2%	2%		0%	0%	10%		2%	0%	6%

Fig. 3.12: Judgements of the Chinese, Malay and Indian subjects when V2 has length = 0.3 sec and V1 has length = 0.2 sec; amplitude and F_0 constant at 70 dB and 120 Hz.

With the difference in vowel length at 0.1 sec, the situation looks similar to what is seen in *D1*. All three groups of subjects consistently choose the test word containing the longer vowel as the more prominent item, as can be seen in Figure 3.12.

Up to 80% of the Chinese subjects choose the longer syllable as the stressed syllable. 78% of the Chinese subjects feel that the longer [sɔ:] and [su:] are more prominent than their shorter counterparts. 80% of the Chinese subjects choose the longer [si:] as the more prominent syllable. The percentage of the Chinese subjects choosing the shorter syllable as the more prominent syllable is 20% for [si:] and [su:], to 22% for [sɔ:]. The percentage of neutral votes is below 5%.

More than 75% of the Malay subjects, for all the three sets of test words, choose the longer vowel as the more prominent syllable. 76% of the Malay subjects choose the longer [sɔ:] over its shorter counterpart as the more prominent syllable. 78% of the Malay subjects choose the longer [su:] and 80% choose the longer [si:] as the more prominent syllable.

Less than 25% of the Malay subjects choose the shorter syllable as the more prominent syllable. The percentage of neutral votes is almost negligible.

Similar to what is observed in the other two groups of subjects, the Indian subjects also, in this case, choose the longer syllable as the more prominent syllable. 76% of the Indian subjects choose the longer [sɔ:] and [su:], and 78% choose the longer [si:] as the more prominent syllable. Up to 20% of the Indian subjects choose the shorter syllable as the more prominent item. The percentage of neutral votes is at about 10%.

Longer or Shorter?

Several remarks can be made about duration as a perceptual cue at this point:

(1) When the difference between the two vowels is 0.1 sec, all three groups of subjects consistently feel that the test word containing the longer vowel is the more prominent item, with more than 75% of each group of subjects choosing the longer test word as the more prominent item, across all three sets of test words.

(2) When the difference between the two vowels is only 0.05 sec, and when the longer vowel precedes the shorter one, only the Malay and Chinese subjects (though the Chinese subjects less so), still maintain that the test word containing the longer vowel is the more prominent item. The Indian subjects are rather divided in this case, with almost half of them choosing the shorter test word as the more prominent item.

(3) When the difference between the two vowels is 0.05 sec, and the shorter vowel precedes the longer vowel, the judgements across all three groups of subjects are divided. Less than 70% of the subjects agree that the test word containing the longer vowel is the more prominent item. For the Indian subjects, less than 60% of them feel that the longer test word is the more prominent item.

It can be concluded, from the four manipulations of vowel length as we see here, that longer vowel length is indeed a cue of stress for all three groups of subjects, albeit the interesting patterns seen in *D2* for the Indian subjects, and particularly *D3*, for three groups of subjects. The reason why a difference of 0.05 sec is the only instance when the Indian subjects have a divided response is perhaps because this difference in vowel length is not large enough for them to clearly tell that there is a difference in vowel length between the two test words. Being unable to clearly tell a difference in length, their responses could be due to their expectations of where the stress should be. They could perhaps also be hazarding a guess as to where the stress is, as they could not tell the difference between the two target words. Thus, it is not to say that the Indian subjects use a shorter vowel length to determine stress. Rather, what can be concluded is that the Indian subjects face a difficulty in deciding stress when the difference in length is not obvious to them, and in this case, a difference of 0.05 sec.

When it comes to *D3*, it is interesting to note that the Chinese and Malay subjects have a larger percentage of their population voting for the shorter test word as the more prominent item, i.e., the subjects feel that the verb in the test materials is more prominent, even though it is 0.05 sec shorter than the following noun. Based on what is shown earlier, there is simply not enough data and evidence to show that this phenomenon is a systematic one, and not a case of coincidence or subjects' idiosyncrasies. However, if one were to hazard a reason for this occurrence, it is perhaps because the noun, at least for *saw* and *sea*, is followed by another noun. For example, in the test sentence, *I* ***see sea*** *creatures*, *sea* (noun) is followed by *creatures* (noun). In this case, there is a tendency for SE speakers to assign stress to the second noun, regardless of whether the lexical item is a compound or a noun phrase (unlike in BrE where stress placement determines if the lexical item is a compound or noun phrase). This phenomenon is noted by researchers such as Tongue (1974) and Platt and Weber (1980). In the case where the subjects could not make a clear distinction between the two test words in the test materials, their natural tendency is to put stress on the second noun. However, since they were not given the choice to assign stress to the second noun, and they feel that the first noun cannot be the prominent one, their choice automatically swings over to the verb.

More tests concentrating on this area could perhaps be conducted to show if the reasoning stands. At this point, this phenomenon can at best only be a possibility.

3.3.4 Comparisons between [si:], [sɔ:] and [su:]

There are no observable patterns to be seen in the Judgements of stress by the three groups of subjects with regard to the three different vowels in the test materials. In other words, there is no particular vowel(s) which the subjects feel are more prominent than others.

3.3.5 Comparison between the Relative Strengths of Each Perceptual Cue

From the last section, it has been established that all three groups of subjects feel that higher pitched syllables, longer syllables and louder syllables are more prominent that lower pitched syllables, shorter syllables and softer syllables, albeit with some interesting irregularities within the results.

What has not been established so far is the relative strength of each perceptual cue for each group of subjects. In other words, given, for example, a higher pitched but shorter syllable compared to a lower pitched but longer syllable, which syllable would the listener feel is more prominent?

This next section explores this question. As mentioned earlier, there are 36 utterances that have two parameters manipulated, with one parameter kept constant. For this, both target words would be manipulated at the same time, one parameter in each word. For example, if the first vowel had the F_0 manipulated, the second vowel would have either the duration or amplitude manipulated.

The parameters were manipulated systematically. For example, if one is to compare the relative strengths of pitch and duration, and if the first vowel had F_0 manipulated to 100 Hz (as in *F1*), then the second vowel would have the vowel length manipulated to 0.1 sec (as in *D1*). The ideal scenario would be to have a permutation of all the different manipulations to see how the different combinations of step differences with each different parameter would affect the judgements of the subjects. However, due to the constraint of time, space and energy, and the sheer amount of listening the subjects would have to go through, a complete permutation of all the different manipulations was not physically possible. What was decided is the most orderly and systematic permutation that one can achieve within the constraints.

From the last section, it has been established that there is no pattern associated with the subjects' judgements on stress between the three vowels, [iː], [ɔː] and [uː] in the test materials. In this next section, the figures seen will be a composition of responses for all three sets of test words, without describing the three vowels separately. The percentages of the subjects' responses are expected to be more divided than those seen in the earlier section. The general thrust of the analysis will be to look at the where the majority votes are, and from there make a comparison between the different groups and manipulations.

For each comparison of perceptual cues, there will be four sub-sections describing the four different step manipulations. The positions of the test words manipulated are rotated systematically. In other words, if vowel length and intensity, for example, are being compared, then there will be two instances in which vowel length is manipulated in the first vowel, and two instances of manipulation of vowel length in the second vowel, and vice-versa for intensity. This is to make sure that the position of the words, and the phonetic properties manipulated have no influence on the subjects' judgement of stress.

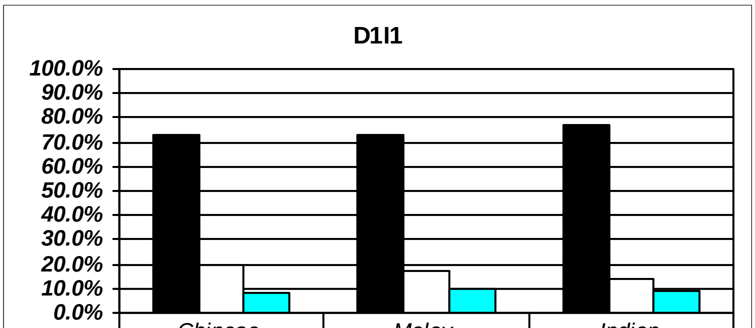
3.3.5.1 The Relative Strength of Duration and Intensity as Perceptual Cues

The following section, sub-sectioned as *D1-I1, I2-D2, D3-I3,* and *I4-D4* respectively, describes the four manipulations of vowel length and intensity, of manipulation each in each vowel for the test words, [si:si:], [sɔ:sɔ:] and [su:su:]. The letter *D* refers to duration, and the letter *I*, intensity; and these are the properties manipulated. The numbers correlate to the step manipulation, the same as that of the earlier section. In the test word in which vowel length is manipulated, amplitude and F_0 are constant at 70 dB and 120 Hz. In the test word in which the amplitude is being manipulated, F_0 and vowel length are kept constant at 120 Hz and 0.2 sec. The result of it will be a comparison between a test word that is longer and softer, versus one that is shorter but louder. The Chinese, Malay and Indian subjects' choice of the more prominent test word is dependant upon which perceptual cue they listen out for when given a choice between loudness and length. The following outlines in detail the percentages of the subjects' choice of the test word which they feel is more prominent.

D1-I1: { V1 = 120 Hz, 70 dB, <u>0.1 sec</u> and V2 = 120 Hz, <u>60 dB</u>, 0.2 sec}

In this manipulation, for all three sets of test words, [si:si:], [sɔ:sɔ:] and [su:su:], the difference between the vowel in the first test word and the vowel in the second test word in each set is 0.1 sec and 10 dB. The first vowel has a length of 0.1 sec and amplitude of 70 dB, and the second one is longer, at 0.2 sec, but softer, at 60 dB. F_0 is constant at 120 Hz.

Figure 3.13 shows the judgements of the Chinese, Malay and Indian subjects when they are made to choose between the louder but shorter first vowel and the softer but longer second vowel.



	Chinese	Malay	Indian
V1	72.7%	72.7%	77.3%
V2	19.3%	17.3%	14.0%
NIL	8.0%	10.0%	8.7%

Fig. 3.13: Judgements of the Chinese, Malay and Indian subjects when V1 has length = 0.1 sec, amplitude = 70 dB and V2 has length = 0.2 sec, amplitude = 60 dB; F_0 constant at 120 Hz.

As can be seen from Figure 3.13, all three groups of subjects, for all three sets of test words, have a percentage of over 70% choosing the word containing the louder but shorter vowel as the more prominent item.

72.7% of the Chinese subjects feel that the louder, but shorter test word is more prominent than its shorter counterpart. The percentages of the Chinese subjects choosing the longer but softer syllable as the more prominent syllable is low, at only 19.3%. The percentage of neutral votes is at 8%.

For the Malay subjects, similar to that of the Chinese subjects, 72.7% of them choose the test word containing the louder but shorter vowel as the more prominent syllable. The percentage of the Malay subjects choosing the softer but longer syllable as the more prominent item is at 17.3%. The percentage of neutral votes is at 10%.

More marked than the other two groups of subjects, more than 75% of the Indian subjects choose the louder but shorter syllable as the more prominent syllable. 77.3% of the Indian subjects choose the louder but shorter test word as the more prominent syllable. The percentage of the Indian subjects choosing the longer but softer syllable as the more prominent item range is at only 14%. As like the other two groups, the percentage of neutral votes is low, at only 8.7%.

I2-D2: { V1 = 120 Hz, 65 dB, 0.2 sec and V2 = 120 Hz, 70 dB, 0.15 sec}

In this second manipulation, the difference between the vowel in the first test word and the vowel in the second test word in each set is 0.05 sec and 5 dB. The first vowel has a length of 0.2 sec and amplitude of 65 dB, and the second one is louder, at 70 dB, but shorter, at 0.15 sec.

Figure 3.14 shows the judgements of the Chinese, Malay and Indian subjects when they are made to choose between the softer but longer first vowel and the louder but shorter second vowel in this second manipulation of amplitude and vowel length.

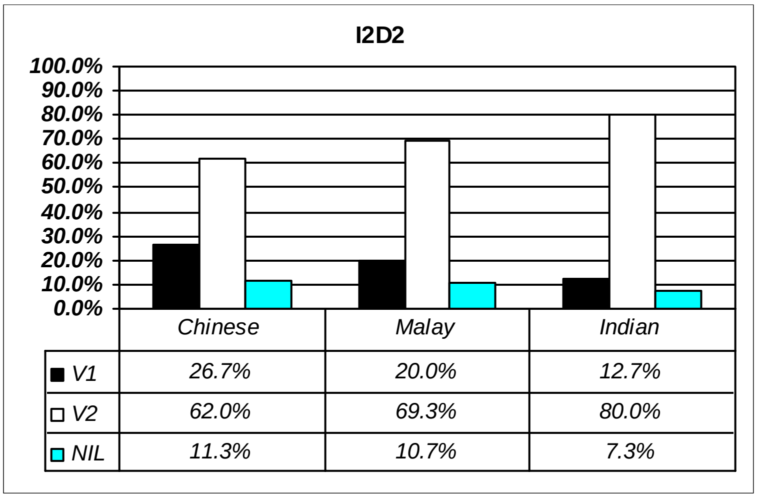


Fig. 3.14: Judgements of the Chinese, Malay and Indian subjects when V1 has length = 0.2 sec, amplitude = 65 dB and V2 has length = 0.15 sec, amplitude = 70 dB; F_0 constant at 120 Hz.

Similar to what is seen in *D1-I1*, all three groups of subjects consistently choose the test word containing the louder but shorter vowel as the more prominent item. However, as can be see in Figure 3.14, the percentage of Chinese subjects and Malay subjects making this option has gone down compared to that in *D1-I1*. Less than 70% of the Chinese and Malay subjects choose the second word as the more prominent item. The Indian subjects however maintain a high percentage of above 75%.

Only 62% of the Chinese subjects feel that the louder, but shorter test word is more prominent than its shorter counterpart. The percentage of the Chinese subjects choosing the longer but softer syllable as the more prominent syllable is above 25%, at 26.7%. The percentage of neutral votes is at 11.3%.

For the Malay subjects, similar to that of the Chinese subjects, only 69.3% of them choose the test word containing the louder but shorter vowel as the more prominent syllable. The percentage of the Malay subjects choosing the softer but longer syllable as the more prominent item is at 20%. The percentage of neutral votes is at 10.7%.

The choice made by the Chinese and Malay subjects is not surprising, since the difference in amplitude is now only 5 dB, compared to 10 dB, as in *D1-I1*. The number of subjects swinging their votes over to choose the longer but softer test word as the more prominent item will no doubt increase.

Unlike the other two groups of subjects, the Indian subjects are very sure about which syllable is more prominent. 80% of the Indian subjects choose the louder but shorter test word as the more prominent syllable. The percentage of the Indian subjects choosing the longer but softer syllable as the more prominent item range is below 15%, at only 12.7%. The percentage of neutral votes is below 10%, at only 7.3%. The Indian subjects consistently, despite the fact that the difference in amplitude is only 5 dB, choose the louder syllable, when they are made to choose between a longer and a louder syllable.

D3-I3: { V1 = 120 Hz, 70 dB, <u>0.25 sec</u> and V2 = 120 Hz, <u>75 dB</u>, 0.2 sec}

In this manipulation, the difference between the vowel in the first test word and the vowel in the second test word in each set is 0.05 sec and 5 dB. The first vowel has a length of 0.25 sec and amplitude of 70 dB, and the second one is louder, at 75 dB, but shorter, at 0.2 sec.

Figure 3.15 shows the judgements of the Chinese, Malay and Indian subjects when they are made to choose between the softer but longer first vowel and the louder but shorter second vowel in this third manipulation of amplitude and vowel length.

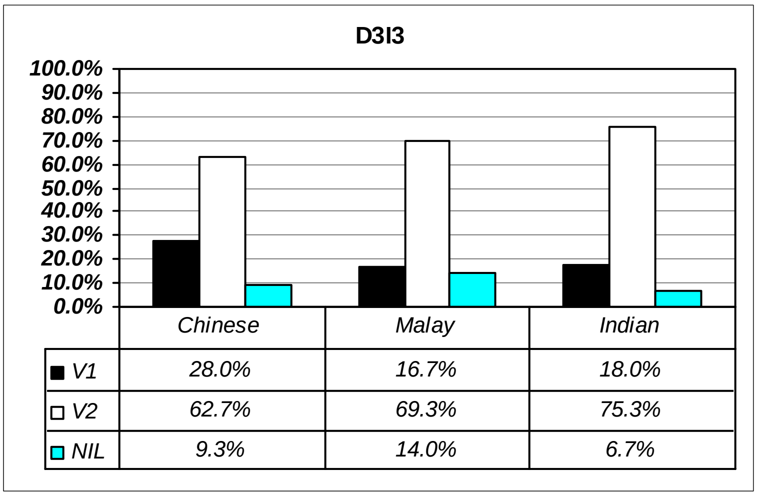


Fig. 3.15: Judgements of the Chinese, Malay and Indian subjects when V1 has length = 0.25 sec, amplitude = 70 dB and V2 has length = 0.2 sec, amplitude = 75 dB; F_0 constant at 120 Hz.

Similar to what is seen in *I2-D2*, while all three groups of subjects consistently choose the test word containing the louder but shorter vowel as the more prominent item. However, as shown in Figure 3.15, the percentage of Chinese subjects and Malay subjects making this option has gone down compared to that in *D1-I1*. Less than 70% of the Chinese and Malay subjects choose the second word as the more prominent word. Similarly, the Indian subjects maintain a high percentage of above 75%.

Only 62.7% of the Chinese subjects feel that the louder, but shorter test word is more prominent than its shorter counterpart. The percentage of the Chinese subjects choosing the longer but softer syllable as the more prominent syllable is above 25%, at 28%. The percentage of neutral votes is below 10%, at 9.3%.

For the Malay subjects, similar to that of the Chinese subjects, only 69.3% of them choose the test word containing the louder but shorter vowel as the more prominent syllable. The percentage of the Malay subjects choosing the softer but longer syllable as the more prominent item is less than 20%, at 16.7%. The percentage of neutral votes is at 14%.

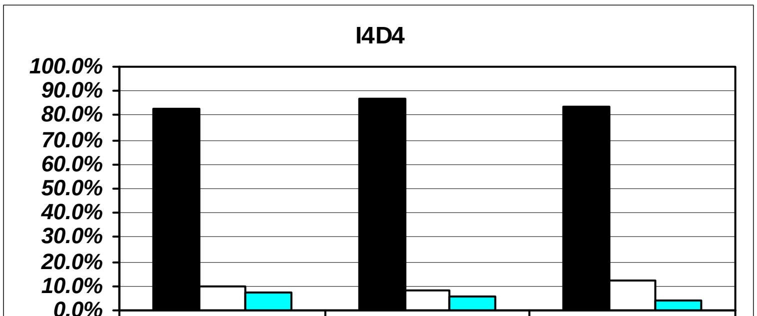
Consistent to what is seen in *I2*-D2, the choice made by the Chinese and Malay subjects is not surprising, since the difference in amplitude is only 5 dB, like the case in *I2-D2*.

Unlike the other two groups of subjects, the Indian subjects again, like the case in *I2*-D2, have more than 75% of them consistently choosing the louder but shorter syllable as the more prominent syllable. The percentage of the Indian subjects choosing the longer but softer syllable as the more prominent item range is at only 18%. The percentage of neutral votes is below 10%, at only 6.7%. The Indian subjects confirm again, despite the fact that the difference in amplitude is only 5 dB, that when they are made to choose between a longer and a louder syllable, they would choose the louder one.

I4-D4: { V1 = 120 Hz, <u>80 dB</u>, 0.2 sec and V2 = 120 Hz, 70 dB, <u>0.3 sec</u>}

In this manipulation, the difference between the vowel in the first test word and the vowel in the second test word in each set is 0.1 sec and 10 dB. The first vowel has a length of 0.2 sec and amplitude of 80 dB, and the second one is longer, at 0.3 sec, but softer, at 70 dB.

Figure 3.16 shows the judgements of the Chinese, Malay and Indian subjects when they are made to choose between the louder but shorter first vowel and the softer but longer second vowel in this fourth manipulation of amplitude and vowel length.



	Chinese	Malay	Indian
V1	82.7%	86.7%	84.0%
V2	10.0%	8.0%	12.0%
NIL	7.3%	5.3%	4.0%

Fig. 3.16: Judgements of the Chinese, Malay and Indian subjects when V1 has length = 0.2 sec, amplitude = 80 dB and V2 has length = 0.3 sec, amplitude = 70 dB; F_0 constant at 120 Hz.

Similar to the situation in *D1-I1*, all three groups of subjects consistently choose the test word containing the louder but shorter vowel as the more prominent item. As can be seen from Figure 3.16, all three groups of subjects, for all three sets of test words, have a high percentage of over 80% choosing the word containing the louder but shorter vowel as the more prominent item.

82.7% of the Chinese subjects feel that the louder, but shorter test word is more prominent than its shorter counterpart. The percentage of the Chinese subjects choosing the longer but softer syllable as the more prominent syllable is low, at only 10%. The percentage of neutral votes is below 10%, at 7.3%.

The majority of the Malay subjects, like the Chinese subjects, choose the test word containing the louder but shorter vowel as the more prominent syllable. A high 86.7% of the Malay subjects feel that the louder but shorter syllable is the stressed syllable. Only 8% of the Malay subjects choose the softer but longer syllable as the more prominent item. The percentage of neutral votes is low, at 5.3%.

84% of the Indian subjects choose the louder but shorter test word as the more prominent syllable. The percentage of the Indian subjects choosing the longer but softer syllable as the more prominent item range is 12%. As like the other two groups, the percentage of neutral votes is at a low 4%.

Louder but shorter or Longer but softer?

When the subjects are made to choose between a louder but shorter word and a longer but softer word, their choice is for the former. For the Indian subjects, the choice is especially clear, with more than 75% of them preferring amplitude to length in all four manipulations. For the Chinese and Malay subjects, when the difference in amplitude is 5 dB, there is a slight swing of the votes over to the longer but softer word. On the whole however, intensity is more dominant than length for all three groups of subjects.

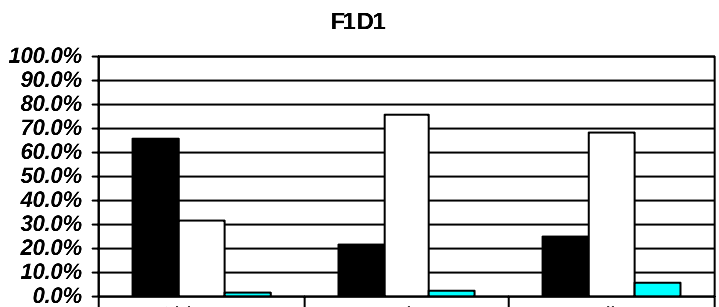
3.3.5.2 The Relative Strength of Duration and F_0 as Perceptual Cues

The following section, sub-sectioned as *F1-D1, D2-F2, F3-D3* and *D4-F4* respectively, describes the four manipulations of fundamental frequency and duration, of manipulation each in each vowel for the test words, [si:si:], [sɔ:sɔ:] and [su:su:]. In the test word in which vowel length is manipulated, amplitude and F_0 will be kept constant at 70 dB and 120 Hz. In the test word in which the F_0 is being manipulated, amplitude and vowel length will be kept constant at 70 dB and 0.2 sec. The result of it will be a comparison between a test word that has a higher pitch and shorter, versus one that is has a lower pitch but longer. The Chinese, Malay and Indian subjects’ choice of the more prominent test word is dependant upon which perceptual cue they listen out for when given a choice between F_0 and length. The following outlines in detail the percentages of the subjects’ choice of the test word which they feel is more prominent.

F1-D1: {V1 = 100 Hz, 70 dB, 0.2 sec and V2 = 120 Hz, 70 dB, 0.1 sec}

In this manipulation, for all three sets of test words, [si:si:], [sɔ:sɔ:] and [su:su:], the difference between the vowel in the first test word and the vowel in the second test word in each set is 0.1 sec and 20 Hz. The first vowel has a length of 0.2 sec and F_0 at 100 Hz, and the second one has a higher pitch, at 120 Hz, but shorter, at 0.1 sec. Amplitude is held constant at 70 dB.

Figure 3.17 shows the judgements of the Chinese, Malay and Indian subjects when they are made to choose between the lower pitched but longer first vowel and the higher pitched but shorter second vowel.



	Chinese	Malay	Indian
V1	66.0%	21.3%	25.3%
V2	32.0%	76.0%	68.7%
NIL	2.0%	2.7%	6.0%

Fig. 3.17: Judgements of the Chinese, Malay and Indian subjects when V1 has F_0 = 100 Hz, length = 0.2 sec and V2 has F_0 = 120 Hz, length = 0.1 sec; amplitude held constant 70 dB.

As can be seen from Figure 3.17, there is a clear difference in choice of test words, particularly for the Chinese subjects. While the Malay and Indian subjects consistently choose the test word containing the higher pitched but shorter vowel as the more prominent item, the Chinese subjects’ choice is clearly different. More than 65% of the Chinese subjects feel that the word containing the lower pitched but longer vowel is the more prominent word.

66% of the Chinese subjects feel that the lower pitched, but longer test word is more prominent than its shorter but higher pitched counterpart. The percentage of the Chinese subjects choosing the longer but softer syllable as the more prominent syllable is at 32%. The percentage of neutral votes is low, at 2%.

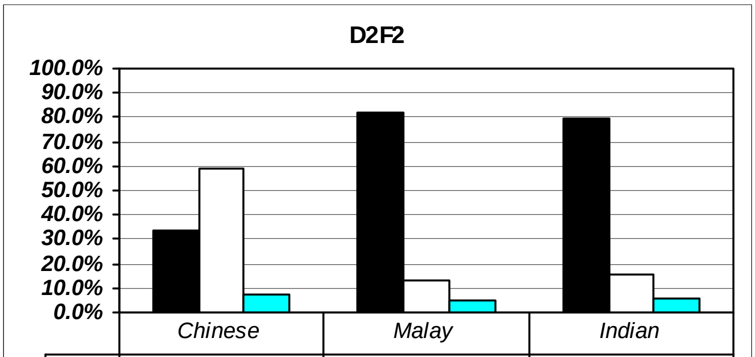
The situation is different for the Malay subjects. 76% of the Malay subjects choose the test word containing the higher pitched but shorter vowel as the more prominent syllable. The percentage of the Malay subjects choosing the lower pitched but longer syllable as the more prominent item is at 21.3%. The percentage of neutral votes is low, at 2.7%.

Like the Malay subjects, a relatively large percentage of the Indian subjects choose the higher pitched but shorter test word as the more prominent syllable. 68.7% of this group of speakers feel that pitch is more salient a perceptual cue compared to length. About quarter of the Indian subjects choosing the longer but lower pitched syllable as the more prominent item. Like the other two groups, the percentage of neutral votes is low, at 6%.

D2-F2: { V1 = 120 Hz, 70 dB, 0.15 sec and V2 = 110 Hz, 70 dB, 0.2 sec}

In this manipulation, the difference between the vowel in the first test word and the vowel in the second test word in each set is 0.05 sec and 10 Hz. The first vowel has a length of 0.15 sec and F_0 at 120 Hz, and the second one is longer, at 0.2 sec, but lower, at 110 Hz.

Figure 3.18 shows the judgements of the Chinese, Malay and Indian subjects when they are made to choose between the higher pitched but shorter first vowel and the lower pitched but longer second vowel in this second manipulation of vowel length and F_0.



	Chinese	Malay	Indian
V1	33.3%	82.0%	79.3%
V2	59.3%	13.3%	15.3%
NIL	7.3%	4.7%	5.3%

Fig. 3.18: Judgements of the Chinese, Malay and Indian subjects when V1 has F_0 = 120 Hz, length = 0.15 sec and V2 has F_0 = 110 Hz, length = 0.2 sec; amplitude held constant at 70 dB.

The situation here is no different from what is observed in *F1-D1*. As can be seen in Figure 3.18, more than 80% of the Malay and Indian subjects consistently choose the test word containing the higher pitched but shorter vowel as the more prominent item. For the Chinese subjects however, the choice is clearly different. About 60% of the Chinese subjects feel that the word containing the lower pitched but longer vowel is the more prominent word.

Length, for the Chinese speakers, is a more reliable perceptual cue to stress, compared to pitch. Almost 60% of the Chinese subjects feel that the lower pitched, but longer test word is more prominent than its shorter but higher pitched counterpart. The percentage of the Chinese subjects choosing the longer but softer syllable as the more prominent syllable is at 33.3%. The percentage of neutral votes is low, at 7.33%.

For the Malay subjects, a higher pitched syllable is more prominent than a longer syllable. 82% of the Malay subjects choose the test word containing the higher pitched but shorter vowel as the more prominent syllable. The percentage of the Malay subjects choosing the lower pitched but longer syllable as the more prominent item is at only 13.3%. The percentage of neutral votes is low, at 4.7%.

Like the Malay subjects, the Indian subjects also feel that a higher pitched syllable is more prominent than a longer one. Almost 80% of the Indian subjects choose the higher pitched but shorter test word as the more prominent syllable. The percentage of the Indian subjects choosing the longer but lower pitched syllable as the more prominent item is at 15.3%. Like the other two groups, the percentage of neutral votes is below 10%.

F3-D3: {V1 = 130 Hz, 70 dB, 0.2 sec and V2 = 120 Hz, 70 dB, 0.25 sec}

In this manipulation, the difference between the vowel in the first test word and the vowel in the second test word in each set is 0.05 sec and 10 Hz. The first vowel has a length of 0.2 sec and F_0 at 130 Hz, and the second one is longer, at 0.25 sec, but lower, at 120 Hz.

Figure 3.19 shows the judgements of the Chinese, Malay and Indian subjects when they are made to choose between the higher pitched but shorter first vowel and the lower pitched but longer second vowel in this third manipulation of vowel length and F_0.

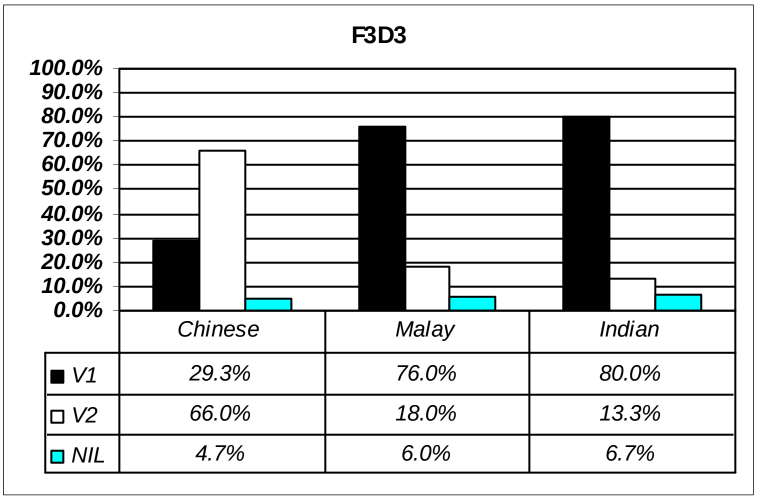


Fig. 3.19: Judgements of the Chinese, Malay and Indian subjects when V1 has F_0 = 130 Hz, length = 0.2 sec and V2 has F_0 = 120 Hz, length = 0.25 sec; amplitude held constant at 70 dB.

In this set of test materials, the result is similar to that seen in *F1-D1* and *D2-F2.* As can be seen in Figure 3.19, more than 75% of the Malay and Indian subjects consistently choose the test word containing the higher pitched but shorter vowel as the more prominent item. For the Chinese subjects however, not unlike what is observed in *F1-D1* and *D2-F2,* more than 65% of the Chinese subjects feel that the word containing the lower pitched but longer vowel is the more prominent word.

Two-thirds of the Chinese subjects listen out for length as a perceptual cue for stress, compared to pitch. 66% of the Chinese subjects feel that the lower pitched, but longer test word is more prominent than its shorter but higher pitched counterpart. The percentage of the Chinese subjects choosing the longer but softer syllable as the more prominent syllable is at 29.3%. The percentage of neutral votes is below 5%.

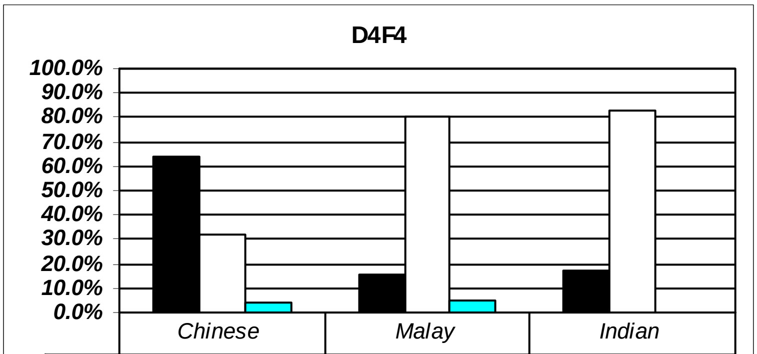
The Malay subjects, unlike the Chinese subjects, tend toward pitch as a perceptual cue, compared to length. 76% of them choose the test word containing the higher pitched but shorter vowel as the more prominent syllable. Less than 20% of the Malay subjects choose the lower pitched but longer syllable as the more prominent item. The percentage of neutral votes is low, at 6%.

Like the Malay subjects, a high 80% of the Indian subjects choose the higher pitched but shorter test word as the more prominent syllable. The percentage of the Indian subjects choosing the longer but lower pitched syllable as the more prominent item is below 15%. Like the other two groups, the percentage of neutral votes is below 10%.

D4-F4: {V1 = 120 Hz, 70 dB, <u>0.3 sec</u> and V2 = <u>140 Hz</u>, 70 dB, 0.2 sec}

In this manipulation, the difference between the vowel in the first test word and the vowel in the second test word in each set is 0.1 sec and 20 Hz. The first vowel has a length of 0.3 sec and F_0 at 120 Hz, and the second one is higher, at 140 Hz, but shorter, at 0.2 sec.

Figure 3.20 shows the judgements of the Chinese, Malay and Indian subjects when they are made to choose between the lower pitched but longer first vowel and the higher pitched but shorter second vowel in this fourth manipulation of vowel length and F_0.



	Chinese	Malay	Indian
V1	64.0%	15.3%	17.3%
V2	32.0%	80.0%	82.7%
NIL	4.0%	4.7%	0.0%

Fig. 3.20: Judgements of the Chinese, Malay and Indian subjects when V1 has F_0 = 120 Hz, length = 0.3 sec and V2 has F_0 = 140 Hz, length = 0.2 sec; amplitude held constant at 70 dB.

Despite the fact that the second test word has a high pitch of 140Hz, the Chinese subjects still confirm that the longer but lower pitched syllable is more prominent. As can be seen in Figure 3.20, more than 60% of the Chinese subjects feel that the word containing the lower pitched but longer vowel is the more prominent word. Similar to what is seen in the previous three sub-sections, more than 80% of the Malay and Indian subjects consistently choose the test word containing the higher pitched but shorter vowel as the more prominent item.

64% of the Chinese subjects feel that the lower pitched, but longer test word is more prominent than its shorter but higher pitched counterpart. The percentage of the Chinese subjects choosing the longer but softer syllable as the more prominent syllable is at 32%. The percentage of neutral votes is low below 5%.

For the Malay subjects, a high 80% of them choose the test word containing the higher pitched but shorter vowel as the more prominent syllable. The percentage of the Malay subjects choosing the lower pitched but longer syllable as the more prominent item is at only 15.3%. The percentage of neutral votes is low, at 4.7%.

A high 82.7% of the Indian subjects choose the higher pitched but shorter test word as the more prominent syllable. Less than 20% of the Indian subjects choose the longer but lower pitched syllable as the more prominent item.

Higher pitched but shorter or longer but lower pitched?

As can be seen, when the subjects are made to choose between F_0 and duration as perceptual cues, the results are very consistent. The Malay and Indian subjects very consistently, with high percentages, choose the word containing the higher pitched but shorter test word as the more prominent item. The Chinese subjects however differ. In every single instance, they consistently choose the word containing the longer but lower pitched test word as the more prominent item.

The results are consistent with what is found in the earlier sections of *F1* to *F4*, and *D1* to *D4*. In the earlier sections, it has been found that the Chinese subjects, when faced with two test words with only a difference of 10 Hz, their judgements are more divided. Yet, they are very consistent when they decide that the test word containing the longer vowel is more prominent than the one containing the shorter vowel. In this case, when asked to make a decision between higher pitch and longer vowel length, it is not surprising that the test word containing the longer vowel is chosen as the more prominent one. As mentioned earlier, it is perhaps because the Chinese subjects hear the difference in pitch as a tonal change, rather than an intonational device that marks stress, much like how the tonal system works in Mandarin. Duration, on the other hand, makes a difference in cueing stress.

It is not surprising as well that the Indian subjects would choose the higher pitched but shorter test word as the more prominent syllable. As seen in the earlier sections for *D1* to *D4*, when the difference in vowel length between the two test words is 0.05 sec, the Indian subjects' responses are almost split half. Yet, in *F1* to *F4*, they very consistently, with high percentages, judge that the higher pitched test word is the more prominent item. As such, it is no wonder that a higher pitch would be the determining factor of stress for the Indian subjects, compared to longer vowel length.

3.3.5.3 The Relative Strength of Intensity and F_0 as Perceptual Cues

The following section, sub-sectioned as *I1-F1, F2-I2, I3-F3,* and *F4-I4* respectively, describes the four manipulations of fundamental frequency and intensity, of manipulation each in each vowel for the test words, [si:si:], [sɔ:sɔ:] and [su:su:]. In the test word in which F_0 is manipulated, amplitude and duration will be kept constant at 70 dB and 0.2 sec. In the test word in which the amplitude is being manipulated, F_0 and duration will be kept constant at 120 Hz and 0.2 sec. The result of it will be a comparison between a test word that has a higher pitch and softer, versus one that has a lower pitch but louder. The Chinese, Malay and Indian subjects' choice of the more prominent test word is dependant upon which perceptual cue they listen out for when given a choice between loudness and pitch. The following outlines in detail the percentages of the subjects' choice of the test word which they feel is more prominent.

I1-F1: {V1 = 120 Hz, <u>60 dB</u>, 0.2 sec and V2 = <u>100 Hz</u>, 70 dB, 0.2 sec}

In this manipulation, for all three sets of test words, [si:si:], [sɔ:sɔ:] and [su:su:], the difference between the vowel in the first test word and the vowel in the second test word in each set is 10 dB and 20 Hz. The first vowel has an amplitude of 60 dB and F_0 of 120 Hz, and the second one is louder, at 70 dB, but lower, at 100 Hz. Vowel length is held constant at 0.2 sec.

Figure 3.21 shows the judgements of the Chinese, Malay and Indian subjects when they are made to choose between the higher pitched but softer first vowel and the lower pitched but louder second vowel.

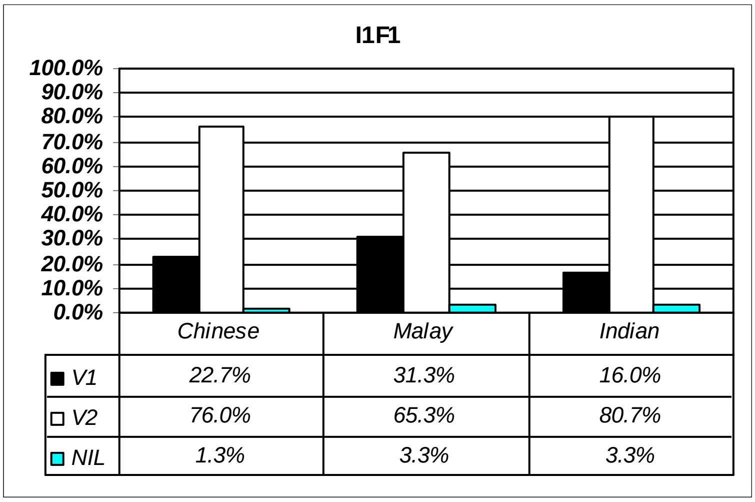


Fig. 3.21: Judgements of the Chinese, Malay and Indian subjects when V1 has F_0 = 120 Hz, amplitude = 60dB and V2 has F_0 = 100 Hz, amplitude = 70 dB; vowel length held constant at 0.2 sec.

As can be seen from Figure 3.21, all three groups of subjects consistently choose the test word containing the louder but lower pitched vowel as the more prominent item. The Chinese and Indian subjects have a high percentage of over 75% choosing the louder but lower pitched test word as the more prominent syllable. However, less than 70% of the Malay subjects make the same judgement.

76% of the Chinese subjects feel that the louder, but lower pitched test word is more prominent than its shorter but higher pitched counterpart. Less than 25% of the Chinese subjects choose the higher pitched but softer syllable as the more prominent syllable. The percentage of neutral votes is at only 1.3%.

Compared to the Chinese speakers, the percentage of Malay speakers preferring amplitude over pitch is slightly lower, with 65.3% of them choosing the test word containing the louder but lower pitched vowel as the more prominent syllable. The percentage of the Malay subjects choosing the softer but higher pitched syllable as the more prominent item is relatively high, at 31.3%. The percentage of neutral votes is at 3.3%.

More marked than the other two groups of subjects, more than 80% of the Indian subjects choose the louder but lower pitched syllable as the more prominent syllable. The percentage of the Indian subjects choosing the higher pitched but softer syllable as the more prominent item range is at only 16%. Like the other two groups, the percentage of neutral votes is below 5%.

F2-I2: {V1 = <u>110 Hz</u>, 70 dB, 0.2 sec and V2 = 120 Hz, <u>65 dB</u>, 0.2 sec}

In this manipulation, the difference between the vowel in the first test word and the vowel in the second test word in each set is 5 dB and 10 Hz. The first vowel has an amplitude of 70 dB and F_0 at 110 Hz, and the second one is higher, at 120 Hz, but softer, at 65 dB.

Figure 3.22 shows the judgements of the Chinese, Malay and Indian subjects when they are made to choose between the lower pitched but louder first vowel and the higher pitched but softer second vowel in this second manipulation of amplitude and F_0.

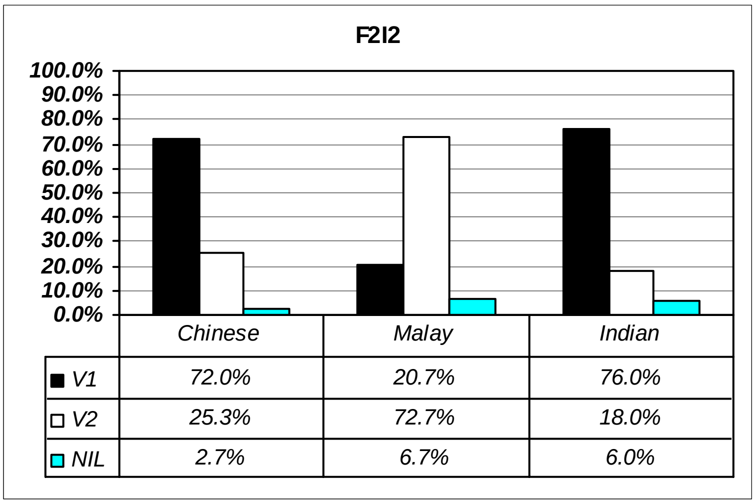


Fig. 3.22: Judgements of the Chinese, Malay and Indian subjects when V1 has F_0 = 110 Hz, amplitude = 70 dB and V2 has F_0 = 120 Hz, amplitude = 65 dB; vowel length held constant at 0.2 sec.

Unlike the situation in *I1-F1* where the difference in amplitude between the two vowels in the two test words is only 10 dB, in this case, the difference is 5 dB. It can be seen from Figure 3.22 that the Malay subjects swing their judgements over to the higher pitched but softer test word, with more than 70% of the Malay subjects feel that the higher pitched but softer test word is more prominent. The Chinese and Indian subjects however are still consistent in their judgements. More than 70% of each group of speakers choose the louder but lower pitched test word as the more prominent syllable.

72% of the Chinese subjects feel that the louder, but lower pitched test word is more prominent than its shorter but higher pitched counterpart. About a quarter of the Chinese subjects choose the higher pitched but softer syllable as the more prominent syllable. The percentage of neutral votes is below 5%.

For the Malay subjects, however, only 20.7% of them choose the test word containing the louder but lower pitched vowel as the more prominent syllable. The percentage of the Malay subjects choosing the softer but higher pitched syllable as the more prominent item is an overwhelming majority of 72.7%. This situation is the exact opposite of what is observed in *I1-F1*.

The Indian subjects' judgements remain true to what is observed earlier in *I1-F1*. 76% of the Indian subjects choose the louder but lower pitched test word as the more prominent syllable. The percentage of the Indian subjects choosing the higher pitched but softer syllable as the more prominent item range is at only 18%. The percentage of neutral votes is at 6%.

I3-F3: {V1 = 120 Hz, <u>75 dB</u>, 0.2 sec and V2 = <u>130 Hz</u>, 70 dB, 0.2 sec}

In this manipulation, the difference between the vowel in the first test word and the vowel in the second test word in each set is 5 dB and 10 Hz. The first vowel has an amplitude of 75 dB and F_0 at 120 Hz, and the second one is higher, at 130 Hz, but softer, at 70 dB.

Figure 3.23 shows the judgements of the Chinese, Malay and Indian subjects when they are made to choose between the lower pitched but louder first vowel and the higher pitched but softer second vowel in this third manipulation of amplitude and F_0.

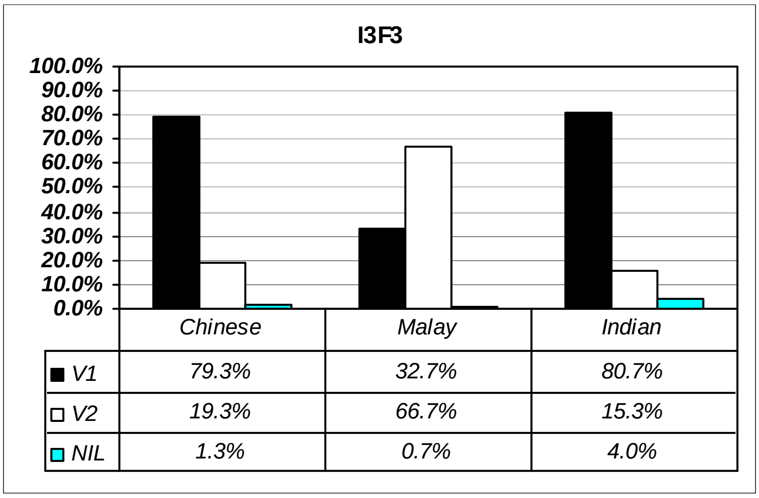


Fig. 3.23: Judgements of the Chinese, Malay and Indian subjects when V1 has F_0 = 120 Hz, amplitude = 75 dB and V2 has F_0 = 130 Hz, amplitude = 70 dB; vowel length held constant at 0.2 sec.

Like the situation in *F2-I2*, the difference in the amplitude of the two vowels is 5 dB. As can be seen from Figure 3.23, the situation is consistent to what is seen earlier in *F2-I2*. The Malay subjects swing their judgements over to the higher pitched but softer test word, with more than 65% of the Malay subjects choosing the higher pitched but softer test word as the stressed syllable. The Chinese and Indian subjects however are still consistent in their judgements, with nearly 80% of each group of speakers choosing the louder but lower pitched test word as the more prominent syllable.

Nearly 80% of the Chinese subjects feel that the louder, but lower pitched test word is more prominent than its shorter but higher pitched counterpart. The percentage of the Less than 20% of the Chinese subjects choose the higher pitched but softer syllable as the more prominent syllable. The percentage of neutral votes is low, at 1.3%.

For the Malay subjects, only 32.7% of them choose the test word containing the louder but lower pitched vowel as the more prominent syllable. About two-thirds of the Malay subjects choose the softer but higher pitched syllable as the more prominent item. The percentage of neutral votes is low, at 0.7%.

Like the Chinese subjects, the Indian subjects tend toward amplitude as a stronger perceptual cue for stress, compared to pitch. More than 80% of the Indian subjects choose the louder but lower pitched test word as the more prominent syllable. About 15% of the Indian subjects choose the higher but softer syllable as the more prominent item. The percentage of neutral votes is 4%.

F4-I4: {V1 = <u>140 Hz</u>, 70 dB, 0.2 sec and V2 = 120 Hz, <u>80 dB</u>, 0.2 sec}

In this manipulation, the difference between the vowel in the first test word and the vowel in the second test word in each set is 10 dB and 20 Hz. The first vowel has an amplitude of 70 dB and F_0 at 140 Hz, and the second one louder, at 80 dB, but lower, at 120 Hz.

Figure 3.24 shows the judgements of the Chinese, Malay and Indian subjects when they are made to choose between the higher pitched but softer first vowel and the lower pitched but louder second vowel in this fourth manipulation of amplitude and F_0.

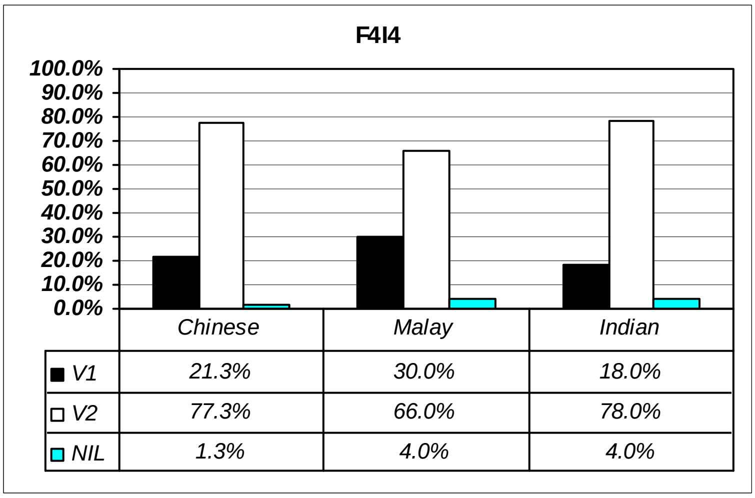


Fig. 3.24: Judgements of the Chinese, Malay and Indian subjects when V1 has F_0 = 140 Hz, amplitude = 70 dB and V2 has F_0 = 120 Hz, amplitude = 80 dB; vowel length held constant at 0.2 sec.

As can be seen in Figure 3.24, all three groups of subjects consistently choose the test word containing the louder but lower pitched vowel as the more prominent item. The Chinese and Indian subjects have a high percentage of over 75% choosing the louder but lower pitched test word as the more prominent syllable. However, less than 70% of the Malay subjects make the same judgement. It is interesting to see how a difference of 10 dB in the two vowels cause the Malay subjects to change their responses, compared to what is seen in *F2-I3* and *I3-F3*, when the difference in amplitude is 5 dB.

77.3% of the Chinese subjects feel that the louder, but lower pitched test word is more prominent than its shorter but higher pitched counterpart. The percentage of the Chinese subjects choosing the higher pitched but softer syllable as the more prominent syllable is at 21.3%. The percentage of neutral votes is at a low of 1.3%.

For the Malay subjects, 66% of them choose the test word containing the louder but lower pitched vowel as the more prominent syllable. The percentage of the Malay subjects choosing the softer but higher pitched syllable as the more prominent item is relatively high, at 30%. This situation is also observed in *I1-F1*.

78% of the Indian subjects choose the louder but lower pitched test word as the more prominent syllable. The percentage of the Indian subjects choosing the higher pitched but softer syllable as the more prominent item range is only 18%. The percentage of neutral votes is at 4%.

Higher pitched but softer or louder but lower pitched?

As can be seen, when the subjects are made to choose between a louder but lower pitched test word and a higher pitched but softer test word, some differences can be observed between the three groups of subjects. The Chinese and Indian subjects consistently, with high percentages, choose a louder but lower pitched syllable over a softer but higher pitched syllable. For the Malay subjects however, the decision is rather split, and a lot of which depends on the difference in amplitude between the two vowels in question. When the difference in amplitude between the two vowels in the test words is 10 dB, the Malay subjects would choose a louder but lower pitched syllable over a higher pitched but softer syllable. However, when the difference in amplitude is only 5 dB, they would go the complete opposite way and choose a higher pitched but softer syllable over a louder but lower pitched syllable. Perhaps the Malay subjects are more acute to small changes in pitch, and not as sensitive to changes in amplitude, such that when the difference is only 5 dB, they hear the pitch changes rather than the changes in amplitude, and thus use the higher pitch they hear to determine stress.

3.4 Summary of Findings: A Hierarchy of Parameters

	Chinese	**Malay**	**Indian**
Higher F_0	✓	✓	✓
Higher amplitude	✓	✓	✓
Longer duration	✓	✓	✓ (when the difference is only 0.5 sec, the subjects' responses were split)
Comparison between	duration & intensity:		
Longer but softer	✗	✗	✗
Louder but shorter	✓	✓	✓
Comparison between	duration and F_0:		
Higher pitched but shorter	✗	✓	✓
Lower pitched but longer	✓	✗	✗
Comparison between	intensity and F_0:		
Higher pitched but softer	✗	✓when the difference in amplitude is 5 dB)	✗
Lower pitched but louder	✓	✓ (when the difference in amplitude is 10 dB)	✓

Table 3.4: Summary of findings.

As can be seen, it is generally consistent that all three groups of subjects would use higher pitch, longer vowel length and increased loudness to determine stress. For the Indian subjects though, when the difference in vowel length between the two test words is only 0.05 sec, their responses are split.

When it comes to the relative strength of the perceptual cues for each group of subjects however, differences can be seen. For each group of speakers, there is a hierarchy of dominance of the parameters for stress perception.

For the Chinese subjects, intensity seems to be the dominant perceptual cue for stress. They would pick the test word containing the louder vowel as the more prominent item, even when the other item is higher pitched or longer. When made to choose between a higher pitched but shorter test word and a longer but lower pitched test word however, the choice is for the latter. This group of subjects would pick the word containing the longer vowel as the stressed item, as opposed to the higher pitched one. Therefore, for the Chinese subjects, in their perception of stress, they would first use intensity, followed by duration, and lastly, pitch.

For the Malay subjects however, the situation is slightly different. When asked to decide between a longer but softer test word and a louder but shorter test word, the choice of the more prominent item would be the one containing the louder vowel. When asked to choose between a higher pitched but softer test word and a louder but lower pitched test word, however, when the difference in amplitude is only 5 dB, the subjects would pick the test word containing the higher pitched vowel. When given a choice between a higher pitched vowel and a longer vowel, the subjects would pick the word containing the higher pitched vowel to be the more prominent item. Therefore, what can be concluded for this group of subjects is that duration is the weakest perceptual cue for stress. While pitch and intensity seems to be equally dominant, the subjects seem to be less sensitive to smaller changes in amplitude compared to smaller changes in pitch, and thus, one could conclude that this group of subjects tends to use pitch as the dominant perceptual cue, followed by intensity, and lastly, duration.

For the Indian subjects, intensity seems to be the most dominant cue. They would pick the test word containing the louder vowel as the more prominent item, even when the other item is higher pitched or longer. When made to choose between a higher pitched but shorter test word and a longer but lower pitched test word however, the choice is for the former. This group of subjects would pick the word containing the higher pitched vowel as the prominent item, as opposed to the longer one. Therefore, for the Indian subjects, in their perception of stress, they would first use intensity, followed by pitch, and lastly, duration.

In the next chapter, the acoustic correlates of stress of the Chinese, Malay and Indian SE speakers will be investigated. One could then determine if there is a correlation between the perceptual cues, as presented in this chapter, and the acoustic properties of stress in these three groups of speakers.

CHAPTER FOUR

ACOUSTIC CORRELATES OF STRESS

4.1 Introduction

According to Lehiste and Peterson, “stress…is reflected in at least four acoustic parameters: speech power, fundamental voice frequency, phonetic quality and duration” (1959: 428). As reviewed in Chapter One, various studies on different languages and different varieties of the same language were carried out to determine the acoustic properties present in stressed syllables.

As highlighted in Chapter Two, one of the assumptions researchers of stress in SE make is that the acoustic correlate(s) of stress in SE is the same as that of BrE, namely, pitch. The biggest gap in these past studies is that the acoustic correlate(s) of stress in SE is not first determined before identifying the stressed syllables. Researchers like Chua (1989) and Low (1998) readily assume that that a higher pitched syllable is a stressed syllable in their investigation of lexical stress placement patterns in SE, using the acoustic correlate of stress in BrE to apply to that in SE. This, as mentioned in Chapter Two, could well lead to erroneous conclusions.

It is the aim of this chapter to investigate the acoustic correlates of stress in SE, looking into the phonetic properties present in the stressed syllables of the Chinese, Malay and Indian SE speakers. The following sections present the experiment and the findings.

4.2 The Experiment

4.2.1 The Challenge

The most difficult task in this research is coming up with an experiment such that one could determine confidently, with a great degree of certainty, which syllable(s) the speakers have stressed, and which they have not. Without this knowledge, all the analyses that follow would be meaningless, if not impossible. As mentioned in the earlier chapters, using one's own perceptions to determine stress in SE, or simply assuming that a higher pitched syllable is a stressed syllable in SE, is flawed and leads to erroneous conclusions. Thus, going by this 'method' of identifying stressed and unstressed syllables is a route not to be ventured. Yet, without identifying which syllables are stressed or unstressed, it is impossible to look into the phonetic properties present in the stressed syllables.

As has been shown in the previous chapter, one cannot readily assume that what one hears as stressed is really stressed, especially in the ethnic varieties of SE. The Chinese, Malay and Indian speakers have their own different set of criteria in the determination of prominence. Thus, one cannot assume that all the speakers, regardless of ethnic group, would place the stress on the same syllable. Even if they do, different groups of listeners hearing the word might have different judgements on where the prominence is.

Another possible way of determining stressed syllables is to make use of stress patterns predictable by phonological rules. With the knowledge of the phonology of stress, which gives an account of where stress would fall, one is able to determine where the 'stressed' syllables are. However, while there is a comprehensive account of the phonology of stress in BrE, there is at this point no account of the phonology of stress of SE. One cannot simply assume that the phonology of stress in SE is the same as that of BrE. Having shown earlier that even the perception of prominence of SE speakers is different from that of the

BrE speakers, it is therefore most plausible that the phonology of stress in SE is different from that of BrE. Thus, not knowing the phonology of SE stress, with no possible prediction of where stressed syllables would be, the task of identifying and measuring the ‘stressed’ syllables becomes difficult.

The phonology of stress, however, cannot be established unless the phonetic facts are known first. As Ladefoged points out, “a linguist cannot give a comprehensive account of the phonology of a language unless he knows all the phonetic facts; if the original observations made in the field are inadequate, the subsequent analysis is liable to be faulty”. (1973: 219). In other words, without first determining the phonetic properties of stress, the phonology of stress cannot be derived. We thus have a problem. There is no research to show the phonology of stress in SE, which makes it difficult, if not impossible to predict stress in SE. Even if such a phonology was made available, one cannot assume that all three groups of speakers have the same phonological rules for stress. The phonology of stress in SE is not available because the phonetic facts of stress in SE are not first determined, which is precisely the endeavour of this dissertation.

Facing such a situation, with no past research providing evidence for the phonology and phonetic properties of stress in SE, this research thus cannot assume a prior knowledge of stress in SE. It is absolutely necessary even to question if the concept *stress* exists in SE. The challenge therefore is to devise an experiment such that

(i) the speakers would most likely make stressed and unstressed distinctions in the test materials;

(ii) all three groups of speakers would place stress on a particular target word for a comparable study.

The next few sections will describe the experiment in detail. The experiment was designed with the above considerations in mind.

4.2.2 Aim

The experiment is intended to show if the three parameters (fundamental frequency, duration and amplitude) are different in the stressed, unstressed and emphatically stressed words.

Sentence stress is the subject of investigation. As mentioned in Chapter 1, *sentence stress*, as opposed to *word stress*, is the stress that functions within the domain of a sentence. Sentence stress does not change the meaning of any lexical item, but only increases the prominence of one or more of the items.

Bierwisch (1966, from Lehiste, 1970: 150) distinguishes between *primary stress* and *emphatic stress* – both of which are *sentence stress*. According to Bierwisch, each sentence has a *primary stress*, which simply refers to the prominence of a lexical item in a sentence. Lehiste (1970) refers to it as *nonemphatic sentence stress*. Szwedek (1986) labels stress of this kind, *neutral stress*. Chomsky and Halle (1968) call it *nuclear stress*. As mentioned in the first chapter, the term *stressed* will be used to refer to sentence stress. The terms, *primary stress*, *neutral stress*, *nuclear stress* and so on will not be used so as to avoid alluding to the theoretical assumptions behind these terms. Words that do not receive the sentence stress or emphatic stress are labelled *unstressed*, in this dissertation. This only means that the words do not receive sentence or emphatic stress, and does not mean that these words do not have lexical stress.

Emphatic stress on the other hand is used to "distinguish a sentence from its negation" (Lehiste, 1970: 151). Emphatic stress is also used "to call the listener's attention to a given syllable or word with greater insistence than is afforded merely by neutral patterns of intonation or lexical stress" (Laver, 1994: 515). As Gimson (1973: 100) points out, "emphatic stress in languages appear rarely, if ever, to be a matter of extra energy alone". It would therefore be interesting to look at the phonetic properties present in the emphatically stressed syllables in the ethnic varieties of SE, and to determine the difference, if there is a difference, between the stressed and the emphatically stressed syllables.

In the investigation of the acoustic correlates of stress of the Chinese, Malay and Indian speakers, this chapter will be concerned at looking at:

(1) the difference between the stressed and unstressed syllables;
(2) the difference between the stressed and emphatically stressed syllables;
(3) the difference between the stressed and unstressed syllables in sentence-final positions and non sentence-final positions; and
(4) the difference between the stressed and unstressed syllables in target words containing the vowel [ɪ] and those containing the vowel [ɒ].

4.2.3 The Argument

In establishing the acoustic correlates of stress in the three ethnic varieties of SE, the analysis is based on the following argument:

Premise (1): Every syllable has the phonetic properties, F_0, amplitude and duration.

Premise (2): Stressed and unstressed syllables have different degrees in at least one of the three phonetic properties.

Premise (3): If a phonetic property, *x*, of a stressed syllable is significantly different from the phonetic property, *x* of the corresponding unstressed syllable, *x* is the property that distinguishes the stressed syllable from the unstressed syllable.

Conclusion: Therefore, *x* is the acoustic correlate of stress.

The analysis of emphatic stress is based on a similar argument:

Premise (1): Every syllable has the phonetic properties, F_0, amplitude and duration.

Premise (2): Stressed and emphatically stressed syllables have different degrees in at least one of the three phonetic properties.

Premise (3): If a phonetic property, *x*, of a stressed syllable is significantly different from the phonetic property, *x* of the corresponding emphatically stressed syllable, *x* is the property that distinguishes the stressed syllable from the emphatically syllable.

Conclusion: Therefore, *x* is the phonetic property used to distinguish between the stressed and emphatically stressed syllables.

The focus of the analysis therefore will be to establish the differences in the phonetic properties, F_0, amplitude and duration of (1) the stressed and unstressed syllables and (2) the stressed and emphatically stressed syllables.

4.2.4 The Experiment

4.2.4.1 The Subjects

4 Chinese, 4 Malay and 4 Indian male undergraduates aged between 23 to 26 years from the National University of Singapore were used as subjects in this experiment. A single sex was chosen to control gender as a variable.

Educational level was also controlled, since the educational background of a speaker can result in differences in the English one speaks (Platt and Weber, 1980; Tay, 1983). Undergraduates were chosen because they can also be said to have achieved a high level of proficiency in English. Presenting a truer view of SE spoken today, it will also serve to confirm or deny the claim that there is an “increasing similarity of Singaporean English as spoken by those of different ethnic groups ... particularly among the younger generation” (Platt and Weber, 1980: 46).

All the subjects are Singaporeans and never lived abroad. Educated in Singapore, they learnt English and their respective Mother Tongues in school until pre-university level.
All the subjects use their respective Mother Tongues in the home domain. In other words, Mandarin, Malay and Tamil are used by the Chinese, Malay and Indian speakers respectively. The respective Mother Tongues are also used with friends who speak the language. English is used in the University and to friends.

4.2.4.2 The Materials

The test material consists of 90 sets of pictures, which the subjects used to answer questions posed by the researcher. Figure 4.1 shows an example of such a set as presented to the speakers during the experiment.

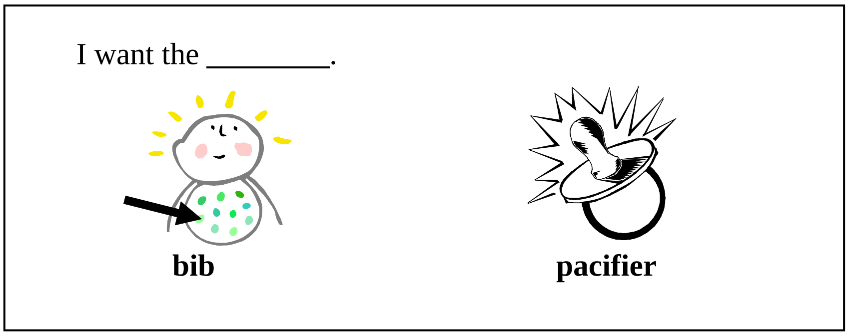


Fig. 4.1: An example of a picture set in the experiment material.

For each set of pictures, the subject was asked three questions. For each question, the speaker was instructed to answer using the sentence construction as provided above each set of pictures. The arrow, seen above the bib in this case, indicates the object to be chosen to fill in the blank in the sentence provided.

The three questions asked of each set are aimed to get the subjects to:

(1) choose one out of the possible two objects in the picture;

(2) repeat the utterance with emphasis on the 'selected' object;

(3) repeat the utterance with emphasis on the personal pronoun.

The three questions that were asked for each set were all designed to elicit the above "hypothesised" responses from the speaker. All the questions asked were of the following form. In the case of Figure 4.1, the questions asked are as follows:

Question 1: Which object do you want?

Question 2: You want the pacifier?

Question 3: The baby wants the bib?

The expected responses were as follows:

Question 1: Which object do you want?

Expected Response: I want the **bib**.

Question 2: You want the pacifier?

Expected Response: I want the **BIB**.

Question 3: The baby wants the bib?

Expected Response: **I** want the bib.

Question 1 of the set is aimed to elicit a stressed *bib*. This is because *bib* in this case is the "information focus" (Halliday, 1967b). Thus, given that the question was posed such that the *bib* would be the answer to *which object*, it is expected that *bib* would be the stressed word, as the sentence has broad focus (Ladd, 1996), and *bib*, being the last lexical item, would receive the stress.

Question 2 is aimed to elicit a more emphatically stressed *bib*. Question 2 in essence is a request for the speaker to repeat the answer to Question 1. The expected response thus is to repeat the utterance *I want the bib* with a lot more emphasis on *bib* than in the answer to Question 1, since this was the word that was in contrast to the *pacifier* as asked by the interviewer. In this case, *bib* receives emphatic stress.

Question 3 on the other hand is designed to elicit an unstressed *bib*. The focus of the question now shifts to the pronoun in the sentence. The question *The baby wants the bib?* asks the speaker to repeat his utterance with the pronoun as the focus of attention. In this case, the speaker is expected to emphasise, or stress on the word *I*, because this is the word that is in contrast to *the baby* as posed in the question. *Bib* in this case, will remain unstressed, as it is not in contrast to the *bib* in the question, nor is it the information focus.

The target word *bib* thus will have three different types of 'stress': *stressed, emphatically stressed* and *unstressed*. For all the 90 sets of pictures, this method of eliciting the different types of stress remains consistent across the board. The three questions asked to each set would elicit the same three types of stress for the target word.

4.2.4.3 Focus-to-Accent

The experiment is designed in this way as the researcher believes that the chances of eliciting stressed syllables are maximised with this experimental design. This is also the most effective way of eliciting stressed syllables without running into possible semantic problems that can occur with the use of word-level stress. When stress functions at the sentence-level, while the meaning of the lexical item is not affected, “it increases the relative prominence of one of the lexical items” (Lehiste, 1970: 150).

Designing the experiment as such, there is however an assumption on the researcher’s part that there is focus-to-accent in SE. In other words, the researcher is assuming that the speakers in SE, regardless of ethnic variety, will use stress to mark the ‘important’ or ‘relevant’ information. As elaborated in Chapter One, the Focus-to-Accent theory states that words and constituents in utterances can be focused for various reasons, and that these focused words and constituents are marked by pitch accents. In this experiment, of course, stress, used in general terms, not pitch accents, is believed to be used to mark the focused words and constituents. This is also in accordance to Halliday’s (1967b) principle that asserts that stress will be assigned to new information, while given information will not be stressed. Though Halliday’s theory on information structure is not language-specific, given that there is no research to show that Halliday’s claim holds true in SE, this principle at best remains an assumption to be made for SE. This is however a necessary assumption, as it would jump-start the research in a positive direction.

One way to get round this assumption is of course to prove that the assumption is true in SE. To prove it, one could run a map-task (Esther Grabe, personal communication, May 2001) for example, get the speakers to give directions with certain target words, and listen out for the expected ‘stressed’ items, then measure the acoustic correlates in these stressed items to determine if they are really stressed. However, for each ‘stressed’ syllable one measures, what parameters would determine this syllable as stressed? This is precisely the question this research is concerned about. Furthermore, we are back to the problem of assuming the perceptual cues of stress in SE. Thus, if one is faced with a target word that is expected to receive stress, and yet does not ‘sound’ stressed, do we then assume that SE speakers do not have focus-to-accent? We are faced with a situation of choosing between (1) making assumptions about focus-to-accent, or (2) making assumptions about the acoustic correlates of stress in SE. The option is clear. One does not want to make assumptions about what ones to investigate. In this case therefore, it is necessary to first assume that focus-to-accent exists in SE, which would then show the acoustic correlates present in focus-to-accent situations. Thus, if one should perform a map task of this sort in the future, one could then use the acoustic correlates found to show where the stress is in spontaneous speech.

Some would perhaps say the assumption that there is focus-to-accent in SE need not be made if one chooses to analyse word-level stress, instead of sentence-level stress. As mentioned earlier, the primary concern in the investigation of the acoustic correlates of stress in SE is finding the most straightforward and direct method for eliciting stressed and unstressed counterparts in comparable words or syllables. In the investigation of phonetic parameters of stress in English, the tradition of past studies has been to use word stress, in particular, noun-verb pairs. This method of investigation however cannot be used for SE. As Tay (1982), Alsagoff (1984) and Sng (1991) have found, stress is, in the first place, not used to demarcate parts of speech in SE. For example, while British speakers would use *<u>in</u>-crease* to refer to a noun, and *in-<u>crease</u>* to refer to a verb, SE speakers would use *in-<u>crease</u>* to refer to both noun and verb.

The use of compound and phrasal stress in SE is also noted to be different from that of BrE, as mentioned in the earlier chapter. SE speakers do not make a distinction between a compound and a phrase. Compounds are also assigned phrasal stress in SE. Thus using compounds and phrases as test materials is not a viable option for the experiment.

Therefore, it is not possible to use word-level stress to determine the acoustic correlates of stress in SE. Furthermore, we cannot assume that all the three groups of speakers are going to place stress on the same syllable in a polysyllabic word. There is no control for an experiment of this sort.

Designing the experiment in this way therefore is the best possible option. While some may argue that the results that follow would only confirm the acoustic correlates of words in *focus*, not *stress*. However, since the assumption is made that in SE there is focus-to-accent, which means to say that all words in focus are stressed, the results will still show the acoustic correlates of stress.

4.2.4.4 Some Comments about the Design

The sentences were designed to pay attention to (i) vowel of the target words (ii) number of syllables and (iii) target words' position in the sentence.

The target words are concerned with two vowels: [ɪ] and [ɒ]. There are in total 10 monosyllabic words that are used as target words in the sentences, 5 of each vowel. The words are:

bib	[bɪb]	*dog*	[dɒg]
bin	[bɪn]	*log*	[lɒg]
rig	[rɪg]	*rod*	[rɒd]
ring	[rɪŋ]	*knob*	[nɒb]
mill	[mɪl]	*doll*	[dɒl]

They are all of the structure [CVC], and all the segments are voiced. As the pitch contours and measurements are crucial to the analysis, one aims to have a smooth pitch curve. Thus, only voiced segments are used, the fundamental frequency of voiceless segments does not show up in the pitch curve.

These target words appear in both sentence-final and non sentence-final position. For example, *I want the* ***bib*** (sentence-final) and *The* ***bib*** *is cheap* (non sentence-final). This is to investigate if there is a difference in the acoustic correlates of stress in relation to sentence position.

Short vowels are used as opposed to long vowels, as researchers (e.g. Brown, 1991; Hung, 1995; Bao, 1998) have found that SE speakers do not make a clear difference between long and short vowels. Brown (1991) asserts that most vowels in SE are pronounced relatively short. Hung (1996) finds no evidence from his spectrographic analysis that there is any difference between long and short vowels in SE. Thus only short vowels are used here for the purpose of control. The vowels [ɪ], which is a high front vowel, and [ɒ] – a low back vowel are chosen because they are as spectrally different as possible.

Two- and three-syllable words are also included in the experiment. This is to determine if the acoustic correlates of stress for each variety of SE is different with regard to the number of syllables. Stress placement within these polysyllabic words will also be the target of investigation. This will be described in further detail in the following chapter.

All the target words, monosyllabic and polysyllabic, appear twice in the experiment.

The speakers were not given free rein to answer the questions any way they wanted. They had to follow the instructions and answer the questions according to the given sentence structure that came with every picture set. This control, though possibly resulting in the loss of some spontaneity in the process, is necessary. The control of the sentences is done to ensure that all the utterances that are recorded in the experiment are comparable within each set itself, as well as across speakers. It is only when the utterances are exactly the same, then one can rule out the influence that can be caused by different phonetic environments. The segmental composition and word position, because of the experiment design can also be manipulated and controlled by the researcher.

The sentence given to the speaker with each set of pictures is not complete. As can be noted from Figure 4.1, the sentence comes with a blank to be filled in. This blank space is for the “target” word of the set of the utterances. There are several reasons why this blank is necessary, though it could be said that this space might inadvertently cause an emphasis on the word, giving the impression of it being the most important word, regardless of the question asked and focus intended. One of the main reasons why this blank space is used instead of just giving the speaker the whole sentence is to an attempt to emulate spontaneous speech to some extent. It is felt that if the whole sentence is given, most speakers might end up simply reading the sentence and not really thinking about the questions, which would lead to unnatural-sounding read speech. If this were to occur, then one might not get data suitable for analysis of this kind. Another reason why the sentence is not given whole is to engage the speaker with the pictures in some way. The blank will require the speaker give some attention to the pictures given, listen to the questions posed and give them some thought. Eliminating read-speech aside, the whole process of recording becomes more natural and thus more spontaneous, even within a laboratory condition. This same experiment was used by Fong and Lim (2000), and they reported that their subjects responded well to the experiment.

The arrows, seen on top of the pictures, serve the purpose of controlling the object being chosen. Since there are two or more objects in each set of pictures, one speaker's choice might be different from the other. Pinpointing the particular object to choose eliminates such differences in choice between the speakers, thus making the utterances more comparable for analysis.

As mentioned earlier, it is necessary that the speakers pay attention to the pictures. The pictures serve the important purpose of providing a context, which is vital in such experiments. The lack of context in answering questions that this experiment requires would make it difficult for the speaker to, firstly, imagine how to answer them to start off with, and even if they could, the answers would come off sounding unnatural and contrived.

There are several alternative ways of providing a context. One of the most obvious ways is through oral means. The interviewer could, before every set of questions, briefly build a context for the speaker. For example, the interviewer could tell the speaker that there is a table with a bib and a pacifier and that he had to choose the bib, or something along that line. This method is counter-productive. It is far too time-consuming for the interviewer to tell a story before each set of questions, and it also requires the speaker to mentally perceive such a scenario before he can answer the questions. This experimental process would lead to time wastage, and there is no guarantee that the speaker would have the same mental picture of the context as one that the interviewer tried to provide. Even if the speaker could, within a short time come up with a context for the question, the context would differ among the different speakers.

Another way of building a context for the speakers would be to write a short passage that describes the context before each set of questions. This is a written form of the oral method. Its drawbacks are also similar. The speaker would have to take time to read the passage then come up with a mental picture that might not be consistent with other speakers or the interviewer. Given that there are 90 sets altogether, reading 90 short passages would be mentally draining, thus not an effective way of providing a context.

The pictures, in a way, did not have the drawbacks that the previous two methods had. Firstly, the pictures themselves are contextual information. They are visual representations of the objects that the speakers and the interviewer are concerned about for each set of questions. One could look at them, point at them, and make references to them without having to think very much about them. This also ensured that the interviewer and the speaker had the same visual thus mental representation of the object(s) for each set of questions. Similarly, the problem that different speakers have different context is also solved, for all the speakers had the same visual representations of the objects in question. Because the pictures are there to be seen, time is not wasted listening to what the context should be, reading about the context, and more importantly, coming up with a mental picture of what the context is. Thus, the simple pictorial representations of the objects could, at a glance, provide the context for each set of questions.

4.2.4.5 Recording

The recording of the speakers was done in the University's sound-proof Phonetics Laboratory. The subject was instructed to sit facing the interviewer. No conventional microphones were used in the recording. It was felt that a microphone would heighten the laboratory setting, and that speakers would feel uncomfortable speaking into a microphone. Therefore, in its place, a sound-grabber (Model: Crown Sound Grabber II PZM) was used. The sound-grabber, while not looking like a microphone, works like one. It is a small-sized but powerful device that captures speech sounds clearly and effectively without the speakers having to speak directly into it. The sound-grabber, for the recording, was placed on a table between the speaker and the interviewer, a distance of about 30 cm away from both the speaker and interviewer. In fact, most of the time, the speakers soon forgot that they were being recorded and thus the self-consciousness that could influence the naturalness in their speech also slipped away. All the utterances were recorded using a TEAC stereo cassette recorder (model: V - 5000).

The Observer's Paradox (Labov, 1972: 209-210) was a problem since the subjects knew that they were being recorded. However, the need for clear speech signals for the acoustic analysis made this method of recording necessary.

To obtain natural-sounding speech was the key concern of the recording procedure. The subjects were told to relax and be natural. The researcher had 10-minute conversations with each subject before the recording began so as to ease any anxiety towards the recording. The fact that the interviewer was also recorded made them feel less self-conscious. As the experiment was conducted in conversational style, the speech tended to sound less formal and stilted, and thus more natural and relaxed. The subjects were not told of the aim of the research so that they would not try to produce the supposed 'right' answers, which would eliminate any interesting findings that one could make in this yet-to-be-explored area in Singapore English.

4.2.4.6 Judgement Test

To ensure that the analysis was not based on the researcher's own perception of stress, 15 native speakers of Singapore English – five of whom were Chinese, five, Malay and five, Indian – were asked to listen to the utterances recorded and mark the words within the sentence which they felt were the most prominent. Similarly for polysyllabic words, they were only asked to identify the most prominent word, not syllable, as a pilot test conducted showed that most speakers had difficulty identifying the stressed syllable. Details and analyses of the pilot test are recorded in Tan (2001). They were made to judge the sentences spoken by speakers of their own respective ethnic groups. As the recordings were very lengthy, it was not possible for the subjects to make judgements for every single utterance from each and every speaker. They were therefore given a random selection of the recorded utterances to listen to, each judgement test lasting 10 minutes. More than 80% of the subjects had the same judgements of stress in the utterances they listened to. The purpose of this procedure was to make sure that it was not the researcher's own perceptions that were used to judge the suitability of the materials. The materials were confirmed by this panel to have the 'stress' on the intended target words. Thus, all the data recorded was taken for statistical analysis.

4.2.4.7 Measurements

In terms of pitch, the highest F_0 value within the vowel was measured and taken for analysis. It was the same for energy level for the measurement of amplitude. The duration of the entire vowel in the target word was also measured.

The Kay CSL (Computerised Speech Lab), Model 4300B, software version 5.X was used for the digitisation of the recorded utterances. Capturing the utterances from the tapes, pitch waveforms were extracted at a sampling rate of 8 - 10 kHz. The analysis range for fundamental frequency was 70 Hz - 350 Hz, frame size and advance at 20 - 25 milliseconds. The analysis range for energy was 40 - 100 dB. Understanding that different speakers speak with different levels of loudness, the utterances were captured with a mean energy level of 70 dB, ± 10 dB. The analysis of all the recorded utterances was done using Praat Version 4.0[1]. Energy and pitch values were noted every 20 milliseconds. For each utterance, each segment was identified, with the use of the spectrograms, as well as by aural identification. The time at which the segments occurred and the length of the segments were also noted and calculated.

4.2.4.8 Statistical Analysis

The main concern of the analyses to follow is to establish, for each group of speakers, if F_0, amplitude and duration are different between the stressed, unstressed and emphatically stressed words.

The following analyses will be performed using the Multivariate Statistical Analysis. The advantages of using this statistical tool are:

(1) it can compare the means of all three parameters at the same time, even though the units of measurements for each parameter are different;

(2) it takes into account the interaction between the three parameters. In other words, if the difference in amplitude is directly correlated to the difference in F_0, this test would take this into consideration as well and eliminate this causal effect.

(3) it reduces the chances of statistical error, especially in cases like these, where the samples are large.

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[1] Different speech analysis softwares and different versions of the same software were used in the analysis of the speech samples. This is due to the fact that the research and experiments were carried out over a period of 3 years, which saw new softwares and new versions being made available.

The analysis will be divided into four sections. Each section will describe the phonetic properties of stress in the Chinese, Malay and Indian subvarieties of SE. In the first section, stressed and unstressed syllables will be compared, and the three parameters will be individually looked at, for all three ethnic varieties. In the second section, stressed and emphatically stressed syllables will be compared to determine if speakers of SE use different acoustic correlates when they stress a syllable emphatically, compared to one that is stressed. In these two sections, the analysis does not separate the sentence-final and non sentence-final utterances.

For these two sections, one multivariate analysis is performed, comparing the means of the parameters in stressed, unstressed and emphatically stressed syllables, followed by a post-hoc test. This is because in the case that a significant difference is shown for the three means of a particular parameter, what is shown merely is that of the three means compared, there is at least one pair of means that is significantly different. This however does not indicate what pair it is. Therefore, a post-hoc Scheffe test, which is one of the simplest and most direct post-hoc tests, is applied after the multivariate test. This post-hoc Scheffe test gives a breakdown of the pair(s) of means that are significantly different.

The third section splits the data into target words in sentence-final and non sentence-final positions respectively. This is to determine if the positions of the words in the sentence have an effect on the acoustic properties present in the stressed syllables. Researchers on SE stress have claimed that SE speakers tend to place prominence on syllables or words in phrase- or sentence-final positions. For example, while BrE speakers say *<u>flaw</u>lessly*, SE speakers would say *flawless<u>ly</u>* (Low and Grabe, 1999). Tongue (1979) and Platt and Weber (1980) suggest that this prominence in sentence-final position is due to phrase-final lengthening. Low and Grabe (1999), comparing duration and F_0 of syllables in sentence-medial and sentence-final positions of SE and BrE speakers found that SE speakers do indeed show syllable-lengthening in the sentence-final position. F_0 however does not present itself to be different in either position. Their findings lead Low and Grabe to conclude that SE speakers use duration as an acoustic correlate of stress. This will also be addressed. In the final section, comparisons are made between the words containing the vowel [ɪ] and [ɒ] respectively. This is to determine if spectral differences in the vowels have an effect on the acoustic properties of stress.

For these two final sections, as only two sets of means are being compared at one time, there is no need for a post-hoc test. Therefore, only the multivariate test is needed.

For the multivariate test, the significance level is set at $p < 0.05$. Thus, if the means of, for instance, the amplitude of stressed and unstressed words of the Malay speakers are found to be significantly different, i.e., $p < 0.05$, then intensity is a feature that distinguishes between the stressed and the unstressed words. It then can be concluded that it is highly likely that intensity is a phonetic property of stress used by the Malay speakers.

40 sets of utterances (the sets containing the monosyllabic words) were taken for analysis in this chapter. Each set, containing three utterances, and for four speakers in each ethnic group, making it a total of 1440 utterances, were analysed. All statistical analyses were performed using the software, SPSS Version 10.0.1. Polysyllabic words will be dealt with in the next chapter.

4.3 Results

4.3.1 Stressed *vs*. Unstressed

In this section, the discussion will focus first on the difference between the means of F_0 of the stressed and the unstressed syllables. Following that, amplitude will be discussed, followed by duration. Each ethnic group will be individually discussed as well.

Pitch

The average values for F_0 in conversational speech in European languages are approximately 120 Hz for men, 220 Hz for women and 330 Hz for children of about ten years old (Fant, 1956). The just-noticeable difference for pitch perception is about 1 Hz, in the span of F_0 from 80 to 160 Hz (Flanagan, 1957: 534).

Figure 4.2 shows the overall means of the F_0 of the stressed and the unstressed words of the three ethnic groups

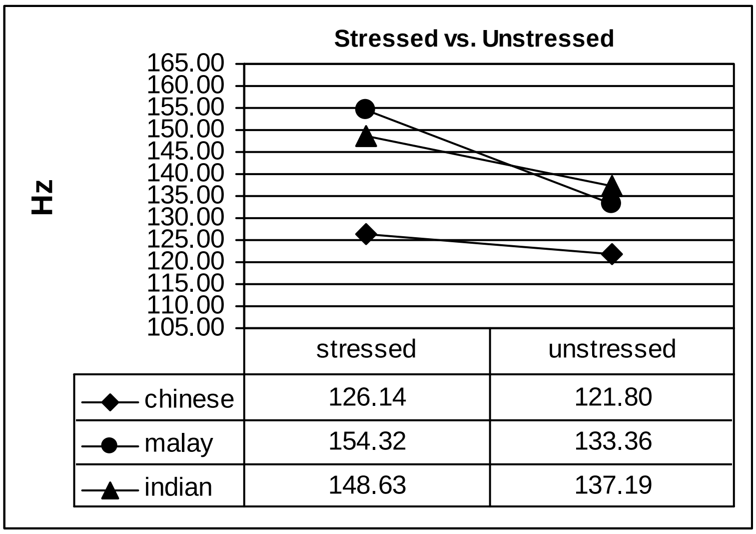


Fig. 4.2: Overall means of the F_0 of the stressed and unstressed words of the Chinese, Malay and Indian subjects.

As can be seen from Figure 4.2, the stressed word is higher pitched than the unstressed word. The difference between the F_0 of the stressed and the unstressed words for the Chinese speakers is 4.24 Hz, i.e. 3 Hz more than the just-noticeable difference of 1 Hz for pitch perception. The multivariate test shows that the means of the F_0 of the stressed, unstressed and emphatically stressed target words are significantly different at $p < 0.01$ ** ($p < 0.005$, df = 2, N = 160). This suggests that there is at least one pair of means that is statistically significant. From the post-hoc Scheffe tests however, the difference in the means of F_0 between the stressed and unstressed words is however found to be not significant at $p < 0.05$ ($p = 0.337$). There is therefore no evidence to show that pitch is a phonetic property that distinguishes between the stressed and the unstressed target words for the Chinese speakers.

The Malay speakers, on the other hand, show a difference of 20.96 Hz in the F_0 between the stressed and unstressed words, which is nearly 20 Hz larger than the just-noticeable difference of 1 Hz in pitch perception. Similarly, the stressed word is higher than the unstressed word. The multivariate test shows that the means of the F_0 of the stressed, unstressed and emphatically stressed target words are significantly different at $p < 0.01$ ** ($p < 0.005$, df = 2, N = 160). The post-hoc Scheffe test, in addition, shows that the difference in the means of F_0 between the stressed and unstressed words is significant at $p < 0.01$ ** ($p < 0.005$). There is therefore strong statistical evidence to show that pitch is a distinguishing feature between the stressed and the unstressed target words for the Malay speakers of SE.

For the Indian speakers, there is a difference of 11.44 Hz in the F_0 of the stressed and the unstressed words. Figure 4.2 shows that the stressed words are higher than the unstressed words. The multivariate test shows that the means of the F_0 of the stressed, unstressed and emphatically stressed target words are significantly different at $p < 0.01$ ** ($p = 0.003$, $df = 2$, $N = 160$). The post-hoc Scheffe test, in addition, shows that the difference in the means of F_0 between the stressed and unstressed words is significant at $p < 0.01$ ** ($p = 0.005$). Pitch can therefore be said to be a distinguishing feature between the stressed and unstressed target words for the Indian speakers, and this is strongly supported by the statistical tests.

Intensity

As Laver (1994) remarks, the human auditory system is remarkably sensitive to the intensity of sounds, and can cope with a large range of intensities. Normal conversation is conducted at about 70 dB, quiet conversation at about 50 dB, and a soft whisper is about 30 dB (Moore, 1982: 8). The just-noticeable difference in intensity has a value of about 0.5 - 1 dB (Rodenburg, 1972) and within the range of 20 dB to 100 dB (Miller, 1947).

Figure 4.3 shows the overall means of the amplitude of the stressed and the unstressed words of the three ethnic groups.

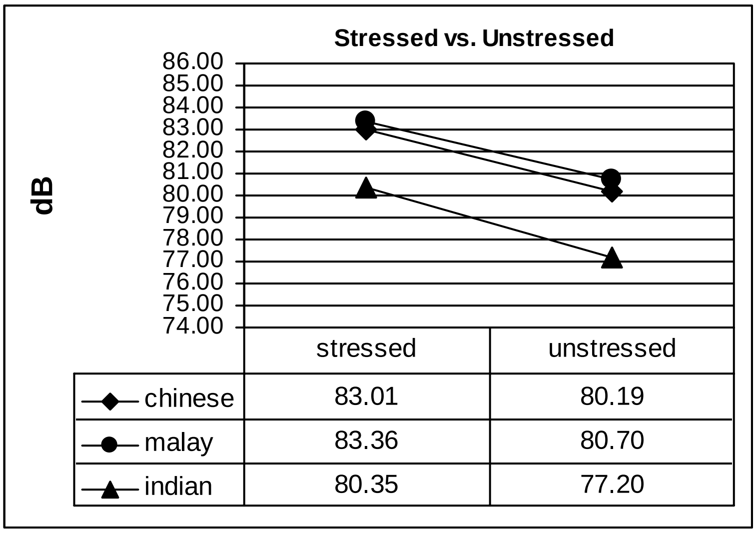


Fig. 4.3: Overall means of the amplitude of the stressed and unstressed words of the Chinese, Malay and Indian subjects.

From Figure 4.3, it can be seen that for the Chinese speakers, the mean of the stressed words is 2.82 dB louder than the mean of the unstressed words, which is beyond the range of the just-noticeable difference of 0.5 - 1 dB. The multivariate test shows that the means of the amplitude of the stressed, unstressed and emphatically stressed target words are significantly different at $p < 0.01$ ** ($p < 0.005$, $df = 2$, $N = 160$). The post-hoc Scheffe test, in addition, shows that the difference in the means of amplitude between the stressed and unstressed words is significant at $p < 0.01$ ** ($p < 0.005$). The tests strongly suggest that intensity is a distinguishing feature between the stressed and unstressed target words for the Chinese speakers.

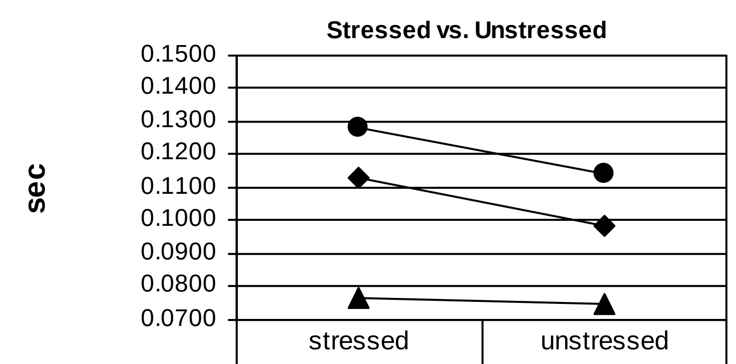
The Malay speakers show a difference of 2.66 dB in the amplitude of the stressed and unstressed words. The stressed words, as can be seen from Figure 4.3, are louder than the unstressed words. The multivariate test shows that the means of the amplitude of the stressed, unstressed and emphatically stressed target words are significantly different at $p < 0.01$ ** ($p < 0.0005$, $df = 2$, $N = 160$). The post-hoc Scheffe test, in addition, shows that the difference in the means of amplitude between the stressed and unstressed words is also significant at $p < 0.01$ ** ($p < 0.0005$). Again, these tests show strong evidence indicating that intensity is a distinguishing feature between the stressed and the unstressed words. Intensity is thus a phonetic property of stress for the Malay speakers.

For the Indian speakers, as can be seen from Figure 4.3, the stressed words are 3.15 dB louder than the unstressed words. The multivariate test shows that the means of the amplitude of the stressed, unstressed and emphatically stressed target words are significantly different at $p < 0.01$ ** ($p < 0.005$, $df = 2$, $N = 160$). The post-hoc Scheffe test, in addition, shows that the difference in the means of amplitude between the stressed and unstressed words is also significant at $p < 0.01$ ** ($p < 0.0005$). There is again strong evidence to suggest that intensity is a distinguishing feature between the stressed and unstressed words for the Indian speakers, making intensity an acoustic correlate of stress for this group of speakers.

Duration

The human auditory system is psychophysically capable of registering very fine temporal differences of duration under favourable experimental conditions, and the psychophyicaly threshold for just-noticable difference in duration between two sounds is about 10 - 40 msec (Lehiste, 1976: 226), which is 0.01 - 0.04 sec.

Figure 4.4 shows the overall means of the vowel length of the stressed and the unstressed words of the three ethnic groups.



	stressed	unstressed
chinese	0.1129	0.0985
malay	0.1279	0.1142
indian	0.0767	0.0749

Fig. 4.4: Overall means of the vowel length of the stressed and unstressed words of the Chinese, Malay and Indian subjects.

From Figure 4.4, it can be observed that the vowel in the stressed word is longer than the vowel in the unstressed word. For the Chinese speakers, the difference between the vowel lengths of the unstressed and stressed words is 0.0144 sec, which is within the range of the just-noticeable difference of 0.01 - 0.04 sec for the perception of duration. The multivariate test shows that the means of the vowel lengths of the stressed, unstressed and emphatically stressed target words are significantly different at $p < 0.01$ ** ($p < 0.005$, df = 2, N = 160). Though the difference in vowel length between the stressed and unstressed words seems small, the post-hoc Scheffe test however shows that this difference is significant at $p < 0.01$ ** ($p < 0.005$). This shows that vowel length is a distinguishing feature between the stressed and unstressed target words for the Chinese speakers. Duration can therefore be said to be an acoustic correlate of stress for the Chinese speakers.

For the Malay speakers, the vowels in the stressed words are 0.0137 sec longer than the vowels in the unstressed words. The multivariate test shows that the means of the vowel lengths of the stressed, unstressed and emphatically stressed target words are significantly different at $p < 0.01$ ** ($p < 0.005$, df = 2, N = 160). The post-hoc Scheffe test, in addition, shows that the difference in the means of vowel lengths between the stressed and unstressed vowels is significant at $p < 0.05$* ($p = 0.047$). Duration is therefore a distinguishing feature between the stressed and the unstressed words, and can be regarded as an acoustic correlate of stress for the Malay speakers, though, compared to the Chinese speakers, this difference is marginal, as the statistical test shows.

As can be seen from Figure 4.4, the vowels in the stressed words are only slightly longer than the vowels in the unstressed words for the Indian speakers. The Indian speakers, in this case, show only a slight difference of 0.0018 sec in the vowel lengths of their stressed and unstressed words, which is not within the range of the just-noticeable difference of 0.01 - 0.04 sec for the perception of duration. The multivariate test shows that the means of the vowel lengths of the stressed, unstressed and emphatically stressed target words are significantly different at $p < 0.01$ ** ($p < 0.0005$, df = 2, N = 160). The post-hoc Scheffe test, however, shows that the difference in the means of vowel lengths between the stressed and unstressed vowels is not significant at $p < 0.05$ ($p = 0.550$). There is therefore no strong statistical evidence to show that duration is a distinguishing feature between the stressed and unstressed words for the Indian speakers.

4.3.2 Stressed *vs*. Emphatically Stressed

In this section, similar to the previous section, the discussion will first focus on the difference between the means of F_0 of the stressed and the emphatically stressed syllables. Following that, amplitude will be discussed, followed by duration. Each ethnic group will be individually discussed as well.

As Szwedek (1986: 87) asserts on the analysis of emphatic stress, "if we want to claim that there is phonetic difference between neutral and emphatic stress, we have to specify those features that are responsible for the difference, since it would mean that there are features in empathic stress that are absent in neutral stress, or that empathic stress has the same features to a degree perceptibly different from the degree of those features in neutral stress".

The focus therefore will be to see if the speakers employ different acoustic correlates for emphatic stress, as opposed to the stressed syllables, or if they use the same acoustic correlates for both emphatically stressed and stressed syllables, but to a different degree.

Pitch

Figure 4.5 shows the overall means of the F_0 of the stressed and the emphatically stressed words of the three ethnic groups.

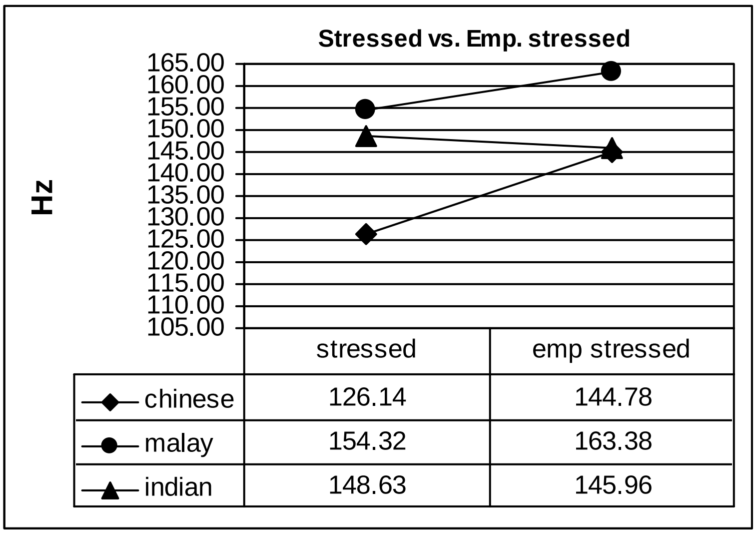


Fig. 4.5: Overall means of the F_0 of the stressed and emphatically stressed words of the Chinese, Malay and Indian subjects.

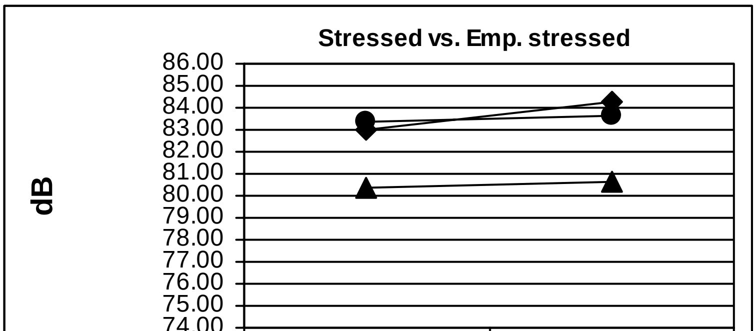
As can be seen from Figure 4.5, the emphatically stressed words of the Chinese speakers are much higher than the stressed words. The difference between the means of the F_0 between the stressed and the emphatically stressed words for the Chinese speakers is 18.64 Hz, a value much larger than the just-noticeable difference of 1 Hz for pitch perception. The multivariate test shows that the means of the F_0 of the stressed, unstressed and emphatically stressed target words are significantly different at $p < 0.01$ ** ($p < 0.0005$, df = 2, N = 160). The post-hoc Scheffe test shows that the difference in the means of F_0 between the stressed and emphatically stressed words is also significant at $p < 0.01$ ** ($p < 0.0005$). Pitch is shown to be a phonetic property that distinguishes between the stressed and the emphatically stressed target words for the Chinese speakers. In other words, while there is no evidence to show that the Chinese speakers use pitch to distinguish between a stressed and unstressed word, the statistical tests in this section show that they use pitch to indicate emphatic stress.

From Figure 4.5, it can also be seen that the emphatically stressed words of the Malay speakers have higher pitch compared to the stressed words. The Malay speakers show a difference of 9.06 Hz in the F_0 between the stressed and emphatically stressed words. The multivariate test shows that the means of the F_0 of the stressed, unstressed and emphatically stressed target words are significantly different at $p < 0.01$ ** ($p < 0.0005$, df = 2, N = 160). The post-hoc Scheffe test, in addition, shows that the difference in the means of F_0 between the stressed and unstressed words is significant at $p < 0.05$ * ($p = 0.003$). Pitch can be said to be a distinguishing feature between the stressed and the emphatically stressed target words for the Malay speakers of SE. In other words, though the Malay speakers already use pitch to distinguish between the stressed and unstressed words, the F_0 of the word is increased to an even larger extent when using emphatic stress.

For the Indian speakers, however, the emphatically stressed words are lower than the stressed words, unlike what is seen in the Malay and Chinese speakers, as can be seen from Figure 4.5. There is a difference of only 2.67 Hz in the F_0 values of the stressed and the emphatically stressed words, though larger than the just-noticeable difference of 1 Hz for pitch perception, is comparatively smaller compared to the differences in means of F_0 seen in the Chinese and also the Malay speakers. The multivariate test shows that the means of the F_0 of the stressed, unstressed and emphatically stressed target words are significantly different at $p < 0.01$ ** ($p = 0.003$, df = 2, N = 160). The post-hoc Scheffe test, however shows that the difference in the means of F_0 between the stressed and emphatically stressed words is not significant at $p < 0.05$ ($p = 0.747$). The tests therefore cannot conclude that pitch is a phonetic property that distinguishes between the stressed and the emphatically stressed target words for the Indian speakers. Even though pitch is an acoustic correlate used to distinguish between the stressed and the unstressed target words for this group of speakers, there is no evidence to show that this is also true for emphatic stress.

Intensity

Figure 4.6 shows the overall means of the amplitude of the stressed and the emphatically stressed words of the three ethnic groups.



	stressed	emp stressed
chinese	83.01	84.29
malay	83.36	83.59
indian	80.35	80.63

Fig. 4.6: Overall means of the amplitude of the stressed and emphatically stressed words of the Chinese, Malay and Indian subjects.

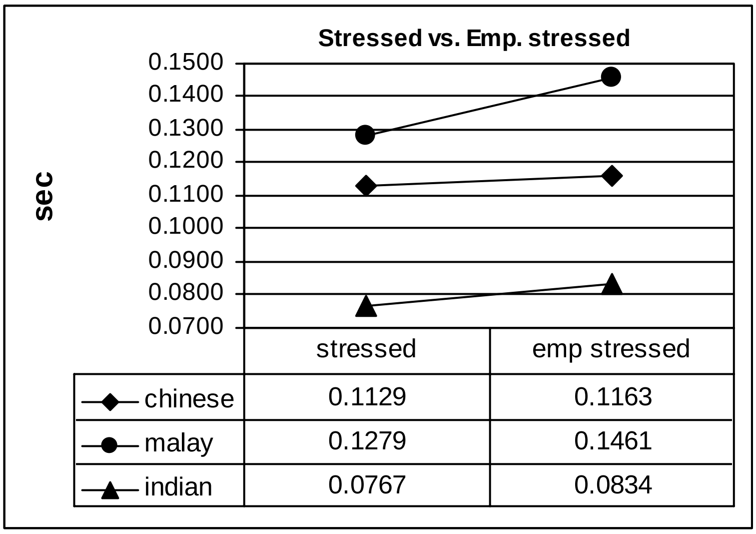
From Figure 4.6, it can be seen that for the Chinese speakers, the emphatically stressed words are louder than the stressed words. The difference between means of amplitude of the stressed and emphatically stressed words is 1.28 dB, which is beyond the range of the just-noticeable difference of 0.5 - 1 dB for perception. The multivariate test shows that the means of amplitude of the stressed, unstressed and emphatically stressed target words are significantly different at $p < 0.01$ ** ($p < 0.0005$, df = 2, N = 160). The post-hoc Scheffe test, in addition, shows that the difference in the means of amplitude between the stressed and emphatically stressed words is significant at $p < 0.05$ * ($p = 0.028$). Since there is a significant difference, intensity can be said to be a distinguishing feature between the stressed and emphatically stressed target words for the Chinese speakers. In other words, though the Chinese speakers already use intensity to distinguish between the stressed and unstressed words, when they want to place emphasis on a word, they increase the amplitude of the word to an even larger extent.

From Figure 4.6, one observes that for the Malay speakers, the emphatically stressed words are only 0.23 dB louder than the stressed words, which is less than the just-noticeable difference of 0.5 - 1 dB. The multivariate test shows that the means of the amplitude of the stressed, unstressed and emphatically stressed target words are significantly different at $p < 0.05$ ** ($p < 0.0005$, df = 2, N = 160). The post-hoc Scheffe test, however shows that the difference in the means of amplitude between the stressed and emphatically stressed words is not significant at $p < 0.05$ ($p = 0.824$). It cannot be concluded therefore that intensity is a distinguishing feature between the stressed and the emphatically stressed instances. In other words, though intensity is used to distinguish between the stressed and unstressed target words, there is no evidence to show that it is also used to distinguish between the emphatically stressed and the stressed target words.

The Indian speakers, like the Malay speakers, as can be seen from Figure 4.6, have the emphatically stressed words only 0.28 dB louder than the stressed words. The multivariate test shows that the means of amplitude of the stressed, unstressed and emphatically stressed target words are significantly different at $p < 0.01$ ** ($p < 0.0005$, df = 2, N = 160). The post-hoc Scheffe test shows that the difference in the means of amplitude between the stressed and emphatically stressed words is not significant at $p < 0.05$ ($p = 0.821$). Again, the tests here cannot prove that intensity is a distinguishing feature between the stressed and the emphatically stressed words. In other words, though intensity is an acoustic correlate to distinguish between the stressed and unstressed target words, there is no statistical evidence to show that intensity is also used to distinguish between the emphatically stressed and the stressed target words.

Duration

Figure 4.7 shows the overall means of the vowel length of the stressed and the emphatically stressed words of the three ethnic groups.



	stressed	emp stressed
chinese	0.1129	0.1163
malay	0.1279	0.1461
indian	0.0767	0.0834

Fig. 4.7: Overall means of the vowel length of the stressed and emphatically stressed words of the Chinese, Malay and Indian subjects.

As can be seen from Figure 4.7, the vowels in the emphatically stressed words are only 0.0034 sec longer than the vowels in the stressed words for the Chinese speakers, and this difference is not within the range of the just-noticeable difference for duration perception of 0.01 - 0.04 sec. The multivariate test shows that the means of the vowel length of the stressed, unstressed and emphatically stressed target words are significantly different at $p < 0.01$ ** ($p < 0.0005$, df = 2, N = 160). The post-hoc Scheffe test shows that the difference in the means of the vowel length between the stressed and emphatically stressed vowels is not significant at $p < 0.05$ ($p = 0.599$). The tests in this case do not provide evidence to show that vowel length is a distinguishing feature between the stressed and the emphatically stressed instances for the Chinese speakers. In other words, though duration is an acoustic correlate to distinguish between the stressed and unstressed target words, one cannot conclude that this same correlate is also used by the Chinese speakers for emphatic stress.

From the same figure, one observes that the vowels in the emphatically stressed words are 0.0182 sec longer than the vowels in the stressed words for the Malay speakers. The multivariate test shows that the means of the vowel length of the stressed, unstressed and emphatically stressed target words are significantly different at $p < 0.01$ ** ($p < 0.0005$, df = 2, N = 160). The post-hoc Scheffe test, in addition, shows that the difference in the means of vowel length between the stressed and emphatically stressed words is significant at $p < 0.01$ ** ($p = 0.005$). Vowel length is therefore a distinguishing feature between the stressed and the emphatically stressed instances. In other words, though the Malay speakers already use duration to distinguish between the stressed and unstressed words, when they want to place emphasis on a word, they increase the duration of the word to an even larger extent.

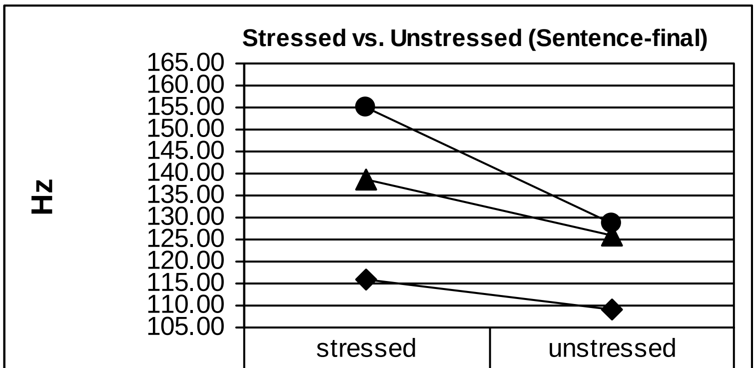
The Indian speakers' vowels in the emphatically stressed words are 0.0167 sec longer than the vowels in the stressed ones, and this difference is not within the range of the just-noticeable difference for perception. The multivariate test shows that the means of vowel length of the stressed, unstressed and emphatically stressed target words are significantly different at $p < 0.01$ ** ($p < 0.0005$, df = 2, N = 160). The post-hoc Scheffe test, in addition, shows that the difference in the means of vowel length between the stressed and emphatically stressed words is significant at $p < 0.01$ ** ($p < 0.005$). Duration is therefore a phonetic property that distinguishes between the stressed and the emphatically stressed target words for the Indian speakers. In other words, while the Indian speakers do not use vowel length to distinguish between a stressed and unstressed word, they use increased duration when they want to emphasise a word.

4.3.3 Stressed and Unstressed Words in Sentence-final Positions and Non Sentence-final Positions

As mentioned earlier, researchers on SE stress (Tongue, 1979, Platt and Weber, 1980; Low and Grabe, 1999) have claimed that SE speakers tend to place prominence on syllables or words in phrase- or sentence-final positions. This section will discuss the differences in the values of the parameters between the vowels in the stressed and unstressed target words for those in the sentence-final position, compared to those in the non sentence-final position. This is to determine if the position of the words in the sentence has an effect on the acoustic properties of stress. Similarly, F_0 will be discussed first, followed by amplitude and duration. Each ethnic group will be individually discussed as well.

Pitch

Figure 4.8 shows the means of the F_0 of the stressed and the unstressed words in sentence-final positions of the Chinese, Malay and Indian speakers. Figure 4.9 shows the means of the F_0 of the stressed and the unstressed words in non sentence-final positions of the Chinese, Malay and Indian speakers.



	stressed	unstressed
chinese	116.00	109.23
malay	154.83	128.62
indian	138.63	126.14

Fig. 4.8: Means of the F_0 of the stressed and unstressed sentence-final words of the Chinese, Malay and Indian subjects.

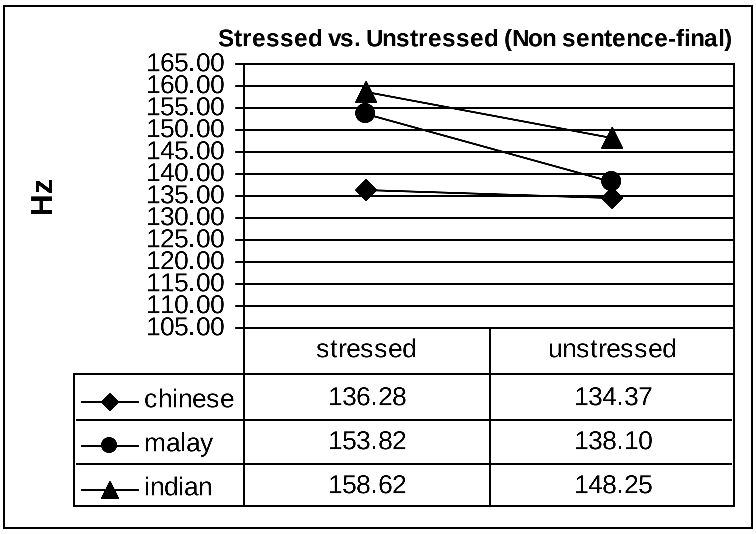


Fig. 4.9: Means of the F_0 of the stressed and unstressed non sentence-final words of the Chinese, Malay and Indian subjects.

As can be seen from Figure 4.8, the mean of F_0 of the stressed target words is higher than the mean of F_0 of unstressed target words in the sentence-final position for the Chinese speakers. The difference between the two means is 6.77 Hz. The multivariate test shows that the difference between the means of the F_0 of the stressed and the unstressed target words in the sentence-final position is not significant at $p < 0.05$ ($p = 0.12$, $df = 1$, $N = 80$). There is not enough statistical evidence to show that pitch is a phonetic property that distinguishes between the stressed and the unstressed target words in the sentence-final position for the Chinese speakers.

Figure 4.9 shows that the stressed target words are higher than the unstressed target words in the non sentence-final position for the Chinese speakers. Comparing Figures 4.8 and 4.9, however, one can see that for the F_0 in non sentence-final position, the difference between the F_0 values of the stressed and the unstressed target words for the Chinese speakers is even smaller than that seen in the sentence-final position, with only a difference of 1.91 Hz. The multivariate test shows that the difference between the means of the F_0 of the stressed and the unstressed target words in the non sentence-final position is not significant at $p < 0.05$ ($p = 0.556$, $df = 1$, $N = 80$). Again, there is no strong statistical evidence to show that pitch is a phonetic property that distinguishes between the stressed and the unstressed target words in the non sentence-final position for the Chinese speakers.

This is consistent with what is seen earlier in Section 4.3.1, as pitch is shown not to be a distinguishing property between the stressed and unstressed syllables for the Chinese speakers. These findings show that regardless of position within the sentence, the Chinese speakers do not use pitch to indicate stress.

For the Malay speakers, as can be seen from Figure 4.8, the stressed target words in the sentence-final position are higher than the unstressed target words in the same position. The Malay speakers show a difference of 26.21 Hz in the F_0 of the stressed and the unstressed target words in the sentence-final position, a difference much larger than the just-noticeable difference of 1 Hz in pitch perception. The multivariate test shows that the difference between the means of the F_0 of the stressed and the unstressed target words in the sentence-final position is significant at $p < 0.01$ ** ($p < 0.0005$, $df = 1$, $N = 80$). This indicates that pitch is a distinguishing feature between the stressed and the unstressed target words in the sentence-final position for the Malay speakers of SE.

From Figure 4.9, it can be seen that, for the Malay speakers, the stressed target words in the non sentence-final position are higher than the unstressed target words in the same position. For the F_0 in non sentence-final position, the difference between the F_0 values of the stressed and the unstressed target words for the Malay speakers is 15.72 Hz. The multivariate test shows that the difference between the means of the F_0 of the stressed and the unstressed target words in the non sentence-final position is significant at $p < 0.01$ ** ($p < 0.0005$, $df = 1$, $N = 80$). Pitch is therefore a phonetic property that distinguishes between the stressed and the unstressed target words in the non sentence-final position for the Malay speakers.

This is again consistent with what is seen earlier in Section 4.3.1, as pitch is shown to be a phonetic property distinguishing between the stressed and unstressed syllables for the Malay speakers. These findings show that regardless of position within the sentence, the Malay speakers use pitch to indicate stress.

From Figure 4.8, it can be seen that, for the Indian speakers, the stressed target words in the sentence-final position are higher than the unstressed target words in the same position. For the Indian speakers, there is a difference of 12.49 Hz in the F_0 of the stressed and the unstressed target words in sentence-final position. The multivariate test shows that the difference between the means of the F_0 of the stressed and the unstressed target words in the sentence-final position is significant at $p < 0.01$ ** ($p = 0.007$, $df = 1$, $N = 80$). Pitch is therefore a phonetic property that distinguishes between the stressed and the unstressed target words in sentence-final position for the Indian speakers.

Similarly for the words in the non sentence-final position, the stressed target words are also higher than the unstressed target words, as can be seen from Figure 4.9. In non sentence-final position, the difference between the F_0 of the stressed and the unstressed target words for the Indian speakers is 10.37 Hz. Though the difference is relatively large, the multivariate test shows that the difference between the means of the F_0 of the stressed and the unstressed target words in the non sentence-final position is not significant at $p < 0.05$ ($p = 0.24$, $df = 1$, $N = 80$). In this case, there is no statistical evidence to show that pitch is a phonetic property that distinguishes between the stressed and the unstressed target words in the non sentence-final position for the Indian speakers.

For the Indian speakers therefore, pitch is an acoustic correlate of stress only for the target words in sentence-final position. For target words in non sentence-final position, pitch is not used to distinguish between the stressed and the unstressed words. This is probably due to what Low (1994) describes as “booster”. According to Low, for SE speakers, there is a tendency to have an upsurge of F_0 in a sentence-medial position whether or not the words in the position are stressed. In this case therefore, though pitch is used by the Indian speakers to indicate stress, there is a possibility that even for the unstressed words in the non sentence-final position, there is a rise of F_0. The difference between F_0 between the stressed and unstressed target words in the non sentence-final position is smaller. What is interesting is that Low uses Chinese SE speakers, yet the Chinese speakers here do not exhibit this trait. Instead, we have the Indian speakers showing what Low has found.

Another reason for why the Indian speakers show an increase in F_0 for syllables in sentence-final position is possibly the influence from Tamil. According to Tan (1999), Tamil speakers have a marked rise-fall pitch contour on the sentence-final syllable, regardless of sentence type. It is perhaps this interference from Tamil that sees a significant increase in F_0 for stressed syllables in the sentence-final position.

Intensity

Figure 4.10 shows the means of the amplitude of the stressed and unstressed words in sentence-final positions of the Chinese, Malay and Indian speakers. Figure 4.11 shows the means of the amplitude of the stressed and the unstressed words in non sentence-final positions of the Chinese, Malay and Indian speakers.

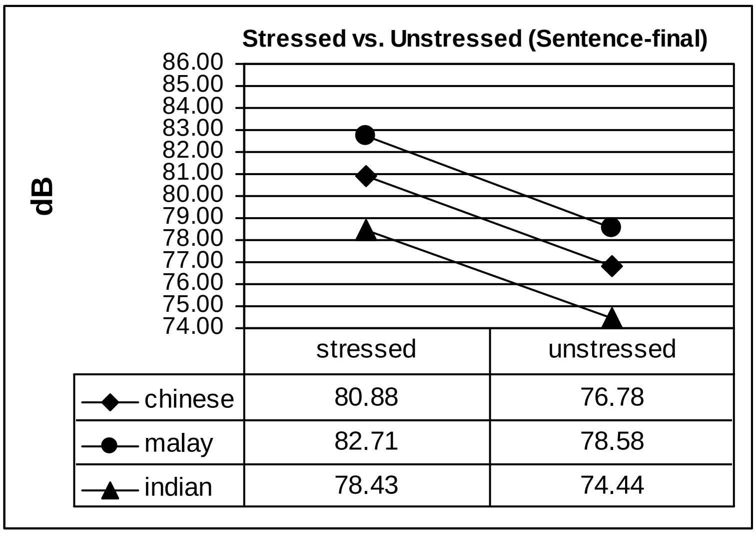


Fig. 4.10: Means of the amplitude of the stressed and unstressed sentence-final words of the Chinese, Malay and Indian subjects.

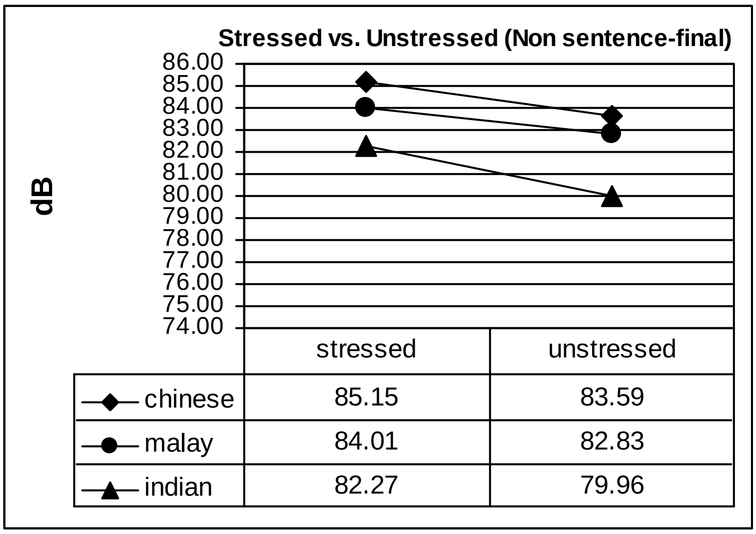


Fig. 4.11: Means of the amplitude of the stressed and unstressed non sentence-final words of the Chinese, Malay and Indian subjects.

From Figure 4.10, it can be seen that, for the Chinese speakers, the stressed target words in the sentence-final position are louder than the unstressed target words in the same position. The difference in the amplitude between the stressed and the unstressed target words in the sentence-final position is 4.1 dB for the Chinese speakers, a value larger than the just-noticeable difference of 0.5 - 1 dB range for perception. The multivariate test shows this difference is significant at $p < 0.01$ ** ($p < 0.0005$, df = 1, N = 80). Intensity is therefore a phonetic property that distinguishes between the stressed and the unstressed target words in the sentence-final position for the Chinese speakers.

Figure 4.11 shows that the stressed target words are louder than the unstressed target words in the non sentence-final position for the Chinese speakers. The difference in the amplitude between the stressed and the unstressed target words is only 1.56 dB, only 0.56 dB higher than the just-noticeable difference of 0.5 – 1 dB. However, despite this small difference, the multivariate test shows that this difference is significant at $p < 0.01$ ** ($p < 0.0005$, df = 1, N = 80). Intensity is therefore a phonetic property that distinguishes between the stressed and the unstressed target words in the non sentence-final position for the Chinese speakers.

This is consistent with what is seen earlier in Section 4.3.1, as intensity is shown to be phonetic property that distinguishes between the stressed and unstressed syllables for the Chinese speakers. These findings show that regardless of position within the sentence, the Chinese speakers use intensity to indicate stress.

From Figure 4.10, it can be seen that, for the Malay speakers, like the Chinese speakers, the stressed target words in the sentence-final position are louder than the unstressed target words in the same position. The Malay speakers show a difference of 4.13 dB in amplitude between the stressed and the unstressed target words in the sentence-final position. The multivariate test shows that this difference is significant $p < 0.01$ ** ($p < 0.0005$, df = 1, N = 80). This indicates that intensity is a distinguishing feature between the stressed and the unstressed target words in the sentence-final position for the Malay speakers of SE.

From Figure 4.11, it can be seen that for the Malay speakers, the stressed target words in the non sentence-final position are also louder than the unstressed target words in the same position. In non sentence-final position, the difference between the amplitude of the stressed and the unstressed target words for the Malay speakers is 1.18 dB. Despite this small difference, the multivariate test shows that this difference is significant at $p < 0.01$ ** ($p = 0.001$, df = 1, N = 80). Intensity is therefore a phonetic property that distinguishes between the stressed and the unstressed target words in the non sentence-final position for the Malay speakers.

This is again consistent with what is seen earlier in Section 4.3.1, as intensity is shown to be an acoustic correlate of stress for the Malay speakers. These findings show that regardless of position within the sentence, the Malay speakers use intensity to distinguish between the stressed and unstressed syllables.

From Figure 4.10, it can be seen that, for the Indian speakers, like the other two groups of speakers, the stressed target words in the sentence-final position are louder than the unstressed target words in the same position. For the Indian speakers, there is a difference of 3.99 dB in amplitude between the stressed and the unstressed target words in sentence-final position. The multivariate test shows that this difference is significant at $p < 0.01$ ** ($p < 0.0005$, df = 1, N = 80). Intensity is therefore a phonetic property that distinguishes between the stressed and the unstressed target words in the sentence-final position for the Indian speakers.

Similarly for the words in non sentence-final position, from Figure 4.11, it can be seen that the stressed target words are 2.31 dB louder than the unstressed target words for the Indian speakers. As expected, the multivariate test shows that this difference between the means is significant at p < 0.01 ** (p < 0.0005, df = 1, N = 80). Intensity is therefore a phonetic property that distinguishes between the stressed and the unstressed target words in the non sentence-final position for the Indian speakers.

This is again consistent with what is seen earlier in Section 4.3.1, as intensity is shown to be a phonetic property that distinguishes between the stressed and unstressed syllables for the Indian speakers. These findings show that regardless of position within the sentence, the Indian speakers use intensity to indicate stress.

Duration

Figure 4.12 shows the means of the vowel length of the stressed and the unstressed words in sentence-final positions of the Chinese, Malay and Indian speakers. Figure 4.13 shows the means of the vowel length of the stressed and the unstressed words in non sentence-final positions of the Chinese, Malay and Indian speakers.

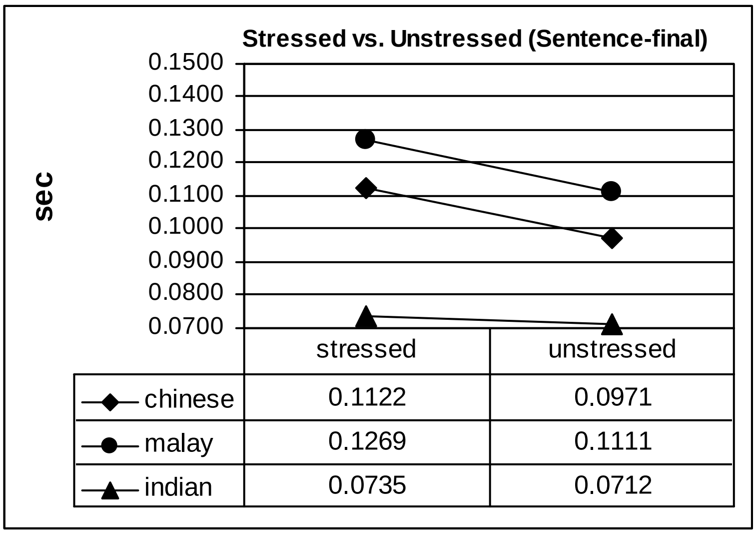


Fig. 4.12: Means of the vowel length of the stressed and the unstressed sentence-final words of the Chinese, Malay and Indian speakers.

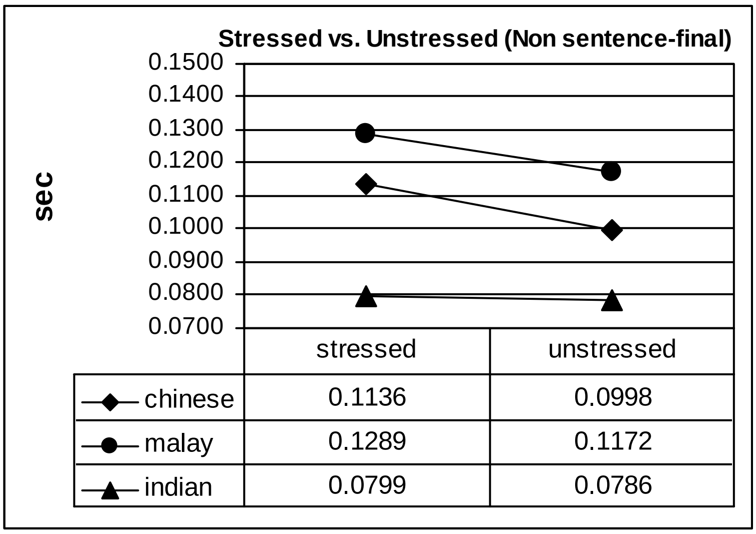


Fig. 4.13: Means of the vowel length of the stressed and the unstressed non sentence-final words of the Chinese, Malay and Indian speakers.

From Figure 4.12, it can be seen that, for the Chinese speakers, the stressed target words in the sentence-final position are longer than the unstressed target words in the same position. The difference in vowel length between the stressed and the unstressed target words in the sentence-final position is 0.0151 sec for the Chinese speakers, a value within the range of the just-noticeable difference of 0.01 - 0.04 sec for perception. The multivariate test that this difference in vowel length is significant at $p < 0.01$ ** ($p < 0.0005$, df = 1, N = 80). Duration is therefore a phonetic property that distinguishes between the stressed and the unstressed target words in the sentence-final position for the Chinese speakers.

Similarly, from Figure 4.13, it can be seen that, for the Chinese speakers, the stressed target words in the non sentence-final position are also longer than the unstressed target words in the same position. The difference between the vowel length between the stressed and the unstressed target words is 0.0138 sec. The multivariate test shows that this difference in vowel length is significant at $p < 0.01$ ** ($p = 0.005$, df = 1, N = 80). Duration is therefore a phonetic property that distinguishes between the stressed and the unstressed target words in the non sentence-final position for the Chinese speakers.

This is consistent with what is seen earlier in Section 4.3.1, as duration is shown to be an acoustic correlate of stress for the Chinese speakers. These findings show that regardless of position within the sentence, the Chinese speakers use duration to distinguish between the stressed and unstressed syllables.

From Figure 4.12, it can be seen that, for the Malay speakers, the stressed target words in the sentence-final position are 0.0158 sec longer than the unstressed target words in the same position. The multivariate test shows that this difference in vowel length is significant at $p < 0.05$ * ($p = 0.038$, df = 1, N = 80). This indicates that duration is a distinguishing feature between the stressed and the unstressed target words in the sentence-final position for the Malay speakers of SE, though, as the statistical test indicates, this difference is marginal.

Similarly for the words in the non sentence-final position, from Figure 4.13, it can be seen that, for the Malay speakers, the stressed target word is 0.0117 sec longer than the unstressed target word. However, the multivariate test shows that this difference is not significant at $p < 0.05$ ($p = 0.084$, df = 1, N = 80). The test therefore does not provide strong evidence to show that duration is a phonetic property that distinguishes between the stressed and the unstressed target words in the non sentence-final position for the Malay speakers.

For the Malay speakers therefore, duration is an acoustic correlate of stress only for the target words in sentence-final position. For target words in non sentence-final position, duration is not used to distinguish between the stressed and the unstressed words. This is in line with what Low and Grabe (1999) have said about sentence-final lengthening for SE speakers. According to Low and Grabe, there is a tendency for SE speakers to lengthen the words at phrase boundary or sentence final positions. For the Malay speakers therefore, it could turn out that duration may not be an acoustic correlate of stress after all, since what is manifested could be simply a case of sentence-final lengthening. This will be further discussed in the next section.

From Figure 4.12, it can be seen that, for the Indian speakers, like the Chinese and Malay speakers, the stressed target words in the sentence-final position are slightly longer than the unstressed target words in the same position. For the Indian speakers, there is a small difference of 0.0023 sec in the values of duration between the stressed and the unstressed target words in sentence-final position, smaller than the just-noticeable difference of 0.01 - 0.04 sec for perception. The multivariate test shows that the difference between the means of the values of duration of the stressed and the unstressed target words in the sentence-final position is not significant $p < 0.05$ ($p = 0.253$, $df = 1$, $N = 80$). Again, the test shows that there is no evidence to claim that duration is a phonetic property that distinguishes between the stressed and the unstressed target words in sentence-final position for the Indian speakers.

Similarly for the words in the non sentence-final position, from Figure 4.13, it can be seen that, for the Indian speakers, the stressed target word is also slightly longer than the unstressed target word. For the values of duration in non sentence-final position, the difference between the values of duration between the stressed and the unstressed target words for the Indian speakers is only 0.0013 sec, a very small difference compared to what is seen in the Chinese and Malay speakers. The multivariate test shows that this difference is not significant at $p < 0.05$ ($p = 0.535$, $df = 1$, $N = 80$). The statistical test shows that one cannot come to the conclusion that duration is a phonetic property that distinguishes between the stressed and the unstressed target words in the non sentence-final position for the Indian speakers.

This is again consistent with what is seen earlier in Section 4.3.1, as duration is shown not to be an acoustic correlate of stress for the Indian speakers. These findings show that regardless of position within the sentence, there is no clear indication that the Indian speakers use vowel length to distinguish between the stressed and unstressed syllables.

Sentence-final Lengthening?

Low and Grabe (1999) have reported that SE speakers tend to place stress sentence- or phrase-finally, leading to words or syllables in these positions to be prominent. They emphasise, in particular, that this increased prominence is brought about by the lengthening of the words or syllables at sentence-final position, which lead them to claim that duration is the acoustic correlate of stress in SE.

As mentioned in Chapter 2, this claim is not well supported. There are several questions one needs to ask. Firstly, does sentence-final lengthening occur in SE whether or not the word in the sentence-final position is stressed? In other words, is it a regular existence in SE speech behaviour? If it is so, then we have to disregard this lengthening as an acoustic correlate of stress. If, on the other hand, sentence-final lengthening only happens for stressed syllables in sentence-final position, then we can safely conclude that duration is indeed an acoustic correlate of stress in SE.

What is particular pressing at this point is to determine if sentence-final lengthening occurs to unstressed syllables in sentence-final position, as well as the stressed syllables in the same position. It is particularly important to determine this because, from the present findings, particularly that of the Malay speakers of SE, increased vowel lengthening is used only for stressed words in sentence-final positions. Duration is not an acoustic correlate of stress for the Malay speakers for words in the non sentence-final position. Can we then regard duration as an acoustic correlate of stress for the Malay speakers of SE, or are they simply exhibiting sentence-final lengthening?

To determine this, the mean of the vowel length of the stressed syllables in the sentence-final position has to be compared to the mean of the vowel length of the stressed syllables in the non sentence-final position. Similarly, the mean of the vowel length of the unstressed syllables in the sentence-final position has to be compared to the mean of the vowel length of the unstressed syllables in the non sentence-final position. Only then can we determine, given the same type of ‘stress’, if vowel length is going to be significantly different between the two positions.

Figure 4.14 shows the means of the vowel length of the stressed words in sentence-final and non sentence-final positions of the Chinese, Malay and Indian speakers. Figure 4.15 shows the means of the vowel length of the unstressed words in sentence-final and non sentence-final positions of the Chinese, Malay and Indian speakers.

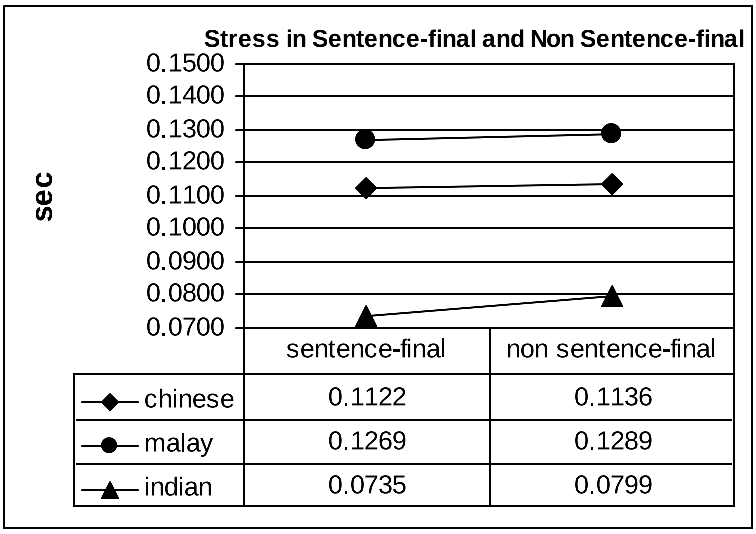


Fig. 4.14: Means of the vowel length of the stressed words in sentence-final and non sentence-final positions of the Chinese, Malay and Indian subjects.

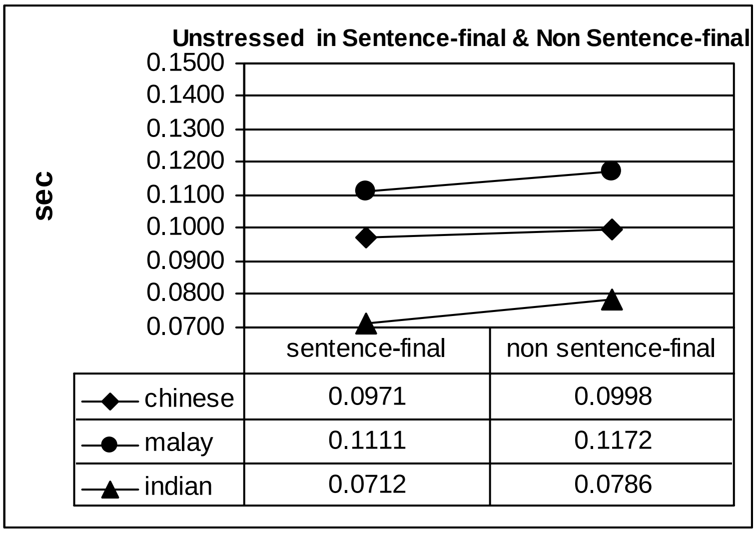


Fig. 4.15: Means of the vowel length of the unstressed words in sentence-final and non sentence-final positions of the Chinese, Malay and Indian subjects.

One thing is very apparent from Figures 4.14 and 4.15. The stressed words in the sentence-final position are shorter than the stressed vowels in the non sentence-final position. Similarly, the unstressed vowels in the sentence-final position are shorter than the unstressed vowels in the non sentence-final position. This is evidence to show that there is no sentence-final lengthening happening here in SE, across all three groups of speakers.

The difference in vowel length between the stressed words in the sentence-final position and the stressed words in the non sentence-final position is 0.0014 sec for the Chinese speakers. As can be seen from Figure 4.14, the stressed words in the non sentence-final position are longer than the ones in the sentence-final position. The t-test comparing the mean of the vowel length of the stressed vowels in the sentence-final position and the mean of the vowel length of the stressed vowels in the non sentence-final position shows that the difference in the means is not significant at $p < 0.05$ ($p = 0.766$, df = 155, N = 80).

From Figure 4.15, it can be seen that the unstressed words in the non sentence-final position are longer than the unstressed words in the sentence-final position for the Chinese speakers. Similarly for the values of vowel length of the unstressed words in the sentence-final position and the unstressed words in the non sentence-final position, the difference in means is only 0.0027 sec. The t-test comparing the mean of the vowel length of the unstressed words in the sentence-final position and the mean of the vowel length of the unstressed words in the non sentence-final position shows that the difference in the means is not significant at $p < 0.05$ ($p = 0.531$, df = 155, N = 80).

The Malay speakers show a difference of 0.002 sec in the vowel length of the stressed words in the sentence-final position and the stressed words in the non sentence-final position. The stressed words in the non sentence-final position, like the Chinese speakers, are observed to be longer than the ones in the sentence-final position, as observed in Figure 4.14. The t-test comparing the mean of the vowel length of the stressed words in the sentence-final position and the mean of the vowel length of the stressed words in the non sentence-final position shows that the difference in the means is not significant at $p < 0.05$ ($p = 0.800$, df = 155, N = 80).

Similarly for the vowel length of the unstressed words in the sentence-final position and the unstressed words in the non sentence-final position, the difference in means is only 0.0061 sec. Again, the unstressed words in the non sentence-final position, as can be seen from Figure 4.15, are found to be longer than the unstressed words in the sentence-final position for the Malay speakers. The t-test comparing the mean of the vowel length of the unstressed vowels in the sentence-final position and the mean of the vowel length of the unstressed words in the non sentence-final position shows that the difference in the means is not significant at $p < 0.05$ ($p = 0.324$, $df = 155$, $N = 80$).

For the Indian speakers, there is a difference of 0.0064 sec in the vowel length between the stressed and the unstressed target words in sentence-final position. Similar to the Chinese and Malay speakers, the unstressed words in the non sentence-final position are also longer than the unstressed words in the sentence-final position, as can be seen from Figure 4.14. Despite this small difference in the means however, the t-test comparing the mean of the vowel length of the stressed words in the sentence-final position and the mean of the vowel length of the stressed words in the non sentence-final position shows that the difference in the means is significant at $p < 0.05$ * ($p = 0.02$, $df = 155$, $N = 80$).

Similarly for the vowel length of the unstressed words in the sentence-final position and the unstressed words in the non sentence-final position, the difference in means is only 0.0074 sec. From Figure 4.15, it can be seen that the unstressed words in the non sentence-final position are also longer than the unstressed words in the sentence-final position for the Indian speakers. Similarly, the t-test comparing the mean of the vowel length of the unstressed words in the sentence-final position and the mean of the vowel length of the unstressed words in the non sentence-final position shows that the difference in the means is significant at $p < 0.01$ ** ($p = 0.005$, $df = 155$, $N = 80$).

This however does not mean that there is sentence-final lengthening for the Indian speakers. The only thing the t-tests show is that there is a significant lengthening in non sentence-final position, for both stressed and unstressed words, which, as mentioned in the earlier section, could be caused by a pitch booster in the sentence-medial position, leading to lengthening as well.

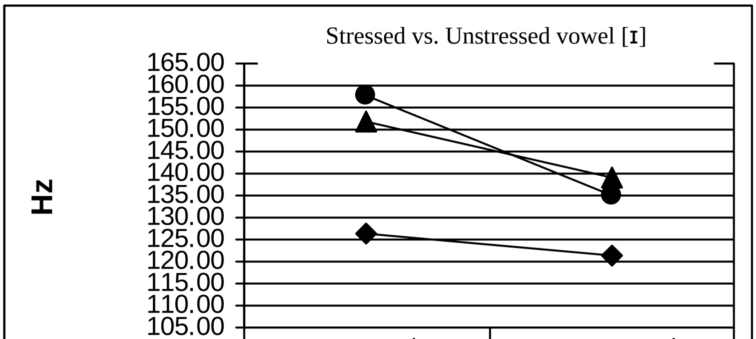
Therefore, it can be concluded that sentence-final lengthening does not happen for monosyllabic words in SE, whether or not the words are stressed or unstressed. This is of course not positive evidence to show that there is no sentence-final lengthening for SE, but the fact that sentence-final monosyllabic words are not lengthened serves to strengthen the finding that durational increases in sentence-final monosyllabic words are signs that duration is an acoustic correlate of stress, and not simply a result of sentence-final lengthening. Going back to the Malay speakers using increased duration to signal stress in SE, duration therefore can be considered as an acoustic correlate of stress for the Malay speakers, as sentence-final lengthening is shown not to have a part to play in this case.

4.3.4 Stressed and Unstressed Words Containing the Vowel [ɪ] *vs.* Stressed and Unstressed Words Containing the Vowel [ɒ]

In this final section, comparisons are made between the words containing the vowel [ɪ] and [ɒ] respectively. This is to determine if spectral differences in the vowels have an effect on the acoustic properties of stress. This section will discuss the differences in the values of the parameters between the vowels in the stressed and unstressed target words containing the vowel [ɪ], compared to those in containing the vowel [ɒ]. Similarly, F_0 will be discussed first, followed by amplitude and duration. Each ethnic group will be individually discussed as well.

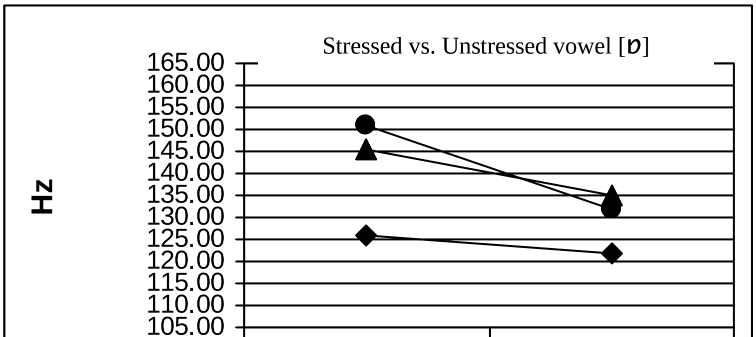
Pitch

Figure 4.16 shows the means of the F_0 values of the stressed and the unstressed words containing the vowel [ɪ] of the Chinese, Malay and Indian speakers. Figure 4.17 shows the means of the F_0 values of the stressed and the unstressed words containing the vowel [ɒ] of the Chinese, Malay and Indian speakers.



	stressed	unstressed
chinese	126.59	121.58
malay	157.91	135.01
indian	151.72	139.31

Fig. 4.16: Means of the F_0 of the stressed and unstressed words containing the vowel [ɪ] of the Chinese, Malay and Indian subjects.



	stressed	unstressed
chinese	125.70	122.02
malay	150.74	131.71
indian	145.54	135.08

Fig. 4.17: Means of the F_0 of the stressed and unstressed words containing the vowel [ɒ] of the Chinese, Malay and Indian subjects.

From Figure 4.16, it can be seen that, for the Chinese speakers, the stressed word with the vowel [ɪ] is higher than the unstressed word with [ɪ]. The difference between the F_0 of the stressed and the unstressed target words containing the vowel [ɪ] is 5.01 Hz for the Chinese speakers, a value larger than the just-noticeable difference of 1 Hz for pitch perception. The multivariate test shows that this difference is not significant at $p < 0.05$ ($p = 0.161$, df = 1, N = 80). The test shows that there is no strong evidence to conclude that pitch is a phonetic property that distinguishes between the stressed and the unstressed target words containing the vowel [ɪ] for the Chinese speakers.

From Figure 4.17, it can be seen that, for the Chinese speakers, the stressed word with the vowel [ɒ] is higher than the unstressed word with [ɒ]. The difference between the F_0 of the stressed and the unstressed target words containing the vowel [ɒ] is only 3.68 Hz. The multivariate test shows that this difference is not significant at $p < 0.05$ ($p = 0.28$, df = 1, N = 80). Again, there is no evidence to show that pitch is a phonetic property that distinguishes between the stressed and the unstressed target containing the vowel [ɒ] for the Chinese speakers.

This is consistent with what is seen earlier in Section 4.3.1, as pitch is shown not to be an acoustic correlate of stress for the Chinese speakers. These findings show that regardless of spectral quality of the vowel, the Chinese speakers do not seem to use pitch differences to distinguish between the stressed and unstressed syllables.

From Figure 4.16, it can be seen that, for the Malay speakers, like the Chinese speakers, the stressed word with the vowel [ɪ] is higher than the unstressed word with [ɪ]. The Malay speakers show a difference of 22.90 Hz in the F_0 values of the stressed and the unstressed target words containing the vowel [ɪ]. The multivariate test shows that this difference is significant at $p < 0.01$ ** ($p < 0.0005$, df = 1, N = 80). This indicates that pitch is a distinguishing feature between the stressed and the unstressed target words containing the vowel [ɪ] for the Malay speakers of SE.

From Figure 4.17, for the Malay speakers, it can be seen that the stressed word with the vowel [ɒ] is higher than the unstressed word with [ɒ]. For the F_0 in target words containing the vowel [ɒ], the difference between the F_0 values of the stressed and the unstressed target words for the Malay speakers is 19.03 Hz. The multivariate test shows that this difference is significant at $p < 0.01$ ** ($p < 0.0005$, df = 1, N = 80). Pitch is therefore a phonetic property that distinguishes between the stressed and the unstressed target words containing the vowel [ɒ] for the Malay speakers.

This is again consistent with what is seen earlier in Section 4.3.1, as pitch is shown to be a phonetic property that distinguishes between the stressed and unstressed syllables for the Malay speakers. These findings show that regardless of the spectral qualities of the vowel, the Malay speakers use differences in pitch to indicate stress.

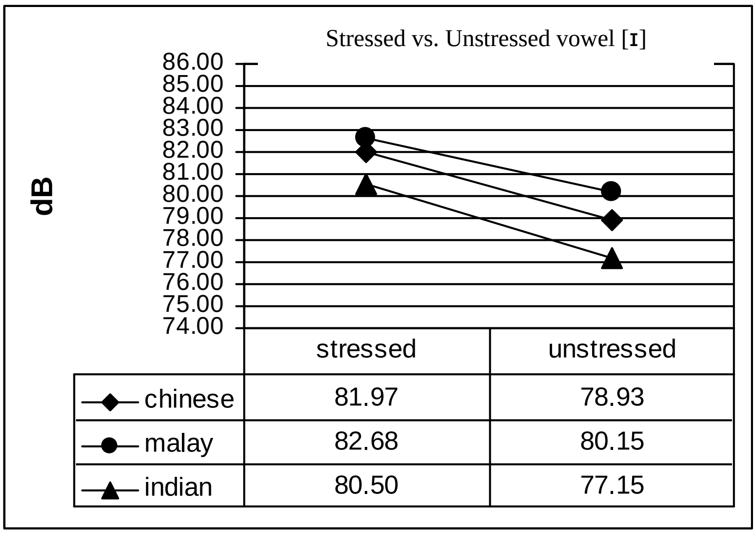
Similar to the Chinese and Malay speakers, from Figure 4.16, it can be seen that, for the Indian speakers, the stressed word with the vowel [ɪ] is higher than the unstressed word with [ɪ]. The Indian speakers show a difference of 12.41 Hz in the F_0 values of the stressed and the unstressed target words containing the vowel [ɪ]. The multivariate test shows that this difference is significant at $p < 0.05$ * ($p = 0.011$, df = 1, N = 80). This indicates that pitch is a distinguishing feature between the stressed and the unstressed target words containing the vowel [ɪ] for the Indian speakers of SE.

From Figure 4.17, for the Indian speakers, it can be seen that the stressed word with the vowel [ɒ] is higher than the unstressed word with [ɒ], similar to what is seen in the vowel [ɪ]. For the F_0 values in target words containing the vowel [ɒ], the difference between the F_0 values of the stressed and the unstressed target words for the Indian speakers is 10.46 Hz. The multivariate test shows that this difference is significant at $p < 0.05$ * ($p = 0.032$, $df = 1$, $N = 80$). Pitch is therefore a phonetic property that distinguishes between the stressed and the unstressed target words containing the vowel [ɒ] for the Indian speakers.

This is again consistent with what is seen earlier in Section 4.3.1, as pitch is shown to be an acoustic correlate of stress for the Indian speakers. These findings show that regardless of the spectral qualities of the vowel, the Indian speakers use differences in pitch to distinguish between the stressed and unstressed syllables.

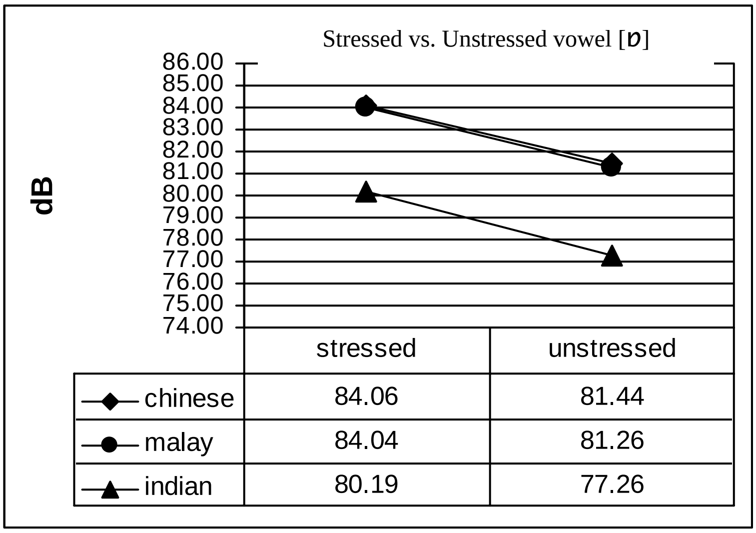
Intensity

Figure 4.18 shows the means of the amplitude of the stressed and the unstressed words containing the vowel [ɪ] of the Chinese, Malay and Indian speakers. Figure 4.19 shows the means of the amplitude of the stressed and the unstressed words containing the vowel [ɒ] of the Chinese, Malay and Indian speakers.



	stressed	unstressed
chinese	81.97	78.93
malay	82.68	80.15
indian	80.50	77.15

Fig. 4.18: Means of the amplitude of the stressed and the unstressed words containing the vowel [ɪ] of the Chinese, Malay and Indian subjects.



	stressed	unstressed
chinese	84.06	81.44
malay	84.04	81.26
indian	80.19	77.26

Fig. 4.19: Means of the amplitude of the stressed and the unstressed words containing the vowel [ɒ] of the Chinese, Malay and Indian subjects.

From Figure 4.18, it can be seen that, for the Chinese speakers, the stressed word with the vowel [ɪ] is louder than the unstressed word with [ɪ]. The difference between the amplitude of the stressed and the unstressed target words containing the vowel [ɪ] is 3.04 dB for the Chinese speakers, a value larger than the just-noticeable difference of 0.5 – 1 dB range for pitch perception. The multivariate test shows that the difference between the two means is significant at $p < 0.01$ ** ($p < 0.0005$, df = 1, N = 80). Intensity can therefore be said to be a phonetic property that distinguishes between the stressed and the unstressed target words containing the vowel [ɪ] for the Chinese speakers.

From Figure 4.19, it can be seen that, for the Chinese speakers, the stressed word with the vowel [ɒ] is 2.62 dB louder than the unstressed [ɒ]. The multivariate test shows that this difference is significant at $p < 0.01$ ** ($p < 0.0005$, df = 1, N = 80). Intensity is therefore a phonetic property that distinguishes between the stressed and the unstressed target words containing the vowel [ɒ] for the Chinese speakers.

This is consistent with what is seen earlier in Section 4.3.1, as intensity is shown to be a distinguishing phonetic property between the stressed and unstressed syllables for the Chinese speakers. These findings show that regardless of spectral quality of the vowel, the Chinese speakers makes use of intensity to indicate stress.

From Figure 4.18, it can be seen that, for the Malay speakers, the stressed word with the vowel [ɪ] is also louder than the unstressed word with [ɪ], like what is seen in the Chinese speakers. The Malay speakers show a difference of 2.53 dB in amplitude between the stressed and the unstressed target words containing the vowel [ɪ].The multivariate test shows that this difference between the means is significant at $p < 0.01$ ** ($p < 0.0005$, df = 1, N = 80). This indicates that intensity is a distinguishing feature between the stressed and the unstressed target words containing the vowel [ɪ] for the Malay speakers of SE.

From Figure 4.19, it can be seen that, for the Malay speakers, the stressed word with vowel [ɒ] is also louder than the unstressed word with [ɒ]. For target words containing the vowel [ɒ], the difference between the amplitude of the stressed and the unstressed target words for the Malay speakers is 2.78 dB. The multivariate test shows that the difference between the two means is significant at $p < 0.01$ ** ($p < 0.0005$, df = 1, N = 80). Intensity is therefore a phonetic property that distinguishes between the stressed and the unstressed target words containing the vowel [ɒ] for the Malay speakers.

This is again consistent with what is seen earlier in Section 4.3.1, as intensity is shown to be an acoustic correlate of stress for the Malay speakers. These findings show that regardless of the spectral qualities of the vowel, the Malay speakers use intensity to distinguish between the stressed and unstressed syllables.

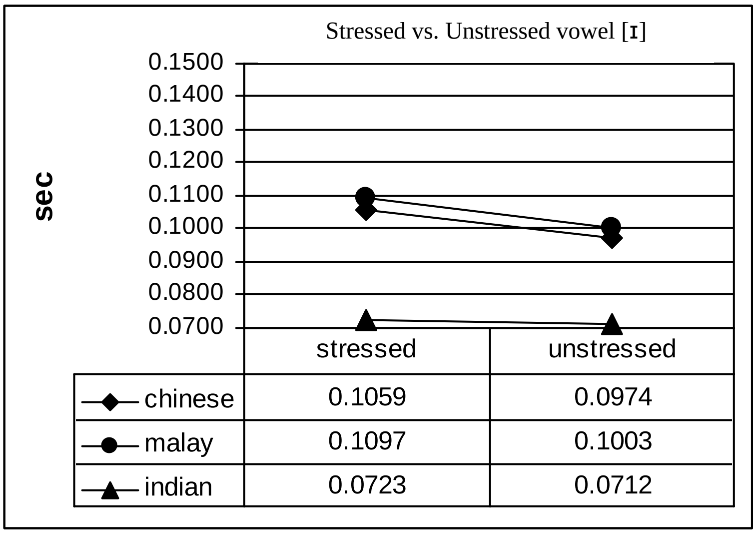
From Figure 4.18, it can be seen that, for the Indian speakers, the stressed word with the vowel [ɪ] is also louder than the unstressed word with [ɪ], like what is seen in the other two groups of speakers. The Indian speakers show a difference of 3.35 dB in the amplitude between the stressed and the unstressed target words containing the vowel [ɪ]. The multivariate test shows that the difference between the two means is significant at $p < 0.01$ ** ($p < 0.0005$, df = 1, N = 80). This indicates that intensity is a distinguishing feature between the stressed and the unstressed target words containing the vowel [ɪ] for the Indian speakers of SE.

From Figure 4.19, it can be seen that, for the Indian speakers, the stressed word with vowel [ɒ] is 2.93 dB louder than the unstressed word with [ɒ]. The multivariate test shows that this difference is significant at $p < 0.01$ ** ($p < 0.0005$, df = 1, N = 80). Intensity is therefore a phonetic property that distinguishes between the stressed and the unstressed target words containing the vowel [ɒ] for the Indian speakers.

This is again consistent with what is seen earlier in Section 4.3.1, as intensity is shown to be an acoustic correlate of stress for the Indian speakers. These findings show that regardless of the spectral qualities of the vowel, the Indian speakers use intensity to distinguish between the stressed and unstressed syllables.

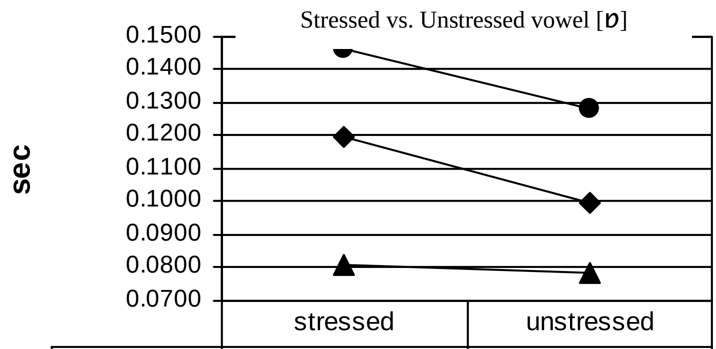
Duration

Figure 4.20 shows the means of the vowel length of the stressed and the unstressed words containing the vowel [ɪ] of the Chinese, Malay and Indian speakers. Figure 4.21 shows the means of the vowel length of the stressed and the unstressed words containing the vowel [ɒ] of the Chinese, Malay and Indian speakers.



	stressed	unstressed
chinese	0.1059	0.0974
malay	0.1097	0.1003
indian	0.0723	0.0712

Fig. 4.20: Means of the vowel length of the stressed and the unstressed words containing the vowel [ɪ] of the Chinese, Malay and Indian subjects.



	stressed	unstressed
chinese	0.1200	0.0995
malay	0.1461	0.1281
indian	0.0811	0.0785

Fig. 4.21: Means of the vowel length of the stressed and the unstressed words containing the vowel [ɒ] of the Chinese, Malay and Indian subjects.

From Figure 4.20, it can be seen that, for the Chinese speakers, the stressed word with vowel [ɪ] is 0.0085 sec longer than the unstressed word with [ɪ], a value smaller than the just-noticeable difference of 0.01 – 0.04 sec range for perception. However, though this difference is small, the multivariate test shows that the difference between the two means is significant at $p < 0.05$ * ($p = 0.031$, df = 1, N = 80). Duration is therefore a phonetic property that distinguishes between the stressed and the unstressed target words target words containing the vowel [ɪ] for the Chinese speakers.

From Figure 4.21, it can be seen that, for the Chinese speakers, the stressed vowel [ɒ] is 0.0205 sec longer than the unstressed [ɒ]. The multivariate test shows that the difference between the two means is significant at $p < 0.01$ ** ($p < 0.0005$, df = 1, N = 80). Duration is therefore a phonetic property that distinguishes between the stressed and the unstressed target containing the vowel [ɒ] for the Chinese speakers.

This is consistent with what is seen earlier in Section 4.3.1, as duration is shown to be an acoustic correlate of stress for the Chinese speakers. These findings show that regardless of spectral quality of the vowel, the Chinese speakers use differences in vowel length to distinguish between the stressed and unstressed syllables.

From Figure 4.20, it can be seen that, for the Malay speakers, like the Chinese speakers, the stressed word with vowel [ɪ] is longer than the unstressed word with [ɪ]. The Malay speakers show a difference of 0.0094 sec in the vowel length between the stressed and the unstressed target words containing the vowel [ɪ]. The multivariate test shows that the difference between the means is not significant at $p < 0.05$ ($p = 0.053$, df = 1, N = 80). This indicates that there is no evidence to conclude that duration is a distinguishing feature between the stressed and the unstressed target words containing the vowel [ɪ] for the Malay speakers of SE.

From Figure 4.21, it can be seen that, for the Malay speakers, the stressed word with [ɒ] is 0.018 sec longer than the unstressed word with [ɒ]. The multivariate test shows that the difference between the two means is significant at $p < 0.05$ * ($p = 0.027$, df = 1, N = 80). Duration is therefore a phonetic property that distinguishes between the stressed and the unstressed target words containing the vowel [ɒ] for the Malay speakers.

Though there is a difference noted here between the vowel [ɪ] and the vowel [ɒ], this is probably not indicative of any real difference. As noted, though the difference between the means of vowel length of the stressed and the unstressed target words containing the vowel [ɪ] is not significant, the value of p is 0.053, very close to the significance level of $p = 0.05$. The difference between the means of vowel length of the stressed and the unstressed target words containing the vowel [ɒ] is also only marginally significant. Thus, one can conclude that in this case, it is again consistent with what is seen earlier in Section 4.3.1, as duration can be said to be a phonetic property that distinguishes between the stressed and unstressed syllables for the Malay speakers, indicating that, regardless of the spectral qualities of the vowel, the Malay speakers use duration to indicate stress. However, as the statistical tests are merely marginal, this is perhaps not a very strong case for arguing that vowel length is a pertinent acoustic property of stress for the Malay speakers.

From Figure 4.20, it can be seen that, for the Indian speakers, like the other two groups of speakers, the stressed word with vowel [ɪ] is longer than the unstressed word with [ɪ]. The Indian speakers show a slight difference of 0.0011 sec in the values of duration between the stressed and the unstressed target words containing the vowel [ɪ]. The multivariate test shows that the difference between the two means is not significant at $p < 0.05$ ($p = 0.585$, $df = 1$, $N = 80$). The test does not provide evidence to indicate that duration is used as a distinguishing feature between the stressed and the unstressed target words containing the vowel [ɪ] for the Indian speakers of SE.

From Figure 4.21, it can be seen that, for the Indian speakers, the stressed word with vowel [ɒ] is 0.0026 sec longer than the unstressed [ɒ]. As expected, the multivariate test shows that the difference between the two means is not significant at $p < 0.05$ ($p = 0.225$, $df = 1$, $N = 80$). Again, there is no evidence provided by the statistical test to show that duration is a phonetic property that distinguishes between the stressed and the unstressed target words containing the vowel [ɒ] for the Indian speakers.

This is again consistent with what is seen earlier in Section 4.3.1, as duration is shown not to be an acoustic correlate of stress for the Indian speakers. These findings show that regardless of the spectral qualities of the vowel, the Indian speakers do not seem to use differences in vowel length to distinguish between the stressed and unstressed syllables.

4.4 Summary of Findings

In this chapter, several observations about the acoustic correlates of stress in the ethnic varieties of SE are established, and they are summarised as follows:

(1) The Chinese, Malay and Indian speakers of SE have different acoustic correlates of stress.

(2) The Chinese speakers use increased amplitude and longer vowel length to indicate stress. In other words, intensity and duration are the Chinese speakers' acoustic correlates of stress.

(3) The Malay speakers use higher F_0, increased amplitude and longer vowel length to indicate stress. In other words, pitch, intensity and duration are the Malay speakers' acoustic correlates of stress. However, as the Malay speakers only use lengthened vowel length for stressed words at sentence-final positions, this correlate is weaker than the other two.

(4) The Indian speakers use higher F_0 and increased amplitude to indicate stress. In other words, pitch and intensity are the Indian speakers' acoustic correlates of stress.

(5) For emphatic stress, the Chinese speakers use higher F_0 and increased amplitude to indicate the emphatic nature of the stress. Therefore, in addition to duration and intensity, pitch is also an acoustic correlate of stress for the Chinese speakers, but for emphatic stress. The emphatically stressed words will also be louder than the words that are normally stressed.

(6) For emphatic stress, the Malay speakers use higher F_0 and longer vowel length to indicate the emphatic nature of the stress. The emphatically stressed words will therefore also be higher and longer than the words that are normally stressed.

(7) For emphatic stress, the Indian speakers use longer vowel length to indicate the emphatic nature of the stress. Therefore, in addition to pitch and intensity, duration is also an acoustic correlate of stress for the Indian speakers, but for emphatic stress.

(8) There is no difference in the acoustic correlates of stress for the Chinese speakers for words in both sentence-final and non sentence-final positions.

(9) For the Malay speakers, sentence-final words are significantly lengthened when compared to unstressed words in the same position. Duration is only used as an acoustic correlate of stress for words in sentence-final position, and not so for words in the non sentence-final position. For pitch and intensity, both correlates are used regardless of position.

(10) For the Indian speakers, pitch is used as an acoustic correlate of stress for words only in the sentence-final position, and not so for words in the non sentence-final position. This is, as mentioned, probably due to the boosted pitch on the words (stressed or unstressed) that happens in non sentence-final positions, diminishing the differences between the stressed and unstressed words in this position. This could also be caused by possible interferences from Tamil, which sees a rise-fall pitch contour at the sentence-final position. Intensity is used as a correlate regardless of position. Duration is not used as a correlate regardless of position.

(11) Sentence-final lengthening does not exist in all three varieties of SE, for the stressed words in the sentence-final positions are shorter than the

stressed words in the non sentence-final positions. Similarly, the unstressed words in the sentence-final positions are shorter than the unstressed words in the non sentence-final positions.

(12) There are no significant differences in the use of acoustic correlates with regard to spectral differences in the words. This is true for all three groups of speakers.

In this chapter, the acoustic correlates of stress of the three ethnic varieties of SE are analysed, concentrating on monosyllabic words. In the next chapter, polysyllabic words will be the focus of investigation, determining the acoustic correlates of stress of the three ethnic varieties of SE as well as the location of the main stress in two- and three- syllable words.

CHAPTER FIVE

STRESS IN POLYSYLLABIC WORDS

5.1 Introduction

As mentioned in the earlier chapters, all the studies done on SE stress focus on word stress (e.g. Tongue, 1974; Platt and Weber, 1980; Tay, 1982; Alsagoff, 1984; Ng, 1985; Chua, 1989; Sng, 1991; Bao, 1998; Low, 1998; Low and Grabe, 1999). These studies are concerned primarily with word stress placement, comparing the word stress patterns in SE to that of BrE.

Most of these studies are concerned with the placement of the main stress within a polysyllabic word. Platt *et al* (1984: 134) observe that stress patterns in SE differ from "the more established varieties of English", especially for words with three or more syllables. The early studies of Tongue (1974), Platt and Weber (1980) and Tay (1982) report that there is a rightward shift of stress on words, which, in BrE, have initial syllable stress. For instance, for the word *educated*, the British speakers pronounce it *<u>e</u>-du-ca-ted*, with the primary lexical stress on the first syllable. The SE speakers however, tend to shift this stress to the right, pronouncing it *e-du-<u>ca</u>-ted*. This observation is also noted by other researchers.

Some other studies are concerned about stress placement in suffixed words. Alsagoff (1984), for example, notes that words with suffixes in SE behave differently from that in BrE. She observes that in suffixed words, there is a shift of stress to the word-initial syllable. Bao (1998) also notes that stress placement in suffixed words in SE is different from that of BrE, especially for words with the suffixes *-logy* and *-ic*. In BrE, stress is assigned to the syllable before *-logy*, for example, *tech-<u>no</u>-lo-gy*. In SE however, stress is placed on the first syllable of the suffix, as seen in *tech-no-<u>lo</u>-gy*. In BrE, words with the -*ic* suffix attract stress placement on the syllable immediately preceding it. For example, for the word *academic*, British speakers will say *a-ca-<u>de</u>-mic*. In SE however, the same word will be pronounced *a-<u>ca</u>-de-mic*, retaining the stress allocation as with that of *a-<u>ca</u>-de-my*.

Another trend in research on SE stress placement is to apply established stress rules, like Chomsky and Halle's (1968) Main Stress Rule and Fudge's (1984) Suffix Rules to SE and see if SE speakers 'follow' the rules. Ng (1985) and Chua (1989) observe that SE speakers do not follow Chomsky and Halle's Main Stress Rule and Fudge's Suffix Rules, therefore concluding that word stress in SE is different from word stress in BrE.

Bao (1998), though not denying that there are differences in the word-accentuation patterns of SE compared to that of BrE, claims that SE deviates only in a few cases. He systematically and neatly captures the differences by three rules, which he claims would account for the word accentuation patterns in SE. His rules state that all heavy syllables are stressed, and that stress occurs on alternate syllables. For words with more than one stressed syllable, the last syllable carries the main stress.

The primary aim of this chapter is, like the previous chapter, to establish the acoustic correlates of stress, but this time in polysyllabic words. Like the past research on SE stress as described earlier, this chapter also seeks to determine the location of the main stress is in polysyllabic words. As like the two previous chapters, the differences between the three ethnic varieties will be focus of investigation. The following sections present the experiment and the findings.

5.2 Method

5.2.1 Materials

The utterances elicited for analysis here are taken from the same experiment as described in Chapter 4. While the last chapter is concerned with describing the monosyllabic target words, this chapter is devoted to analysing the polysyllabic words.

The experiment, as described earlier, consists of a set of 90 pictures. The pictures were presented to the subjects of which each subject was asked three questions posed by the researcher for each set of pictures. The three questions asked are meant to elicit three different types of 'stress' being, *stressed*, *emphatically stressed* and *unstressed*.

The target words are concerned with two vowels: [ɪ] and [ɒ]. There are in total 12 two-syllable words that are used as target words in the sentences, 6 of each vowel. Each word appears twice. The words are:

dinner	[dɪnə]	*goggle*	[gɒgəl]
mirror	[mɪrə]	*model*	[mɒdəl]
ribbon	[rɪbən]	*body*	[bɒdɪ]
riddle	[rɪdəl]	*dolly*	[dɒlɪ]
linen	[lɪnən]	*lorry*	[lɒrɪ]
lily	[lɪlɪ]	*robin*	[rɒbɪn]

All the words have phonemic word stress on the first syllable. The first syllable contains either the vowel [ɪ] or [ɒ]. The second syllable has either [ɪ] or [ə] as the vowel. All the segments are voiced. The target words only appear in the non sentence-final position, to avoid possible sentence-final lengthening which might cause the final vowel to be lengthened.

The three-syllable words in the test material are also only concerned with the vowel [ɪ]. There are in total 6 three-syllable words that are used as target words in the sentences. Each word appears twice. The words are:

mineral	[mɪnərəl]	*beginning*	[bɪgɪnɪŋ]
minister	[mɪnɪstə]	*manila*	[mənɪlə]
millipede	[mɪlɪpiːd]	*gorilla*	[gərɪlə]

The words *mineral*, *minister* and *millipede* have the phonemic word stress on the first syllable. This syllable contains the vowel [ɪ]. The words *beginning*, *manila* and *gorilla* have the phonemic word stress on the second syllable. This syllable also contains the vowel [ɪ]. The other syllables that does not receive the phonemic stress has either [ɪ], [ə] or [iː] as the vowel. All the segments are voiced, except [p] in *millipede*. The target words only appear in the non sentence-final position, so as to avoid possible sentence-final lengthening which might cause the final vowel to be lengthened.

The speakers were 4 Chinese, 4 Malay and 4 Indian male undergraduates aged between 23 to 26 years. They are all Singaporean English speakers who are equally proficient in their respective Mother Tongues.

5.2.2 The Theoretical Basis

The term *word-stress* presupposes the domain of stress to be restricted to the word. Laver defines *word-stress* as "the placement of phonological stress on a particular syllable within a word", and which is also "a defining property of that word" (1994: 511).

Every word has word stress, mono- or polysyllabic and also regardless or whether this word receives sentence stress or not. For the word that receives sentence stress, the syllable that has the word stress will be the most prominent syllable within the utterance. In other words, a polysyllabic word, even in an unstressed position within the sentence, will have at least one syllable that receives word stress. However, if this polysyllabic word receives sentence stress, then the syllable(s) that has word stress will be the syllable that exhibits the sentence stress, making it more prominent. For example, the sentence, *The <u>monkey</u> is naughty* has sentence stress on the word *monkey*. The word, *monkey* has word stress on the syllable *`mon-*. Within the sentence therefore, the syllable *mon-* will be the most prominent syllable. In the same sentence, *The monkey is <u>naughty</u>*, the sentence stress now falls on the word *naughty*. The word, *monkey* is now unstressed, but it still has word stress on the syllable *mon-*, except now, the most prominent syllable within the sentence is no longer on *mon-*, but on *naugh-* instead.

To avoid confusion, for the following analyses, similar to what is used in the earlier chapter, the term *stressed* is used when referring to the word that receives sentence stress. The syllable that receives word stress will be *lexically stressed*.

5.2.3 The Argument

In the previous chapter, in establishing the acoustic correlates of stress in the three ethnic varieties of SE, the analysis is based on the argument that if a particular phonetic property in a stressed syllable is significantly different from the corresponding unstressed syllable, this phonetic property is one that distinguishes the stressed syllable from the unstressed syllable, making it the acoustic correlate of stress. This argument is still used for the analysis in this chapter.

As mentioned earlier, the analysis also seeks to establish where the lexical stress falls in a polysyllabic word. To do so, the analysis is based on the following argument:

Premise (1): In a polysyllabic word, there is at least one syllable that receives lexical stress.

Premise (2): The same syllable(s) has word stress regardless of whether the word receives sentence stress.

Premise (3): The syllable(s) that receives sentence stress will have some or all of the phonetic properties, F_0, amplitude and duration show significant difference to the syllable that does not receive sentence stress.

Premise (4): If the syllable, *x*, is stressed, it shows significant difference in at least one phonetic property when compared to a corresponding syllable that is unstressed.

Premise (5): Syllable *x* shows significant difference in at least one phonetic property when compared to a corresponding syllable that is unstressed.

Conclusion: Therefore, *x* is the syllable that receives lexical stress.

The analysis will therefore identify the syllable(s) in the polysyllabic words that shows significant difference in at least one phonetic property when compared to a corresponding syllable that is unstressed.

Comparison between the individual syllables within the word itself will not be made, as the segmental composition of each syllable is different, and differences observed in these values could not be positively correlated to stress.

5.2.4 The Analysis

For each syllable, the values for F_0, amplitude and duration were measured and compared. In terms of pitch, the highest F_0 value within each vowel in the target word was measured and taken for analysis. Similarly, the highest value for energy level was taken for the measurement of amplitude. The duration of the each vowel in the target word was also measured. This is done for both the two- and three-syllable words.

As the analysis aims to establish the acoustic correlates of stress in polysyllabic words, there will therefore be a comparison between the stressed and unstressed counterpart for each syllable. This is similar to what is seen in Chapter 4. For example, both syllables in the stressed *dinner* will be compared to the syllables in the unstressed *dinner*. The values of F_0, amplitude and duration of the stressed *din-* will be compared to the values of F_0, amplitude and duration of the unstressed *din-*. The same goes for the second syllable *-ner*. This is to look into the acoustic correlates of stress in polysyllabic words, to see if there is a difference between what was shown in the earlier chapter and what is shown here in polysyllabic words.

All comparisons between the means will be analysed using the Multivariate Test. The results will be presented in two main parts, describing the two-syllable words first, followed by the three-syllable words. Within each part, Chinese, Malay and Indian subvarieties of SE are analysed and compared.

5.3 Results

5.3.1 Two-syllable Words

As described in the earlier section, the 12 two-syllable words can be categorised into two groups. The first group are words containing [ɪ] in the first syllable. This group consists of the following words: *dinner*, *mirror*, *ribbon*, *riddle*, *linen* and *lily*. This group of words will be labelled SET A.

The second group consists of words containing [ɒ] in the first syllable. This group consists of the words *goggle*, *model*, *body*, *dolly*, *lorry* and *robin*. This group of words will be labelled SET B.

This section seeks to compare the means of F_0, amplitude and duration between:

(1) Syllable 1 (of the stressed target word) and Syllable 1 (of the unstressed target word) for all the words in SET A.

(2) Syllable 2 (of the stressed target word) and Syllable 2 (of the unstressed target word) for all the words in SET A.

(3) Syllable 1 (of the stressed target word) and Syllable 1 (of the unstressed target word) for all the words in SET B.

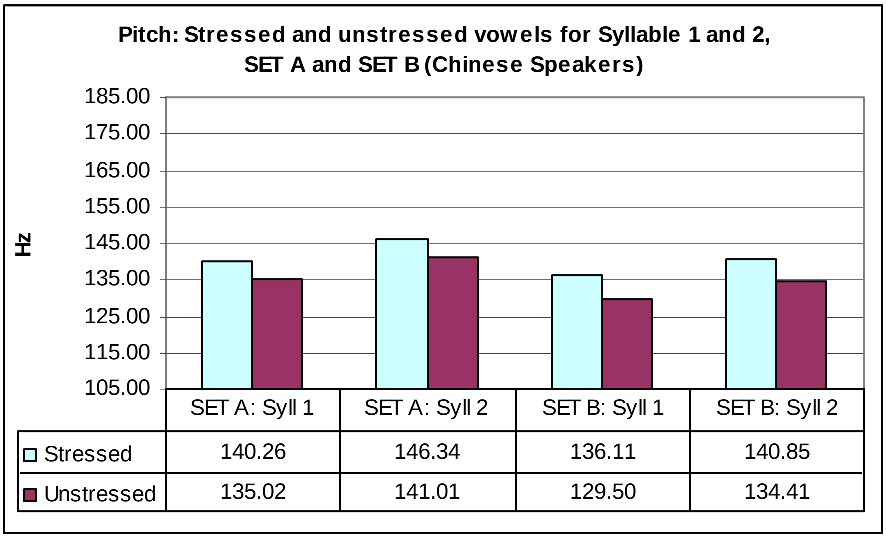
(4) Syllable 2 (of the stressed target word) and Syllable 2 (of the unstressed target word) for all the words in SET B.

This is to investigate the acoustic correlates of stress present in the stressed syllable which makes it different from the unstressed syllable. In doing so, one could also identify the syllable(s) in the polysyllabic words that shows significant difference in at least one phonetic property when compared to a corresponding syllable that is unstressed, thus determining the location of the lexical stress within the polysyllabic word. The Chinese, Malay and Indian speakers will be discussed separately.

5.3.1.1 Chinese Speakers

Pitch

Figure 5.1 shows the means of the F_0 of the stressed and unstressed words, for each syllable, in SET A and SET B words of the Chinese speakers.



	SET A: Syll 1	SET A: Syll 2	SET B: Syll 1	SET B: Syll 2
Stressed	140.26	146.34	136.11	140.85
Unstressed	135.02	141.01	129.50	134.41

Fig. 5.1: Means of F_0 of the stressed and unstressed words, for each syllable, in SET A and SET B words of the Chinese speakers.

From Figure 5.1, it can be seen that for SET A words, the first syllable of the stressed word is 5.25 Hz higher than the first syllable of the unstressed word, about 4 Hz more than the just-noticeable difference of 1 Hz for pitch perception. The multivariate test however shows that this difference is not significant at $p < 0.05$ ($p = 0.189$, $df = 1$, $N = 48$). This shows that there is no strong statistical evidence to conclude that pitch is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word for SET A words.

The second syllable of the stressed word is also higher than the second syllable of the unstressed word, in SET A. The difference between the two means in F_0 for the Chinese speakers is 5.33 Hz. The multivariate test also shows that this difference is not significant at $p < 0.05$ ($p = 0.280$, $df = 1$, $N = 48$). Again, the statistical test shows that one cannot conclude that pitch is the phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word.

The same situation occurs for SET B. The first syllable of the stressed word also is 6.61 Hz higher than the first syllable of the unstressed word. Despite this difference, the multivariate test shows these two means are not significantly different at $p < 0.05$ ($p = 0.093$, df = 1, N = 48). For SET B words, similar to what is seen in SET A words, there is no strong evidence to show that pitch is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word.

From the same figure, for SET B words, it can be seen that the second syllable of the stressed word is 6.44 Hz higher than the second syllable of the unstressed word. The multivariate test, again, shows that the means are not significantly different at $p < 0.05$ ($p = 0.149$, df = 1, N = 48). The statistical test shows that there is no strong evidence to conclude that pitch is the phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word for SET B words.

The result so far is not unexpected, as it has been established from Chapter 4 that pitch is not an acoustic correlate of stress for the Chinese speakers in the monosyllabic words. It is therefore not surprising that for words in both SET A and SET B, there is no statistical evidence to show pitch to be a distinguishing property between the syllables in stressed word and the syllables in the unstressed word. This further affirms that the Chinese speakers do not seem to use differences in pitch to indicate stress, whether the words have one or two syllables.

Intensity

Figure 5.2 shows the means of amplitude of the stressed and the unstressed words, for both the first and second syllables, in SET A and SET B words of the Chinese speakers.

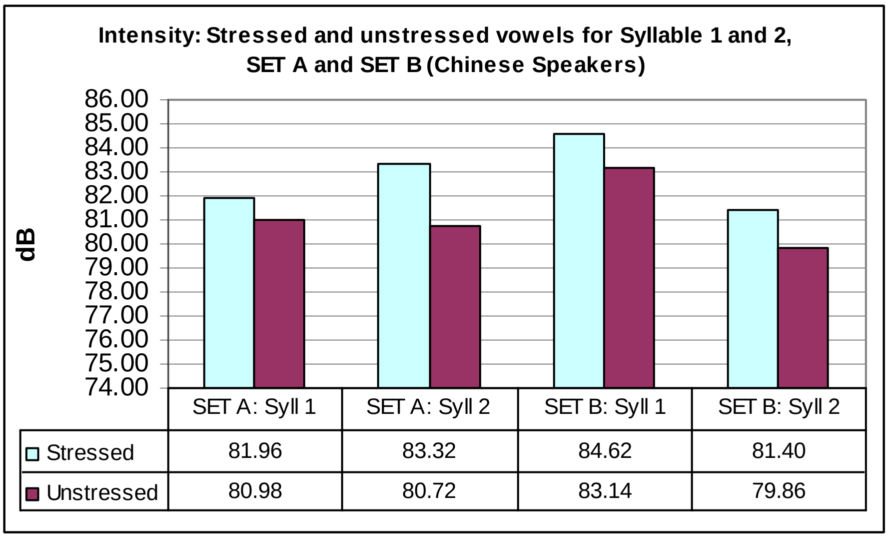


Fig. 5.2: Means of the values of amplitude of the stressed and unstressed words, for each syllable, in SET A and SET B words of the Chinese speakers.

From Figure 5.2, for the words in SET A, one observes that the first syllable of the stressed word is 0.98 dB louder than the first syllable of the unstressed word. This difference is within the range of the just-noticeable difference of 0.5 – 1 dB for perception of intensity. The multivariate test shows that these two means are not significantly different at $p < 0.05$ ($p = 0.072$, df = 1, N = 48). There is therefore no statistical evidence to show that, for SET A words, intensity is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word.

From the same figure, it can be seen that the second syllable of the stressed word is 2.60 dB louder than the second syllable of the unstressed word. The multivariate test shows that this difference is significant at $p < 0.01$ ** ($p < 0.0005$, df = 1, N = 48). This shows that for the words in SET A, intensity is a phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word.

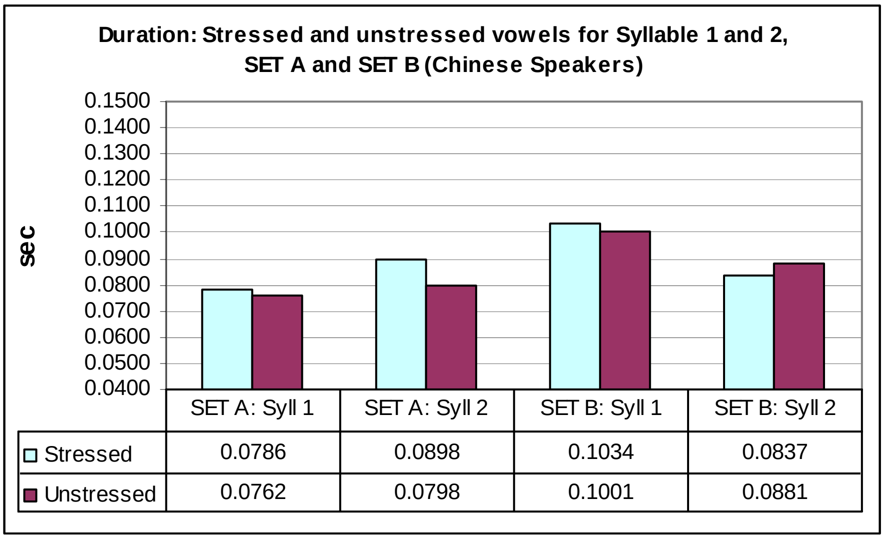
For the words in SET B, the situation is reversed. From Figure 5.2, it can be seen that the first syllable of the stressed word is 1.47 dB louder than the first syllable of the unstressed word. The multivariate test however, unlike what is shown in the first syllable of SET A, shows that the means of amplitude of the first syllable of the stressed target word and the first syllable of the unstressed target word of SET B words are significantly different at $p < 0.01$ ** ($p = 0.009$, $df = 1$, $N = 48$). This shows that for SET B words, intensity is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word, unlike the first syllable of the words in SET A, where there is no statistical evidence to show that intensity is significantly different between the stressed and unstressed target words.

The second syllable of the stressed word in SET B is also louder than the vowel in the unstressed word. The difference between the means of the two amplitudes is 1.54 dB. The multivariate test however shows that the two means are not significantly different at $p < 0.05$ ($p = 0.070$, $df = 1$, $N = 48$). This shows that for the second syllable in SET B words, statistically, there is no evidence to show that intensity is a phonetic property that distinguishes between the stressed target word and the unstressed target word. This is also unlike the situation in SET A words, where the opposite happens.

From Chapter 4, it has been established that intensity is an acoustic correlate of stress for the Chinese speakers. For words in SET A, there is a significant difference in amplitude between the second syllable of the stressed and unstressed target words, but not so for the first syllable. This shows that for words in SET A, the lexical stress is on the second syllable. For SET B, however, the opposite happens. There is a significant difference in amplitude between the first syllable of the stressed and unstressed target words, but not so for the second syllable. This shows that for words in SET B, the lexical stress is on the first syllable. It can be seen therefore that lexical stress placement between the words in SET A and SET B differ. The results also further affirm that intensity is an acoustic correlate of stress for the Chinese speakers, for both one- and two-syllable words.

Duration

Figure 5.3 shows the means of vowel length of the stressed and unstressed words, for each syllable, in SET A and SET B, for the Chinese speakers.



	SET A: Syll 1	SET A: Syll 2	SET B: Syll 1	SET B: Syll 2
Stressed	0.0786	0.0898	0.1034	0.0837
Unstressed	0.0762	0.0798	0.1001	0.0881

Fig. 5.3: Means of vowel length of the stressed and unstressed words, for each syllable, in SET A and SET B, for the Chinese speakers.

From Figure 5.3, for SET A words, it can be seen that the first syllable of the stressed word is 0.0024 sec longer than the first syllable of the unstressed word, which is not even within the range of the just-noticeable difference of 0.01 – 0.04 sec for perception of duration. The multivariate test shows that the means are not significantly different at $p < 0.05$ ($p = 0.473$, $df = 1$, $N = 48$). The statistical test does not provide evidence to show that duration is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word for the first syllable in SET A words.

The second syllable of the stressed target word is 0.01 sec longer than the second syllable of the unstressed target word, for SET A words. Unlike what is seen in the first syllable, the multivariate test shows this difference is significant at $p < 0.01$ ** ($p = 0.004$, $df = 1$, $N = 48$). In SET A words, duration is a phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word.

For the words in SET B, the situation is different from what is seen in SET A. From Figure 5.3, for SET B words, it can be seen that for the first syllable of the stressed word is only 0.0033 sec longer than the first syllable of the unstressed word, which is not even within the range of the just-noticeable difference of 0.01 – 0.04 sec for perception of length. The multivariate test shows that the difference between the two means is not significant at $p < 0.05$ ($p = 0.472$, $df = 1$, $N = 48$). Thus, for SET B words, the test does not provide evidence to show that duration is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word.

Interestingly, in SET B words, the second syllable of the stressed word is 0.0044 sec shorter than the second syllable of the unstressed word. This is a situation that is not seen in SET A. The multivariate test however shows that the means are not significantly different at $p < 0.05$ ($p = 0.338$, $df = 1$, $N = 48$). This shows that for SET B words, there is no evidence to show that duration is a phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word. This is also unlike the situation in SET A words, where the opposite happens.

From Chapter 4, it has been established that duration is an acoustic correlate of stress for the Chinese speakers. For words in SET A, there is a significant difference in vowel length between the second syllable of the stressed and unstressed target words, but not so for the first syllable. This shows that for words in SET A, the lexical stress is on the second syllable. For SET B, however, the statistical tests do not provide evidence to show that duration is a distinguishing property between the stressed and the unstressed target words, for both syllables. While duration cannot be used to determine the lexical stress placement in the words in SET B, the results nevertheless also confirm that duration is an acoustic correlate of stress for the Chinese speakers, for both one- and two-syllable words, though in this case, only for SET A words.

Chinese Speakers: Stress in two-syllable words

The results so far can be summarised as the following:

1) For the words in SET A, there is a significant difference in amplitude and duration between the second syllable of the stressed and unstressed target words. This suggests that the lexical stress placement is on the second syllable, as it is only in this syllable that there is a significant difference in the two phonetic properties.
2) There is a significant difference in amplitude between the first syllable of the stressed and unstressed target words in SET B. This shows that for words in SET B, the lexical stress placement is on the first syllable.
3) The results also further affirm that intensity and duration are acoustic correlates of stress for the Chinese speakers in two-syllable words.
4) Pitch does not seem to be used as an acoustic correlate of stress for this group of speakers, as there is no strong statistical evidence to show that it is the distinguishing property between the stressed and unstressed words, for every syllable.

5.3.1.2 Malay Speakers

Pitch

Figure 5.4 shows the means of the F_0 of the stressed and unstressed words, for each syllable, in SET A and SET B words of the Malay speakers.

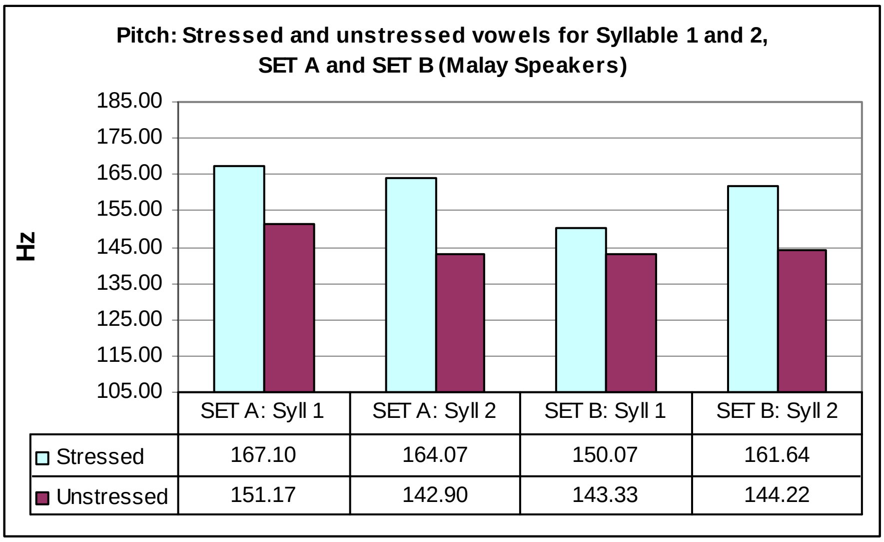


Fig. 5.4: Means of the F_0 of the stressed and unstressed words, for each syllable, in SET A and SET B words of the Malay speakers.

From Figure 5.4, for SET A words, it can be seen that the first syllable of the stressed word is 15.93 Hz higher than the first syllable of the unstressed word, about 15 Hz more than the just-noticeable difference of 1 Hz for pitch perception. The multivariate test shows that this difference is significant at $p < 0.05$ * ($p = 0.001$, $df = 1$, $N = 48$). This shows that for SET A words, pitch is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word for the Malay speakers of SE.

The second syllable of the stressed word is also higher pitched than the second syllable of the unstressed word. The difference between the two means is 21.17 Hz. The multivariate test shows that this difference is significant at $p < 0.01$ ** ($p < 0.005$, $df = 1$, $N = 48$). This shows that for SET A words, pitch is a phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word.

For SET B, from Figure 5.4, it can be seen that for the first syllable of the stressed word is 6.75 Hz higher than the first syllable of the unstressed word. The multivariate test shows these two means are not significantly different at $p < 0.05$ ($p = 0.068$, df = 1, N = 48). The test does not provide evidence to show that pitch is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word for SET B words. This is unlike what is seen in the first syllable for the words in SET A.

From the same figure, for SET B words, it can be seen that the second syllable of the stressed word is 17.42 Hz higher than the second syllable of the unstressed word. The multivariate test shows that the two means are significantly different at $p < 0.01$ ** ($p < 0.005$, df = 1, N = 48). This shows that for the Malay speakers, pitch is a phonetic property that distinguishes between the second syllable of stressed target word and the second syllable of the unstressed target word in SET B.

The result so far is not unexpected, as it has been established from Chapter 4 that pitch is an acoustic correlate of stress for the Malay speakers in the monosyllabic words. It is therefore not surprising that for both syllables in SET A words, and the second syllable for words in SET B, pitch is also shown to be a distinguishing property between the stressed and the unstressed target words. This further affirms that pitch is an acoustic correlate of stress for the Malay speakers, whether the words have one or two syllables.

Intensity

Figure 5.5 shows the means of amplitude of the stressed and the unstressed words, for both the first and second syllables, in SET A and SET B words of the Malay speakers.

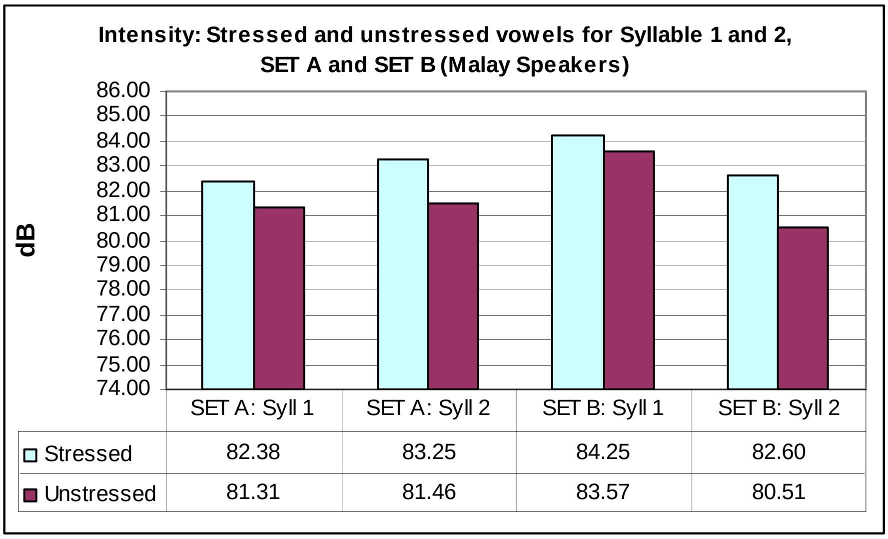


Fig. 5.5: Means of amplitude of the stressed and the unstressed words, for both each syllable, in SET A and SET B words of the Malay speakers.

For SET A words, from Figure 5.5, it can be seen that the first syllable of the stressed syllable is 1.07 dB louder than the first syllable of the unstressed syllable. The difference between the two means of amplitude is only slightly larger than the just-noticeable difference of 0.5 – 1 dB for perception of intensity. The multivariate test shows that these two means are significantly different at $p < 0.05$ * ($p = 0.048$, df = 1, N = 48). This shows that for SET A words, intensity is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word.

For SET A words, the second syllable of the stressed word is 1.79 dB louder than the second syllable of the unstressed word. The multivariate test shows that this difference is significant at $p < 0.05$ * ($p = 0.001$, df = 1, N = 48). This shows that for the Malay speakers, intensity is a phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word in SET A.

For the words in SET B, the situation is slightly different. From Figure 5.5, for SET B words, it can be seen that the first syllable of the stressed target word is only 0.068 dB louder than the first syllable of the unstressed target word. The multivariate test shows that the means of the amplitude of the first syllable of the stressed target word and the first syllable of the unstressed target word of SET B words are not significantly different at $p < 0.05$ ($p = 0.057$, df = 1, N = 48). This shows that for the Malay speakers, there is no statistical evidence to show that intensity is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word in SET B. This is unlike the words in SET A, where intensity is found to be significantly different between the first syllable of the stressed and unstressed target words.

The second syllable of the stressed word is 2.08 dB louder than the second syllable of the unstressed word. The multivariate test shows that the two means are significantly different at $p < 0.01$ ** ($p < 0.005$, df = 1, N = 48). This shows that for SET B words, intensity is a phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word.

From Chapter 4, it has been established that intensity is an acoustic correlate of stress for the Malay speakers. For words in SET A, there is a significant difference in amplitude between the stressed and unstressed target words, for both the first and second syllable. This shows that for words in SET A, the lexical stress is on both the first and second syllable. For SET B, however, the situation is different. There is a significant difference in amplitude between the second syllable of the stressed and unstressed target words, but not so for the first syllable. This shows that for words in SET B, the lexical stress is on the second syllable. It can be seen therefore that lexical stress placement between the words in SET A and SET B differ. The results also further affirm that intensity is an acoustic correlate of stress for the Malay speakers, for both one- and two-syllable words.

Duration

Figure 5.6 shows the means of vowel length of the stressed and unstressed words, for each syllable, in SET A and SET B, for the Malay speakers.

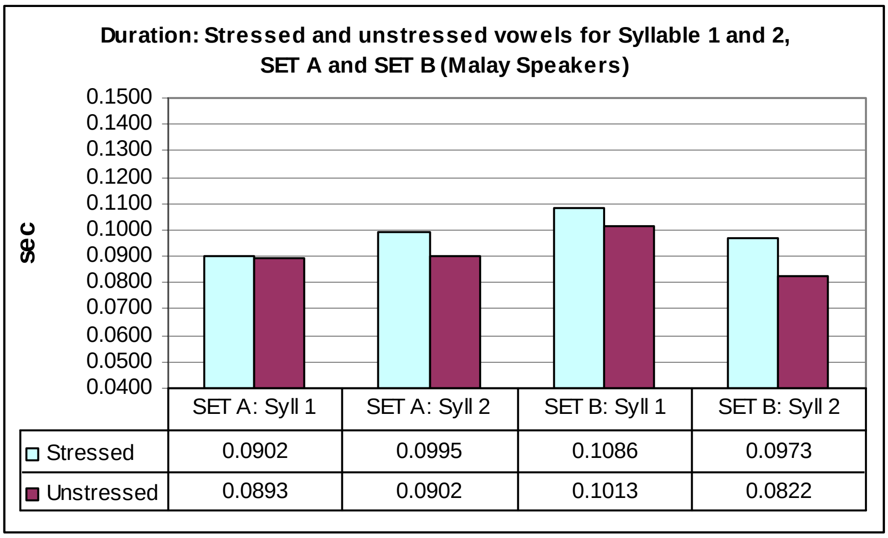


Fig. 5.6: Means of vowel length of the stressed and unstressed words, for each syllable, in SET A and SET B, for the Malay speakers.

From Figure 5.6, for words in SET A, it can be seen that the first syllable of the stressed word is only 0.0009 sec longer than first syllable of the unstressed word. This difference is not even within the range of the just-noticeable difference of 0.01 – 0.04 sec for perception of duration. The multivariate test shows that the means are not significantly different at $p < 0.05$ ($p = 0.828$, df = 1, N = 48). There is therefore no evidence to conclude that duration is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word in SET A words.

The second syllable of the stressed target word is 0.0093 sec longer than the second syllable of the unstressed target word, and again, this difference is also not within the range of just-noticeable difference for perception of length. The multivariate test shows this difference is not significant at $p < 0.05$ ($p = 0.057$, df = 1, N = 48). For SET A words therefore, the statistical test does not provide evidence to show that duration is a phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word.

From Figure 5.6, it can be seen that for SET B words, the first syllable of the stressed word is only 0.0073 sec longer than the first syllable of the unstressed word. The multivariate test shows that the difference between the two means is not significant at $p < 0.05$ ($p = 0.167$, df = 1, N = 48). For SET B words, there is no strong evidence from the statistics to show that duration is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word.

From the same figure, it can be seen that the second syllable of the stressed word is 0.0150 sec longer than the second syllable of the unstressed word. The multivariate test shows that the means are significantly different at $p < 0.05$ * ($p = 0.010$, df = 1, N = 48). This shows that for SET B words, duration is a phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word. This is unlike the situation in SET A words, where there is no significant difference between the means of vowel length in the second syllable of the stressed and unstressed words.

From Chapter 4, it has been established that duration is an acoustic correlate of stress for the Malay speakers. For words in SET A, for both the first syllable and second syllable, there is no significant difference in duration between the stressed and unstressed target words. For SET B, however, duration is shown to be a distinguishing property between the stressed and the unstressed target words, but only for the second syllable, and not so for the first syllable. While duration cannot be used to determine the lexical stress placement for the words in SET A, the results nevertheless still confirm that duration is an acoustic correlate of stress for the Malay speakers, for both one- and two-syllable words, though in this case, only for SET B words, and only in the second syllable. This perhaps suggests that duration is a weaker correlate of stress for the Malay speakers.

Malay Speakers: Stress in two-syllable words

The results so far can be summarised as the following:

(1) For the words in SET A, there is a significant difference in amplitude and F_0 between the stressed and unstressed target words, for both the first and second syllable. This suggests that the lexical stress placement is on both syllables, as it is in both syllables that there is a significant difference in these two phonetic properties.

(2) There is a significant difference in F_0, amplitude and duration between the second syllable of the stressed and unstressed target words in SET B. This shows that for words in SET B, the lexical stress placement is on the second syllable.

(3) The results also further affirm that pitch, intensity and duration are acoustic correlates of stress for the Malay speakers in two-syllable words.

5.3.1.3 Indian Speakers

Pitch

Figure 5.7 shows the means of the F_0 of the stressed and unstressed words, for each syllable, in SET A and SET B words of the Indian speakers.

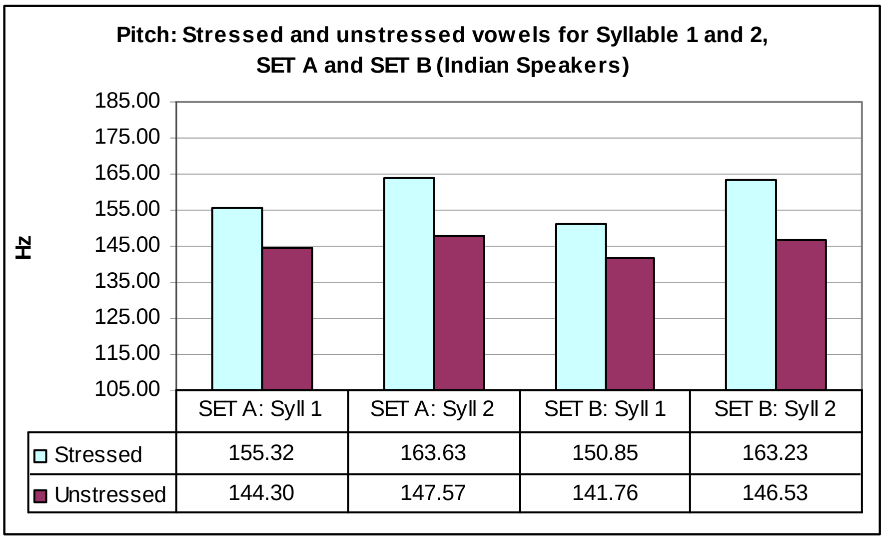


Fig. 5.7: Means of the F_0 of the stressed and unstressed words, for each syllable, in SET A and SET B words of the Indian speakers.

For SET A words, as can be seen from Figure 5.7, the first syllable the stressed word is 11.03 Hz higher than the first syllable of the unstressed word, more than the just-noticeable difference of 1 Hz for pitch perception. The multivariate test however shows that this difference is not significant at $p < 0.05$ ($p = 0.057$, $df = 1$, $N = 48$). This shows that for SET A words, the statistical test cannot provide evidence to conclude that pitch is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word.

From the same figure, it can be seen that the second syllable of the stressed word is 16.06 Hz higher than the second syllable of the unstressed word. The multivariate test shows that this difference is significant at $p < 0.01$ ** ($p = 0.007$, $df = 1$, $N = 48$). This shows that for

SET A words, pitch is a phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word.

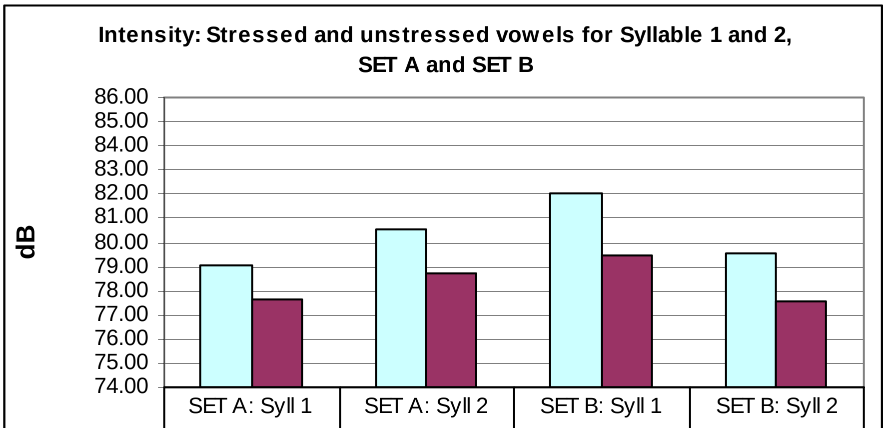
A similar situation occurs for the words in SET B. For SET B, from Figure 5.7, it can be seen that the first syllable of the stressed word is 9.09 Hz higher than the first syllable of the unstressed word. The multivariate test shows these two means are not significantly different at $p < 0.05$ ($p = 0.100$, $df = 1$, $N = 48$). Therefore, for SET B words, there is no evidence to show that pitch is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word. This is similar to what is seen in the first syllable for the words in SET A.

From the same figure, it can be seen that the second syllable of the stressed word is also higher than the second syllable of the unstressed word. The difference between the two means is 16.69 Hz, more than 15 Hz larger than the just-noticeable difference. The multivariate test shows that the two means are significantly different at $p < 0.01$ ** ($p = 0.003$, $df = 1$, $N = 48$). This shows that for SET B words, pitch is a phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word, similar to what is seen in SET A.

The result so far is to be expected, as it has been established from Chapter 4 that pitch is an acoustic correlate of stress for the Indian speakers in the monosyllabic words. Pitch is also shown to be a distinguishing property between the second syllable of the stressed target word and the second syllable of the unstressed target word, for words in both SET A and SET B. This further affirms that pitch is an acoustic correlate of stress for the Indian speakers, whether the words have one or two syllable.

Intensity

Figure 5.8 shows the means of amplitude of the stressed and the unstressed words, for both the first and second syllables, in SET A and SET B words of the Indian speakers.



	SET A: Syll 1	SET A: Syll 2	SET B: Syll 1	SET B: Syll 2
Stressed	79.02	80.55	82.01	79.52
Unstressed	77.64	78.76	79.44	77.57

Fig. 5.8: Means of amplitude of the stressed and unstressed words, for each syllable, in SET A and SET B words of the Indian speakers.

From Figure 5.8, it can be seen that for SET A words, the first syllable of the stressed word is louder than the first syllable of the unstressed word. The difference in amplitude between the two means is 1.37 dB, larger than the just-noticeable difference of 0.5 – 1 dB for perception of intensity. The multivariate test shows that these two means are not significantly different at $p < 0.05$ ($p = 0.053$, $df = 1$, $N = 48$). This shows that for SET A words, there is no statistical evidence to conclude that intensity is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word.

From the same figure, it can be seen that the second syllable of the stressed word is 1.80 dB louder than the second syllable of the unstressed word, about 1 dB more than the just-noticeable difference of 1 dB for intensity perception. The multivariate test shows that this difference is significant at $p < 0.01$ ** ($p = 0.008$, $df = 1$, $N = 48$). This shows that for SET

A words, intensity is a phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word.

For the words in SET B, the situation is slightly different. From Figure 5.8, it can be seen that for SET B words, the first syllable of the stressed word is 2.57 dB louder than the first syllable of the unstressed word. The multivariate test however, unlike what is shown in the first syllable of SET A, shows that the means of the amplitude of the first syllable of the stressed target word and the first syllable of the unstressed target word of SET B words are significantly different at $p < 0.01$ ** ($p < 0.005$, df = 1, N = 48). This shows that for the words in SET B, intensity is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word, unlike the first syllable of the words in SET A, where intensity is found not to be significantly different between the stressed and unstressed target words.

From the same figure, it can be seen that the second syllable of the stressed word is 1.95 dB louder than the second syllable of the unstressed word. The multivariate test shows that the two means are significantly different at $p < 0.01$ ** ($p = 0.007$, df = 1, N = 48). This shows that for the words in SET B, intensity is a phonetic property that distinguishes between the second syllable of the stressed words and the second syllable of the unstressed words.

From Chapter 4, it has been established that intensity is an acoustic correlate of stress for the Indian speakers. For words in SET A, there is a significant difference in amplitude between the second syllable of the stressed target words and the second syllable of the unstressed target words. This shows that for words in SET A, the lexical stress is on the second syllable. For SET B, however, the situation is different. There is a significant difference in amplitude between the stressed and unstressed target words for both the first syllable and second syllable. This shows that for words in SET B, the lexical stress is on both the first and the second syllable. It can be seen therefore that lexical stress placement between the words in SET A and SET B differ. The results also further confirm that intensity is an acoustic correlate of stress for the Indian speakers, for both one- and two-syllable words.

Duration

Figure 5.9 shows the means of vowel length of the stressed and unstressed words, for each syllable, in SET A and SET B, for the Indian speakers.

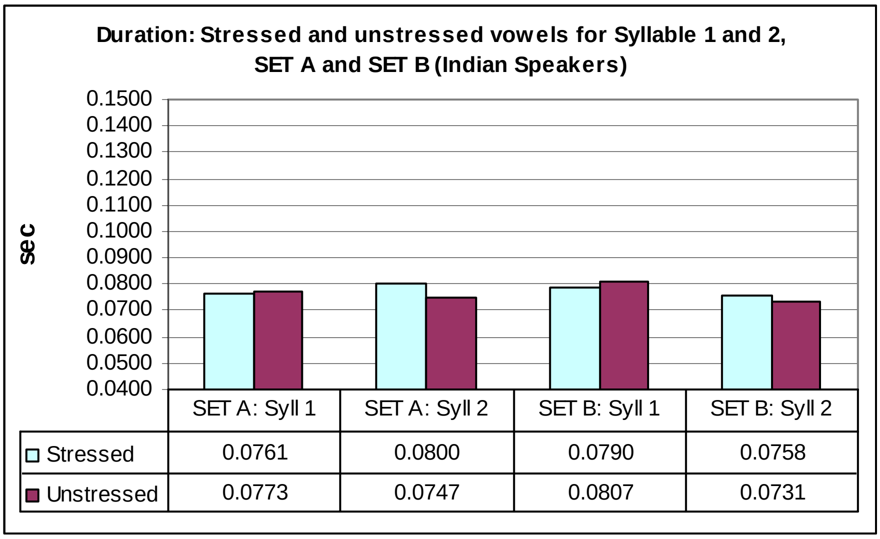


Fig. 5.9: Means of vowel length of the stressed and unstressed words, for each syllable, in SET A and SET B, for the Indian speakers.

From Figure 5.9, it can be seen that for the first syllable of SET A words, unlike what is observed in the Chinese and Malay speakers, the vowel in the stressed target word is actually 0.0012 sec shorter than the vowel in the unstressed target word. The multivariate test shows that the means are not significantly different at $p < 0.05$ ($p = 0.683$, df = 1, N = 48). For the Indian speakers, one cannot conclude from the statistical test that duration is a phonetic property that distinguishes between the first syllables of the stressed and unstressed words for SET A.

From the same figure, it can be seen that the second syllable of the stressed word is 0.0054 sec longer than the second syllable of the unstressed word, which is not within the range of just-noticeable difference for perception of length. The multivariate test shows this difference is not significant at $p < 0.05$ ($p = 0.103$, df = 1, N = 48). In SET A words, the statistical test does not allow for the conclusion that duration is a phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word.

The situation is the same for the words in SET B. From Figure 5.9, it can be seen that for the first syllable of SET B words, the vowel in the stressed word is 0.0017 sec shorter than the vowel in the unstressed word, which is what is also observed in the words in SET A. The multivariate test shows that the difference between the two means is not significant at $p < 0.05$ ($p = 0.582$, df = 1, N = 48). Again, for SET B words, there is no strong statistical evidence to show that duration is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word.

From the same figure, it can be seen that second syllable of the stressed word is longer 0.0028 sec than the second syllable of the unstressed word. The multivariate test shows that the means are not significantly different at $p < 0.05$ ($p = 0.329$, df = 1, N = 48). Similarly, in this case, for SET B words, the statistical test cannot allow for the conclusion that duration is a phonetic property that distinguishes between the second syllable of the stressed words and the second syllable of the unstressed words.

From Chapter 4, it has been established that duration is not an acoustic correlate of stress for the Indian speakers. For words in both SET A and SET B, there is no significant difference in vowel length between the stressed and unstressed target words, for both the first and the second syllable. The statistical tests therefore does not allow for the conclusion that duration is an acoustic correlate of stress for the Indian speakers, for both one- and two-syllable words.

Indian Speakers: Stress in two-syllable words

The results so far can be summarised as the following:

(1) For the words in SET A, there is a significant difference in amplitude and F_0 between the second syllable of the stressed target word and the second syllable of the unstressed target words. This suggests that the lexical stress placement is on the second syllable, as it is in this syllable that there is a significant difference in these two phonetic properties.

(2) There is a significant difference in F_0 and amplitude between the second syllable of the stressed target words and the second syllable of the unstressed target words in SET B. In addition, it is observed that there is a significant difference in amplitude between the first syllable of the stressed target word and first syllable of the unstressed target words. This shows that for words in SET B, the lexical stress placement is on both the first and second syllable.

(3) The results also further affirm that pitch and intensity are acoustic correlates of stress for the Indian speakers in two-syllable words. There is no statistical evidence to show that duration is an acoustic correlate of stress for this group of speakers.

5.3.2 Three-Syllable Words

As described in the earlier section, the 6 three-syllable words can be categorised into two groups. The first group of words *mineral*, *minister* and *millipede* have the phonemic word stress on the first syllable. This group of words will be labelled SET C. The second group words, *beginning*, *manila* and *gorilla* have the phonemic word stress on the second syllable. This group of words will be labelled SET D.

This section seeks to compare the means of F_0, amplitude and vowel length between:

(1) Syllable 1 (of the stressed target word) and Syllable 1 (of the unstressed target word) for all the words in SET C.

(2) Syllable 2 (of the stressed target word) and Syllable 2 (of the unstressed target word) for all the words in SET C.

(3) Syllable 3 (of the stressed target word) and Syllable 3 (of the unstressed target word) for all the words in SET C.

(4) Syllable 1 (of the stressed target word) and Syllable 1 (of the unstressed target word) for all the words in SET D.

(5) Syllable 2 (of the stressed target word) and Syllable 2 (of the unstressed target word) for all the words in SET D.

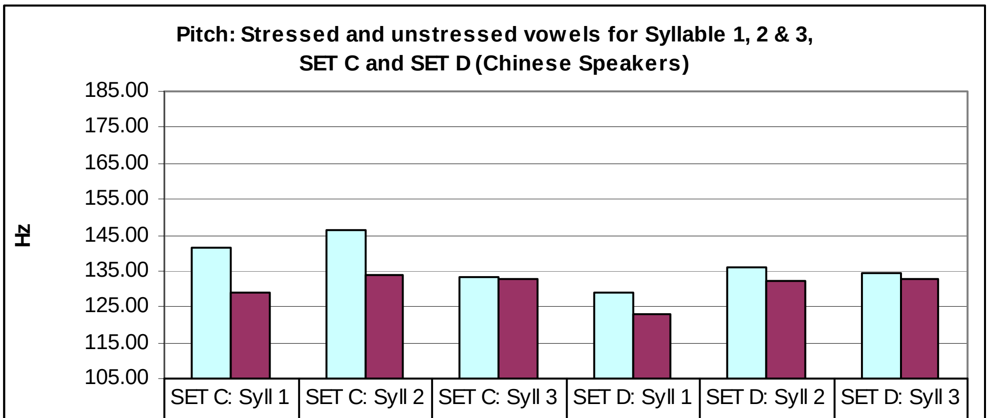
(6) Syllable 3 (of the stressed target word) and Syllable 3 (of the unstressed target word) for all the words in SET D.

This is to investigate the acoustic correlates of stress present in the stressed syllable which makes it different from the unstressed syllable. In doing so, one could also identify the syllable(s) in these three-syllable words that shows significant difference in at least one phonetic property when compared to a corresponding syllable that is unstressed, thus determining the location of the lexical stress within the polysyllabic word. Similar to the previous section on two-syllable words, the Multivariate Test will be performed. Each group of speakers will be discussed separately.

5.3.2.1 Chinese Speakers

Pitch

Figure 5.10 shows the means of the F_0 of the stressed and unstressed words, for each syllable, in SET C and SET D words of the Chinese speakers.



	SET C: Syll 1	SET C: Syll 2	SET C: Syll 3	SET D: Syll 1	SET D: Syll 2	SET D: Syll 3
Stressed	141.25	146.11	133.39	129.20	135.76	134.66
Unstressed	128.97	133.91	132.91	122.93	132.16	132.66

Fig. 5.10: Means of the F_0 of the stressed and unstressed words, for each syllable, in SET C and SET D words of the Chinese speakers.

From Figure 5.10, it can be seen that for SET C words, the first syllable of the stressed target word is 12.28 Hz higher than the first syllable of the unstressed word, about 11 Hz more than the just-noticeable difference of 1 Hz for pitch perception. The multivariate test however shows that this difference is not significant at $p < 0.05$ ($p = 0.075$, $df = 1$, $N = 24$). This shows that for SET C words, there is no statistical evidence to show that pitch is a phonetic property that distinguishes between the first syllable of the stressed word and the first syllable of the unstressed word.

The second syllable of the stressed target word is 12.20 Hz higher than the second syllable of the unstressed word. The multivariate test, like the test for the first syllable, shows that this difference is not significant at $p < 0.05$ ($p = 0.081$, df = 1, N = 24). Again, for SET C words, there is no statistical evidence to show that pitch is a phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word.

The third syllable of the stressed word is only 0.48 Hz higher than the third syllable of the unstressed word. The multivariate test shows that this difference is not significant at $p < 0.05$ ($p = 0.936$, df = 1, N = 24). This shows that for SET C words, there is no evidence to show that pitch is a phonetic property that distinguishes between the third syllable of the stressed target word and the third syllable of the unstressed target word.

A similar situation occurs for the words in SET D. For SET D, from Figure 5.10, it can be seen that for the first syllable of the stressed word is 6.27 Hz higher than the first syllable of the unstressed word. The multivariate test shows these two means are not significantly different at $p < 0.05$ ($p = 0.244$, df = 1, N = 24). Therefore, for SET D words, one cannot conclude from the statistical test that pitch is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word. This is similar to what is seen in the first syllable for the words in SET C.

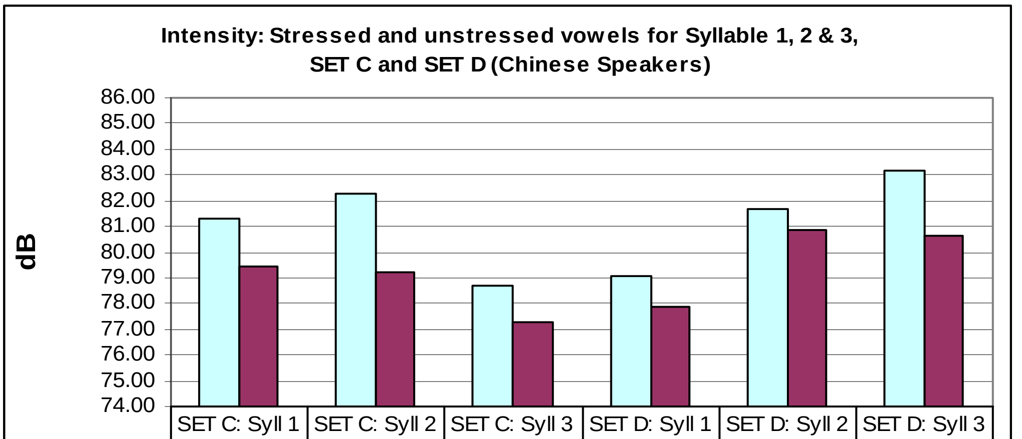
The second syllable of the stressed word is 3.60 Hz higher than the second syllable of the unstressed word. The multivariate test shows that the two means are not significantly different at $p < 0.05$ ($p = 0.359$, df = 1, N = 24). Similarly, for SET D words, there is no statistical evidence to show that pitch is a phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word, similar to what is seen in SET C.

From Figure 5.10, for SET D words, it can be seen that the third syllable of the stressed word is 2 Hz higher than the third syllable of the unstressed word. The multivariate test shows that this difference is not significant at $p < 0.05$ ($p = 0.603$, df = 1, N = 24). The test does not provide evidence to show that pitch is a phonetic property that distinguishes between the third syllable of the stressed target word and the third syllable of the unstressed target word for SET D words.

There is no statistical evidence to show that pitch is a distinguishing property between the stressed and the unstressed target words, for all the three syllables, in both SET C and SET D. One therefore cannot conclude that pitch is an acoustic correlate of stress for the Chinese speakers, and this is regardless of the number of syllables the word has.

Intensity

Figure 5.11 shows the means of amplitude of the stressed and the unstressed words, for each syllable, in SET C and SET D words of the Chinese speakers.



	SET C: Syll 1	SET C: Syll 2	SET C: Syll 3	SET D: Syll 1	SET D: Syll 2	SET D: Syll 3
Stressed	81.31	82.27	78.73	79.06	81.71	83.18
Unstressed	79.46	79.19	77.25	77.90	80.89	80.63

Fig. 5.11: Means of amplitude of the stressed and the unstressed words, for each syllable, in SET C and SET D words of the Chinese speakers.

From Figure 5.11, it can be seen that for SET C words, the first syllable of the stressed word is 1.85 dB louder than the first syllable of the unstressed word, larger than the just-noticeable difference of 0.5 – 1 dB for perception of intensity. The multivariate test shows that these two means are significantly different at $p < 0.05$ * ($p = 0.014$, df = 1, N = 24). This shows that for SET C words, intensity is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word.

From the same figure, it can be seen that the second syllable of the stressed word is 3.08 dB louder than the second syllable of the unstressed word. The multivariate test shows that this difference is significant at $p < 0.05$ * ($p = 0.001$, df = 1, N = 24). This shows that for SET C words, intensity is a phonetic property that distinguishes between the second syllable of stressed target word and the second syllable of the unstressed target word.

The third syllable of the stressed word is 1.48 dB louder than the third syllable of the unstressed word. The multivariate test however, unlike the test for the first two syllables, shows that this difference is not significant at $p < 0.05$ ($p = 0.259$, df = 1, N = 24). This shows that for SET C words, there is no statistical evidence to show that intensity is a phonetic property that distinguishes between the third syllable of the stressed words and the third syllable of the unstressed words.

For the words in SET D, the situation is the exact opposite. From Figure 5.11, it can be seen that for SET D words, the first syllable of the stressed word is 1.16 dB louder than the first syllable of the unstressed word. The multivariate test, unlike what is shown in the first syllable of SET C, shows that the means of the amplitude of the first syllable of the stressed target word and the first syllable of the unstressed target word of SET D words are not significantly different at $p < 0.05$ ($p = 0.246$, df = 1, N = 24). This shows that for the words in SET D, one cannot conclude from the statistical test that intensity is a phonetic property that distinguishes between the first syllable of stressed target word and the first syllable of the unstressed target word, unlike the words in SET C, where intensity is found to be significantly different between the first syllable of stressed target words and the first syllable of the unstressed target words.

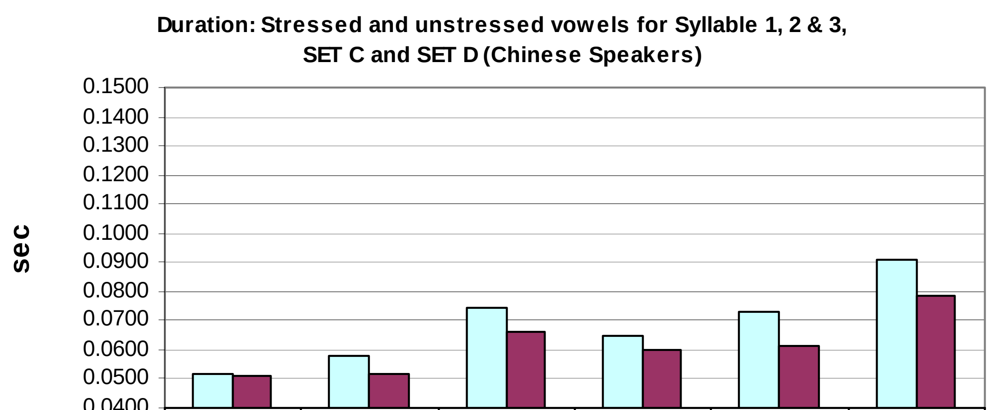
From the same figure, it can be seen that the second syllable of the stressed target word is 0.83 dB louder than the second syllable of the unstressed target word. The multivariate test shows that the two means are not significantly different at $p < 0.05$ ($p = 0.307$, df = 1, N = 24). This shows that for SET D words, there is no statistical evidence to show that intensity is a phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word. Again, this is different from what is seen in the second syllable of SET C, where a significant difference in amplitude is found between the second syllable of the stressed words and the second syllable of the unstressed words.

The third syllable of the stressed word is 2.55 dB louder than the third syllable of the unstressed word. The multivariate test, unlike the tests for the first two syllables, shows that this difference is significant at $p < 0.01$ ** ($p = 0.002$, df = 1, N = 24). This shows that for SET D words, intensity is a phonetic property that distinguishes between the third syllable of the stressed target word and the third syllable of the unstressed target word. This is again different from what is seen in the SET C, where no significant difference in amplitude is found between the third syllable of the stressed target words and the third syllable of the unstressed target words.

Intensity is shown to be a distinguishing property between the stressed and the unstressed target words, for the first and second syllables in SET C and the third syllable in SET D. This further confirms that intensity is an acoustic correlate of stress for the Chinese speakers, whether the words have one, two or three syllables.

Duration

Figure 5.12 shows the means of vowel length of the stressed and unstressed words, for each syllable, in SET C and SET D words of the Chinese speakers.



	SET C: Syll 1	SET C: Syll 2	SET C: Syll 3	SET D: Syll 1	SET D: Syll 2	SET D: Syll 3
Stressed	0.0519	0.0580	0.0744	0.0645	0.0731	0.0909
Unstressed	0.0510	0.0519	0.0660	0.0602	0.0613	0.0783

Fig. 5.12: Means of vowel length of the stressed and unstressed words, for each syllable, in SET C and SET D words of the Chinese speakers.

From Figure 5.12, it can be seen that for SET C words, the first syllable of the stressed word is only 0.0009 sec longer than first syllable of the unstressed word, which is not even within the range of the just-noticeable difference of 0.01 – 0.04 sec for perception of duration. The multivariate test shows that the means are not significantly different at $p < 0.05$ ($p = 0.808$, $df = 1$, $N = 24$). The test therefore cannot show conclusively that duration is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word for the first syllable in SET C words.

From the same figure, it can be seen that the second syllable of the stressed word is 0.0061 sec longer than the second syllable of the unstressed word, which is also not within the range of just-noticeable difference for perception of length. The multivariate test however shows this difference is significant at $p < 0.05$ * ($p = 0.047$, df = 1, N = 24). Therefore, in SET C words, duration is a phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word.

The third syllable of the stressed word is 0.0084 sec longer than the third syllable of the unstressed word, as can be seen from Figure 5.12. Like the test for the first syllable, the multivariate test shows that this difference is not significant at $p < 0.05$ ($p = 0.085$, df = 1, N = 24). There is therefore also no statistical evidence in this case to show that duration is a phonetic property that distinguishes between the third syllable of the stressed target word and the third syllable of the unstressed target word for the words in SET C.

The situation is the same for the words in SET D. From Figure 5.12, for the words in SET D, it can be seen that the first syllable of the stressed word is only 0.0043 sec longer than the first syllable of the unstressed word. The multivariate test shows that the difference between the two means is not significant at $p < 0.05$ ($p = 0.317$, df = 1, N = 24). For SET D words, there is therefore no strong statistical evidence to show that duration is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word.

The second syllable of the stressed word is 0.0118 sec longer than the second syllable of the unstressed word. Like the test for the second syllable of the words in SET C, the multivariate test shows that the means are significantly different at $p < 0.01$ ** ($p = 0.009$, df = 1, N = 24). This shows that for SET D words, duration is a phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word.

The third syllable of the stressed syllable is 0.0126 sec longer than the third syllable of the unstressed word, as can be seen from Figure 5.12. Like the test for the third syllable of SET C words, the multivariate test shows that this difference is not significant at $p < 0.05$ ($p = 0.080$, df = 1, N = 24). Therefore, for words in SET D, one cannot conclude from the statistical test that duration is a phonetic property that distinguishes between the third syllable of the stressed target word and the third syllable of the unstressed target word.

Duration is shown to be a distinguishing property between the stressed and the unstressed target words for the second syllable in both SET C and SET D. This further confirms that duration is an acoustic correlate of stress for the Chinese speakers, for one-, two- or three-syllables words.

Chinese speakers: stress in three-syllable words

The results so far can be summarised as the following:

1) For words in SET C, there is a significant difference in amplitude between the first syllable of the stressed target words and the first syllable of the unstressed target words. There is, in addition, a significant difference in amplitude and vowel length between the second syllable of the stressed target words and the second syllable of the unstressed target words. This suggests that the lexical stress placement is on

the first and second syllable, as it is in these two syllables that there is a significant difference in these two phonetic properties.

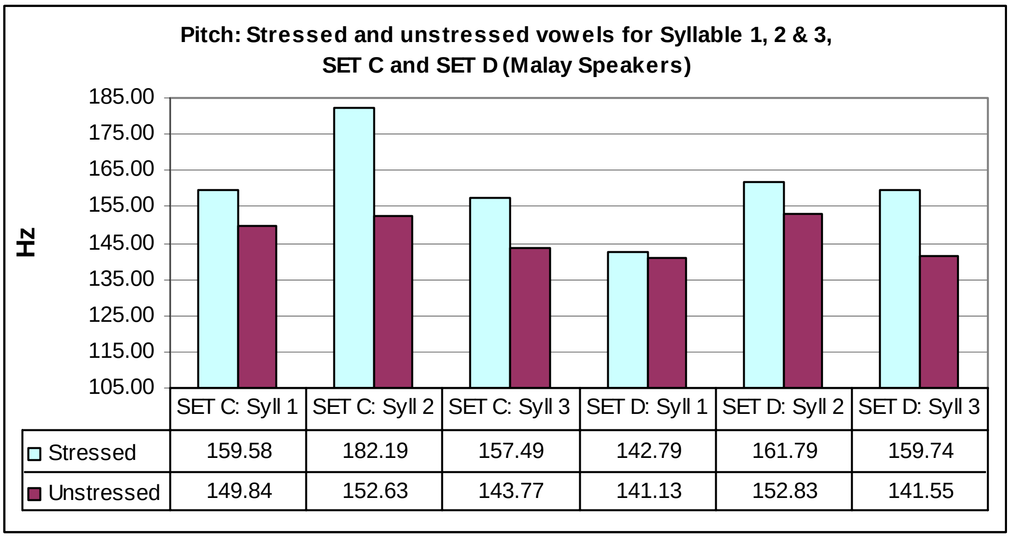
2) There is a significant difference in vowel length between the second syllable of the stressed target words and the second syllable of the unstressed target words in SET D. It is also observed that there is a significant difference in amplitude between the third syllable of the stressed target words and third syllable of the unstressed target words. This shows that for words in SET D, the lexical stress placement is on both the second and third syllable.

3) The results also further confirm that duration and intensity are acoustic correlates of stress for the Chinese speakers in three-syllable words. The statistical tests do not indicate that pitch is an acoustic correlate of stress for this group of speakers.

5.3.2.2 Malay Speakers

Pitch

Figure 5.13 shows the means of the F_0 of the stressed and unstressed words, for each syllable, in SET C and SET D words of the Malay speakers.



	SET C: Syll 1	SET C: Syll 2	SET C: Syll 3	SET D: Syll 1	SET D: Syll 2	SET D: Syll 3
Stressed	159.58	182.19	157.49	142.79	161.79	159.74
Unstressed	149.84	152.63	143.77	141.13	152.83	141.55

Fig. 5.13: Means of the F_0 of the stressed and unstressed words, for each syllable, in SET C and SET D words of the Malay speakers.

From Figure 5.13, it can be seen that for SET C words, the first syllable of the stressed word is 9.74 Hz higher than the first syllable of the unstressed word, about 8 Hz more than the just-noticeable difference of 1 Hz for pitch perception. The multivariate test shows that this difference is not significant at $p < 0.05$ ($p = 0.193$, df = 1, N = 24). This shows that for SET C words, there is no statistical evidence to show that pitch is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word.

From the same figure, it can be seen that the second syllable of the stressed word is 29.56 Hz higher than the second syllable of the unstressed word, more than 28 Hz higher than the just-noticeable difference for pitch perception. The multivariate test shows that this difference is significant at $p < 0.01$ ** ($p < 0.005$, df = 1, N = 24). This shows that for SET C words, pitch is a phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word.

The third syllable of the stressed word is 13.72 Hz higher than the third syllable of the unstressed word. The multivariate test shows that this difference is not significant at $p < 0.05$ ($p = 0.099$, df = 1, N = 24). This shows that for SET C words, one cannot strongly conclude that pitch is a phonetic property that distinguishes between the third syllable of the stressed target word and the third syllable of the unstressed target word.

For SET D, from Figure 5.13, it can be seen that the first syllable of the stressed word is 1.65 Hz higher than the first syllable of the unstressed word. The multivariate test shows these two means are not significantly different at $p < 0.05$ ($p = 0.735$, df = 1, N = 24). For SET D words, there is also no strong statistical evidence to show that pitch is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word. This is similar to what is seen in the first syllable of the words in SET C.

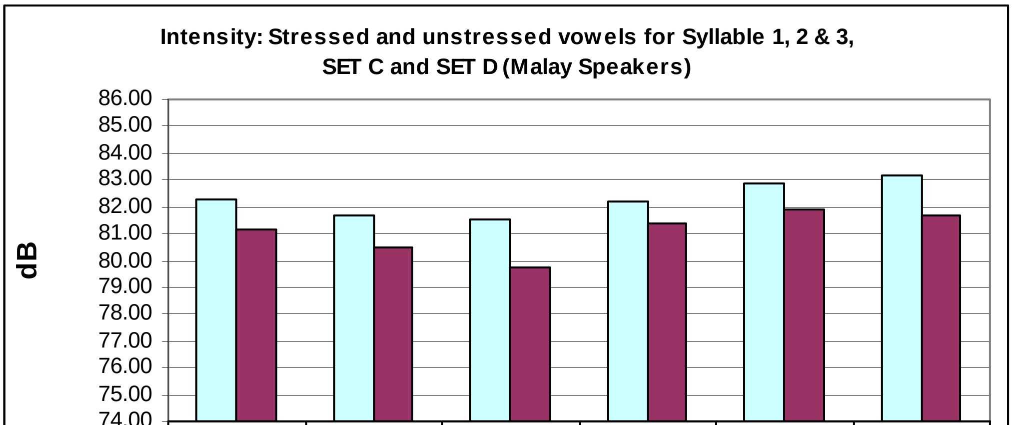
From the same figure, it can be seen that for SET D words, the second syllable of the stressed word is 8.96 Hz higher than the second syllable of the unstressed word. The multivariate test shows that the two means are not significantly different at $p < 0.05$ ($p = 0.102$, df = 1, N = 24). This shows that for SET D words, there is no statistical evidence to show that pitch is a phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word. This is unlike what is seen in the words in SET C, where the multivariate test shows that there is a significant difference in pitch between the second syllable of the stressed target word and the second syllable of the unstressed target word.

The third syllable of the stressed word is 18.19 Hz higher than the third syllable of the unstressed word, 17 Hz more than the just-noticeable difference of 1 Hz for pitch perception. The multivariate test shows that this difference is significant at $p < 0.01$ ** ($p = 0.005$, df = 1, N = 24). This shows that in SET D words, pitch is a phonetic property that distinguishes between the third syllable of the stressed target word and third syllable of the unstressed target word.

Pitch is a distinguishing property between the second syllable of the stressed target words and the second syllable of the unstressed target words for SET C, and the third syllable for SET D. This further confirms that pitch is an acoustic correlate of stress for the Malay speakers, regardless of the number of syllables the word has.

Intensity

Figure 5.14 shows the means of amplitude of the stressed and the unstressed words, for each syllable, in SET C and SET D words of the Malay speakers.



	SET C: Syll 1	SET C: Syll 2	SET C: Syll 3	SET D: Syll 1	SET D: Syll 2	SET D: Syll 3
Stressed	82.27	81.69	81.56	82.20	82.84	83.13
Unstressed	81.14	80.48	79.74	81.35	81.93	81.68

Fig. 5.14: Means of the amplitude of the stressed and the unstressed words, for each syllable, in SET C and SET D words of the Malay speakers.

From Figure 5.14, it can be seen that for SET C words, the first syllable of the stressed word is 1.13 dB louder than the first syllable of the unstressed word. This difference is slightly larger than the just-noticeable difference of 0.5 – 1 dB for the perception of intensity. The multivariate test shows that these two means are not significantly different at $p < 0.05$ ($p = 0.077$, df = 1, N = 24). This shows that for SET C words, one cannot strongly conclude that intensity is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word.

From the same figure, it can be seen that the second syllable of the stressed word is 1.21 dB louder than the second syllable of the unstressed word. The multivariate test shows that this difference is not significant at $p < 0.05$ ($p = 0.135$, df = 1, N = 24). This shows that for SET C words, there is no strong statistical evidence to show that intensity is a phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word.

The third syllable the stressed word is 1.82 dB louder than the third syllable of the unstressed word. The multivariate test, like the tests for the first two syllables, shows that this difference is not significant at $p < 0.05$ ($p = 0.085$, $df = 1$, $N = 24$). Again, there is no strong statistical evidence to show intensity is a phonetic property that distinguishes between the third syllable of the stressed target word and the third syllable of the unstressed target word for SET C words.

The situation is exactly the same for the words in SET D. From Figure 5.14, it can be seen that for SET D words, the first syllable of the stressed word is 0.85 dB louder than the first syllable of the unstressed word, which is within the range of the just-noticeable difference of 0.5 - 1 dB for perception. The multivariate test shows that the means of the amplitude of the first syllable of the stressed target word and the first syllable of the unstressed target word of SET D words are not significantly different at $p < 0.05$ ($p = 0.316$, $df = 1$, $N = 24$). This shows that for SET D words, one cannot conclude from the statistical test that intensity is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word.

From the same figure, it can be seen that for SET D words, the second syllable of the stressed word is 0.90 dB louder than the second syllable of the unstressed word. The multivariate test shows that the two means are not significantly different at $p < 0.05$ ($p = 0.224$, $df = 1$, $N = 24$). This shows that for the words in SET D, one cannot conclude from the statistical test that intensity is a phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word. Again, this is not different from what is seen in SET C, where no significant difference in amplitude is found between the second syllable of the stressed target words and the second syllable of the unstressed target words.

The third syllable of the stressed word is 1.45 dB louder than the third syllable of the unstressed word. The multivariate test shows that this difference is not significant at $p < 0.05$ ($p = 0.109$, $df = 1$, $N = 24$). This shows that for SET D words, there is no evidence to show that intensity is a phonetic property that distinguishes between the third syllable of the stressed target word and the third syllable of the unstressed target word. This is again similar to what is seen in SET C, where no significant difference in amplitude is found between the third syllable of the stressed target word and the third syllable of the unstressed target word.

There has been no strong statistical evidence to show that intensity is a distinguishing property between the stressed and the unstressed words for all three syllables in both SET C and SET D. This is different from what is established in Chapter 4, as well as the earlier section on the two-syllable words, where intensity is found to be an acoustic correlate of stress for the Malay speakers. It can be said from here therefore that while intensity is used as an acoustic correlate of stress for three-syllable words, but showing itself as a phonetic property of stress for one- and two-syllable words, is perhaps a weak acoustic correlate of stress for the Malay variety of SE.

Duration

Figure 5.15 shows the means of vowel length of the stressed and unstressed words, for each syllable, in SET C and SET D words of the Malay speakers.

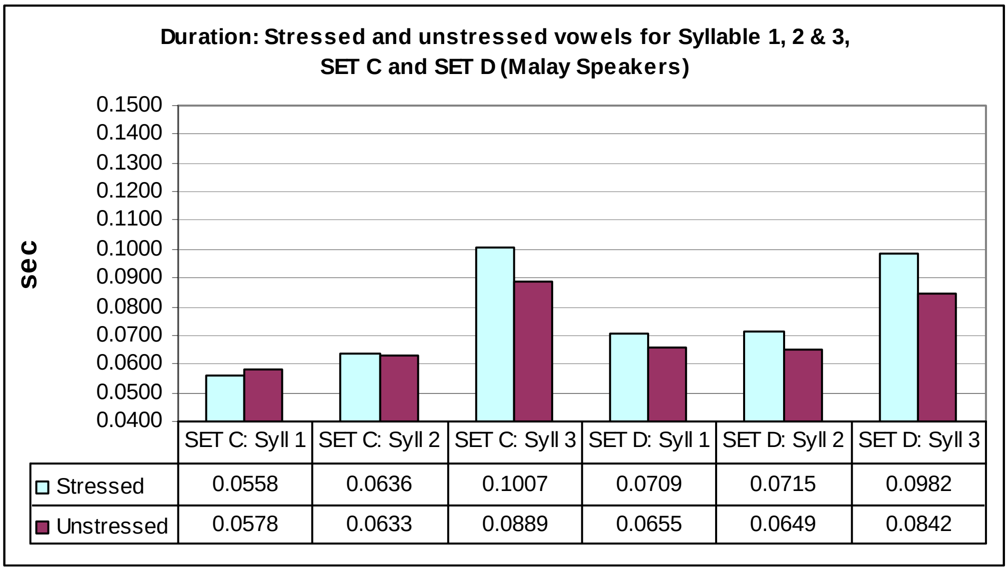


Fig. 5.15: Means of vowel length of the stressed and unstressed words, for each syllable, in SET C and SET D words of the Malay speakers.

From Figure 5.15, it can be seen that for SET C words, the first syllable of the stressed word is only 0.0020 sec longer than the first syllable of the unstressed word, which is not even within the range of the just-noticeable difference of 0.01 – 0.04 sec for perception of duration. The multivariate test shows that the means are not significantly different at $p < 0.05$ ($p = 0.691$, df = 1, N = 24). One therefore cannot conclude from the statistical test that duration is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word for the first syllable in SET C words.

From the same figure, it can be seen that the second syllable of the stressed word is only 0.0004 sec longer than the second syllable of the unstressed word, which is also not within the range of just-noticeable difference for perception of length. The multivariate test shows that this difference is not significant at $p < 0.05$ ($p = 0.943$, df = 1, N = 24). In SET C words, there is no statistical evidence to show that duration is a phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word.

For SET C words, the third syllable of the stressed word is 0.0117 sec longer than the third syllable of the unstressed word, as can be seen from Figure 5.15. Like the test for the first two syllables, the multivariate test shows that this difference is not significant at $p < 0.05$ ($p = 0.119$, df = 1, N = 24). In SET C words, there is again no evidence to show that duration is a phonetic property that distinguishes between the third syllable of the stressed target word and the third syllable of the unstressed target word.

The situation is the same for the words in SET D. From Figure 5.15, it can be seen that the first syllable of the stressed word is 0.0054 sec longer than the first syllable of the unstressed word, which is what is also observed in the words in SET C. The difference in vowel length of these two syllables in question, for the Malay speakers, is not within the range of the just-noticeable difference of 0.01 – 0.04 sec for perception of length. The multivariate test shows that the difference between the two means is not significant at $p < 0.05$ ($p = 0.336$, df = 1, N = 24). For SET D words, there is also no statistical evidence provided to show that duration is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word.

From the same figure, it can be seen that the second syllable of the stressed word is 0.0065 sec longer than the second syllable of the unstressed word, which is also not within the range of the just-noticeable difference for duration perception. Like the test for the first syllable, the multivariate test shows that the means are not significantly different at $p < 0.05$ ($p = 0.296$, df = 1, N = 24). This shows that for SET D words, one cannot conclude from the statistical test that duration is a phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word.

For SET D words, the third syllable of the stressed word is 0.0140 sec longer than the third syllable of the unstressed word, as can be seen from Figure 5.15. Like the test for the first two syllables and the three syllables in SET C, the multivariate test shows that this difference is not significant at $p < 0.05$ ($p = 0.160$, $df = 1$, $N = 24$). In SET D words, there is also no strong statistical evidence to show that duration is a phonetic property that distinguishes between the third syllable of the stressed target word and the third syllable of the unstressed target word.

There has not been strong statistical evidence to show that duration is a distinguishing property between the stressed and the unstressed words for all three syllables in both SET C and SET D. Like what is shown in earlier in the case of intensity, this is again different from what is established in Chapter 4, as well as the earlier section on the two-syllable words, where duration is found to be an acoustic correlate of stress for the Malay speakers. Therefore, while duration is not used as an acoustic correlate of stress for three-syllable words, it shows itself as a phonetic property of stress for one- and two-syllable words. This perhaps suggests that duration, like intensity, is a weak acoustic correlate of stress for the Malay variety of SE.

Malay speakers: stress in three-syllable words

The results so far can be summarised as the following:

1) For the words in SET C, there is a significant difference in F_0 between the second syllable of the stressed target words and the second syllable of the unstressed target words. This suggests that the lexical stress placement is on the second syllable, as it is in this syllable that there is a significant difference in this phonetic property.
2) There is also a significant difference in F_0 between the third syllable of the stressed target words and the third syllable of the unstressed target words in SET D. This

shows that for words in SET D, the lexical stress placement is on the third syllable, as it is in this syllable that there is a significant difference in this phonetic property.

3) The results also confirm that pitch is an acoustic correlate of stress for the Malay speakers in three-syllable words.

4) Intensity and duration, while are shown to be acoustic correlates of stress for one- and two- syllable words, do not have the same results for three-syllable words. This is because there is no significant difference in amplitude or vowel length, between the stressed and unstressed words for all three syllables in both SET C and SET D. There is no statistical evidence to allow for the conclusion that intensity and duration are acoustic correlates of stress for the three syllable words.

5) One can therefore conclude that pitch is a strong acoustic correlate of stress for the Malay variety of SE, and intensity and duration, weak ones.

5.3.2.3 Indian Speakers

Pitch

Figure 5.16 shows the means of the F_0 of the stressed and unstressed words, for each syllable, in SET C and SET D words of the Indian speakers.

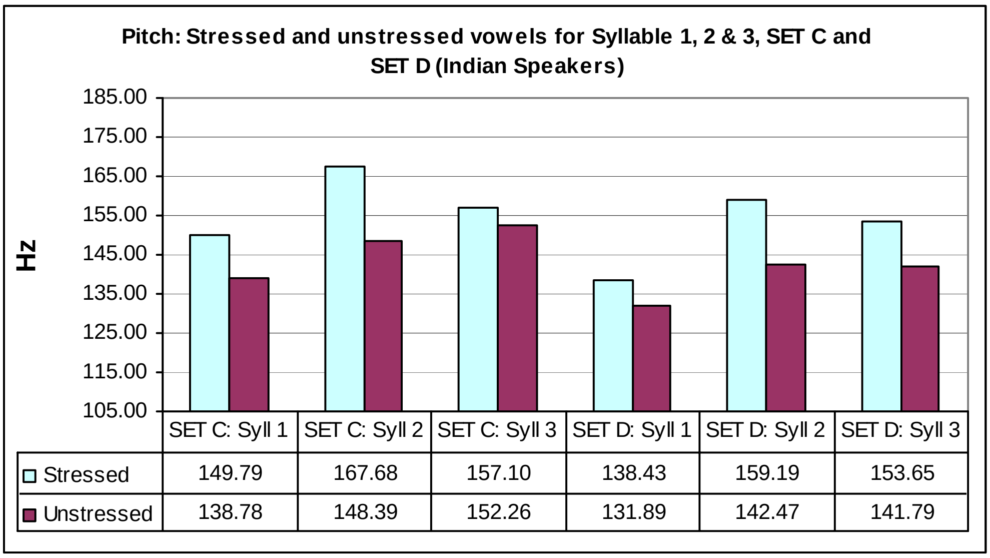


Fig. 5.16: Means of the F_0 of the stressed and unstressed words, for each syllable, in SET C and SET D words of the Indian speakers.

From Figure 5.16, it can be seen that for SET C words, the first syllable of the stressed word is 11.01 Hz higher than the first syllable of the unstressed word, about 10 Hz more than the just-noticeable difference of 1 Hz for pitch perception. The multivariate test however shows that this difference is not significant at $p < 0.05$ ($p = 0.158$, df = 1, N = 24). This shows that for SET C words, there is no statistical evidence to show that pitch is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word.

From the same figure, it can be seen that for SET C words, the second syllable of the stressed word is 19.29 Hz higher than the second syllable of the unstressed word. The multivariate test shows that this difference is significant at $p < 0.05$ * ($p = 0.028$, df = 1, N = 24). This shows that for the words in SET C, pitch is a phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word.

For SET C words, the third syllable of the stressed word is 4.84 Hz higher than the third syllable of the unstressed word. This difference is larger than the just-noticeable difference for pitch perception. The multivariate test shows that this difference is not significant at $p < 0.05$ ($p = 0.574$, df = 1, N = 24). This shows that for SET C words, one cannot conclude from the statistical test that pitch is a phonetic property that distinguishes between the third syllable of the stressed target word and the third syllable of the unstressed target word.

The situation is exactly the same for the words in SET D. For SET D, from Figure 5.16, it can be seen that the first syllable of the stressed word is 6.54 Hz higher than the first syllable of the unstressed word. The multivariate test shows these two means are not significantly different at $p < 0.05$ ($p = 0.226$, df = 1, N = 24). For the words in SET D, there is no statistical evidence to show that pitch is a phonetic property that distinguishes between the first syllable of stressed target word and the first syllable of the unstressed target word. This is similar to what is seen in the first syllable for the words in SET C.

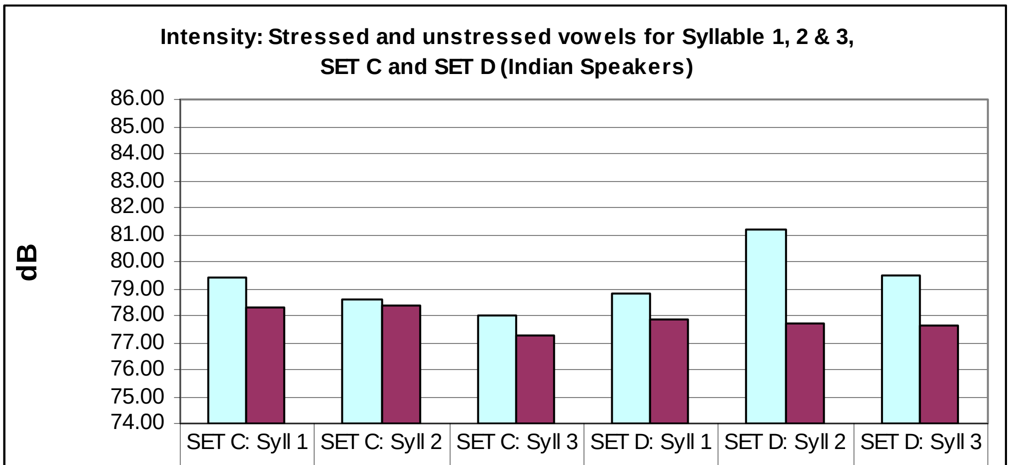
From the same figure, it can be seen that for SET D words, the second syllable of the stressed word is 16.72 Hz higher than the second syllable of the unstressed word. The multivariate test shows that the two means are significantly different at $p < 0.05$ ($p = 0.031$, df = 1, N = 24). This shows that for SET D words, pitch is a phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word. This is again similar to what is seen in the words in SET C, where the multivariate test for the second syllable shows that there is a significant difference in pitch between the second syllable of the stressed target word and the second syllable of the unstressed target word.

For SET D words, the third syllable of the stressed word is 11.86 Hz higher than the third syllable of the unstressed word. The multivariate test shows that this difference is not significant at $p < 0.05$ ($p = 0.099$, df = 1, N = 24). This shows that in SET D words, one cannot conclude from the statistical test that pitch is a phonetic property that distinguishes between the third syllable of the stressed target word and the third syllable of the unstressed target word.

Pitch is a distinguishing property between the stressed and the unstressed target words in the second syllable in SET C words and the second syllable in SET D words. This further confirms that pitch is an acoustic correlate of stress for the Indian speakers, whether the words have one, two or three syllables.

Intensity

Figure 5.17 shows the means of amplitude of the stressed and the unstressed words, for each syllable, in SET C and SET D words of the Indian speakers.



	SET C: Syll 1	SET C: Syll 2	SET C: Syll 3	SET D: Syll 1	SET D: Syll 2	SET D: Syll 3
Stressed	79.40	78.60	77.99	78.78	81.17	79.48
Unstressed	78.33	78.35	77.23	77.88	77.72	77.62

Fig. 5.17: Means of amplitude of the stressed and the unstressed words, for each syllable, in SET C and SET D words of the Indian speakers.

From Figure 5.17, it can be seen that for SET C words, the first syllable of the stressed word is 1.07 dB louder than the first syllable of the unstressed word, which is only slightly larger than the just-noticeable difference of 0.5 – 1 dB for perception of intensity. The multivariate test shows that these two means are not significantly different at $p < 0.05$ ($p = 0.210$, df = 1, N = 24). This shows that in SET C words, one cannot conclude from the statistical test that intensity is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word.

From the same figure, it can be seen that for SET C words, the second syllable of the stressed word is 0.25 dB louder than the second syllable of the unstressed word. The multivariate test shows that this difference is not significant at $p < 0.05$ ($p = 0.796$, $df = 1$, $N = 24$). For SET C words, there is no strong statistical evidence to show that intensity is a phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word.

The third syllable of the stressed word is 0.76 dB louder than the third syllable of the unstressed word. The multivariate test, like the tests for the first two syllables, shows that this difference is not significant at $p < 0.05$ ($p = 0.536$, $df = 1$, $N = 24$). This shows that for SET C words, there is again no strong statistical evidence to show that intensity is a phonetic property that distinguishes between the third syllable of the stressed target word and the third syllable of the unstressed target word.

For SET D words, from Figure 5.17, it can be seen that the first syllable of the stressed word is 0.91 dB louder than the first syllable of the unstressed word. The multivariate test shows that the two means are not significantly different at $p < 0.05$ ($p = 0.395$, $df = 1$, $N = 24$). This shows that for SET D words, one cannot conclude from the statistical test that intensity is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word.

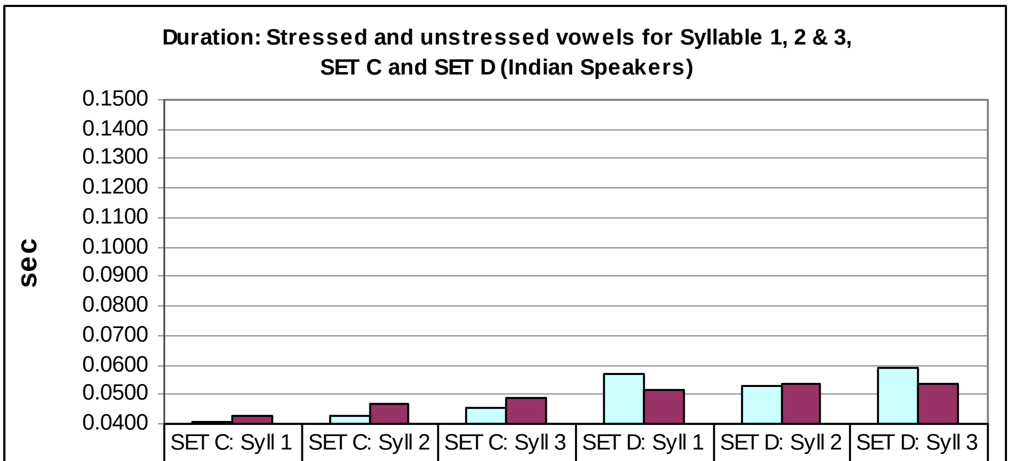
From the same figure, it can be seen that for SET D words, the second syllable of the stressed word is 3.45 dB louder than the second syllable of the unstressed word. The multivariate test shows that the two means are significantly different at $p < 0.01$ ** ($p = 0.001$, $df = 1$, $N = 24$). This shows that for the words in SET D, intensity is a phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word. This is different from what is seen in SET C, where no significant difference in amplitude is found between the second syllable of the stressed target words and the second syllable of the unstressed target words.

The third syllable of the stressed word is 1.86 dB louder than the third syllable of the unstressed word. The multivariate test shows that this difference is not significant at $p < 0.05$ ($p = 0.072$, $df = 1$, $N = 24$). This shows that for SET D words, there is no strong statistical evidence to show that intensity is a phonetic property that distinguishes between the third syllable of the stressed target word and the third syllable of the unstressed target word. This is similar to what is seen in SET C, where no significant difference in amplitude is found between the third syllable of the stressed target words and the third syllable of the unstressed target words.

Intensity is shown to be a distinguishing property between the second syllable of the stressed target words and the second syllable of the unstressed target words for the in SET D, but not in SET C. This is perhaps due to the small sample size, since intensity has, consistently, shown itself to be a strong acoustic correlate of stress for the Indian speakers in every single instance so far, except SET C. Its strength as an acoustic correlate should therefore not be dismissed.

Duration

Figure 5.18 shows the means of vowel length of the stressed and unstressed words, for each syllable, in SET C and SET D words of the Indian speakers.



	SET C: Syll 1	SET C: Syll 2	SET C: Syll 3	SET D: Syll 1	SET D: Syll 2	SET D: Syll 3
Stressed	0.0407	0.0429	0.0451	0.0568	0.0528	0.0589
Unstressed	0.0424	0.0465	0.0487	0.0513	0.0535	0.0533

Fig. 5.18: Means of vowel length of the stressed and unstressed words, for each syllable, in SET C and SET D words of the Indian speakers.

Unlike what is seen in the Chinese and Malay varieties of SE, from Figure 5.18, it can be seen that for SET C words, the first syllable of the stressed target words is shorter than the first syllable of the unstressed target words. The multivariate test shows that the means are not significantly different at $p < 0.05$ ($p = 0.508$, df = 1, N = 24). There is therefore no strong statistical evidence to show that duration is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word for the first syllable in SET C words.

Similarly, the second syllable of the stressed target words is also shorter than the second syllable of the unstressed target words. The multivariate test, again, shows that this difference is not significant at $p < 0.05$ ($p = 0.168$, df = 1, N = 24). In SET C words, the statistical test does not provide strong evidence to show that duration is a phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word.

Similar to the first and second syllable, the third syllable of the stressed target words is again shorter than the vowel in the unstressed target words, as can be seen from Figure 5.18. The difference in vowel length between the third syllable of the stressed target word and the third syllable of the unstressed target word for the Indian speakers is 0.0035 sec. Like the tests for the first two syllables, the multivariate test shows that this difference is not significant at $p < 0.05$ ($p = 0.172$, df = 1, N = 24). In SET C, the statistical test again does not provide strong evidence to show that duration is a phonetic property that distinguishes between the third syllable of the stressed target word and the third syllable of the unstressed target word.

From Figure 5.18, it can be seen that for SET D words, the first syllable of the stressed target words is 0.0055 sec longer than the first syllable of the unstressed target words, unlike what is also observed in the words in SET C. This difference is however is not even within the range of the just-noticeable difference of 0.01 – 0.04 sec for perception of length. The multivariate test shows that the difference between the two means is not significant at $p < 0.05$ ($p = 0.121$, df = 1, N = 24). For SET D words, there is no evidence from the statistical test to show that duration is a phonetic property that distinguishes between the first syllable of the stressed target word and the first syllable of the unstressed target word.

From the same figure, it can be seen that the second syllable of the stressed target words is again shorter than the second syllable of the unstressed target words. The difference in vowel length between the second syllable of the stressed target word and the second syllable of the unstressed target word for the Indian speakers is 0.0008 sec. The multivariate test shows that the means are not significantly different at $p < 0.05$ ($p = 0.825$, df = 1, N = 24). This shows that for SET D words, there is, similarly, no statistical evidence to show that duration is a phonetic property that distinguishes between the second syllable of the stressed target word and the second syllable of the unstressed target word.

The third syllable of the stressed target words is 0.0056 sec longer than the third syllable of the unstressed target words, as can be seen from Figure 5.18. This difference is however not even within the range of just-noticeable difference for perception of length. Like the first two syllables and the three syllables in SET C, the multivariate test shows that this difference is not significant at $p < 0.05$ ($p = 0.147$, $df = 1$, $N = 24$). In SET D words, there is again no statistical evidence to show that duration is a phonetic property that distinguishes between the third syllable of the stressed target word and the third syllable of the unstressed target word.

Consistently, the statistical tests have not provided strong evidence to show that duration is a distinguishing property between the stressed and the unstressed target words, for all the three syllables, in both SET C and SET D. One cannot draw the conclusion that duration is an acoustic correlate of stress for the Indian speakers, whether the words have one, two or three syllables.

Indian speakers: stress in three-syllable words

The results so far can be summarised as the following:

1) For the words in SET C, there is a significant difference in F_0 between the second syllable of the stressed target words and the second syllable of the unstressed target words. This suggests that the lexical stress placement is on the second syllable, as it is in this syllable that there is a significant difference in this phonetic property.

2) There is also a significant difference in F_0 and amplitude between the second syllable of the stressed target words and the second syllable of the unstressed target words in SET D. This shows that for words in SET D, the lexical stress placement is also on the second syllable, as it is in this syllable that there is a significant difference in this phonetic property.
3) The results also confirm that pitch and intensity are acoustic correlates of stress for the Indian speakers in three-syllable words. There is no statistical evidence to show that duration is an acoustic correlate of stress for this group of speakers.

5.4 Summary of Findings

5.4.1 Acoustic Correlates of Stress in Polysyllabic Words

For both two-syllable words and three-syllable words, it is confirmed from the results that the Chinese speakers do not use pitch as an acoustic correlate of stress. Intensity and duration, on the other hand, are phonetic properties that are used to distinguish between the stressed and unstressed target words, confirming that these two properties are acoustic correlates of stress for the Chinese speakers.

For the Malay speakers, all three phonetic properties, pitch, intensity and duration are used to distinguish the stressed target words from the unstressed ones. However, pitch is a particularly strong acoustic correlate of stress, showing itself as a dominant phonetic property in for the words in all four sets of words. Intensity and duration, on the other hand, are shown to be weaker. While intensity and duration are used to distinguish the stressed target words from the unstressed ones for the two-syllable words, these two phonetic properties are not used for both sets of three-syllable words.

For the Indian speakers, the statistical results do not provide evidence to show that duration is used as an acoustic correlate of stress. Intensity and pitch, on the other hand, are phonetic properties that are used to distinguish between the stressed and unstressed target words, showing that they are acoustic correlates of stress for the Indian speakers.

5.4.2 Lexical Stress Placement

From the results, one can also infer that there are differences in lexical stress placement across the three different groups of speakers. Table 5.1 summarises the findings.

		SET A: *dinner, mirror, ribbon, riddle, linen, lily*		**SET B**: *goggle, model, body, dolly, lorry, robin*		**SET C**: *mineral, minister, millipede*			**SET D**: *beginning, manila, gorilla*		
		Syll1	Syll2	Syll1	Syll2	Syll1	Syll2	Syll3	Syll1	Syll2	Syll3
Chinese Speakers	**Pitch**										
	Intensity		✓	✓		✓	✓				✓
	Duration		✓				✓			✓	
Malay Speakers	**Pitch**	✓	✓		✓		✓				✓
	Intensity	✓	✓		✓						
	Duration				✓		✓				
Indian Speakers	**Pitch**		✓		✓		✓			✓	
	Intensity		✓	✓	✓					✓	
	Duration										

Table 5.1: Significant differences between the stressed and unstressed syllables.

For the Chinese speakers, for SET A words, the lexical stress is on the second syllable, as this is the syllable that exhibits significant differences in amplitude and length between the stressed and unstressed words. For SET B words, however, the lexical stress is on the first syllable, showing significant differences in amplitude between the stressed and unstressed target words. For three-syllable words, in SET C, the Chinese speakers place lexical stress on the first and second syllables, with the first syllable exhibiting significant differences in amplitude between the stressed and unstressed syllables, and amplitude and length in the second syllable. For SET D words however, the lexical stress is on the second and third syllables, with significant differences in amplitude observed between the second syllables of the stressed and unstressed words and significant differences in length for the third syllable of the stressed and unstressed target words.

For the Malay speakers, for SET A words, both syllables receive lexical stress. Significant differences in F_0 and amplitude are observed in both the first and second syllables of the stressed and unstressed target words. For SET B words however, the lexical stress is on the second syllable, with differences in F_0, duration and amplitude observed in the second syllable of the stressed and unstressed target words. For the three-syllable words, in SET C, the lexical stress falls on the second syllable, as it is this syllable that shows a significant difference between the F_0 and vowel length of the stressed and unstressed words. In SET D, the lexical stress is on the third syllable, with significant differences in length between the third syllables of the stressed and unstressed target words.

For the Indian speakers, for SET A words, the lexical stress falls on the second syllable, as this is the syllable that exhibits significant differences in F_0 and amplitude between the stressed and unstressed words. For the SET B words however, both syllables receive lexical stress. Significant differences in amplitude are observed in the first syllable of the stressed and unstressed target words, and differences in F_0 and amplitude in the second syllables of the stressed and unstressed target words. For the three-syllable words, the lexical stress is on the second syllable for words in both SET C and SET D. In SET C words, significant differences in F_0 are observed between the second syllables of the stressed and unstressed words. In SET D words, significant differences in both amplitude and F_0 are observed between the second syllables of the stressed and unstressed words.

The results are not contradictory to what earlier researchers have observed. The early studies of Tongue (1974), Platt and Weber (1980) and Tay (1982) report that there is a rightward shift of stress on words, which, in BrE, have initial syllable stress, and this is especially so for words with three syllables or more. For instance, for the word *educated*, the British speakers pronounce it *e-du-ca-ted*, with the primary lexical stress on the first syllable. The SE speakers however, tend to shift this stress to the right, pronouncing it *e-du-ca-ted*. There are signs of this in the results.

For SET C words – *minister, millipede* and *minister,* BrE speakers would place the lexical stress on the first syllable. For all three groups of speakers, they consistently place lexical stress on the second syllable, 'shifting' the lexical stress to the right. This is also the case for SET D words. The words *beginning*, *manila* and *gorilla* have the phonemic stress on the second syllable. Only the Indian speakers place the lexical stress on this syllable. The Chinese and Malay speakers have the lexical stress on the third syllable, again, moving towards the right. It is however interesting to note that the Chinese speakers place lexical stress not only on the 'rightward' syllable. They also, at the same time, place lexical stress on the syllable that the BrE speakers would have placed the stress on. This is perhaps due to the fact that the speakers are conscious of where the 'correct' lexical stress placement is, yet at the same time not able to control the natural tendency to 'shift' the lexical stress to the right.

This 'rightward shift' of stress can also be observed in the two-syllable words. All the two-syllable words have the phonemic stress on the first syllable. All the subjects, except the Chinese speakers in SET B words, 'shift' the lexical stress to the second syllable.

The sample size of the polysyllabic words in this study is certainly not large enough to give full picture of lexical stress placement patterns in SE, and it is hoped that these preliminary observations could certainly lead to further in-depth study on the subject.

CHAPTER SIX

CONCLUSION

6.1 Introduction

This dissertation aimed to look into nature of stress in the three ethnic varieties of SE. The perceptual cues and acoustic composition of stress in the Chinese, Malay and Indian varieties of SE formed the basis of enquiry.

In Chapter Three, the perceptual properties of stress in the three ethnic varieties of SE were investigated, using experiments that consisted of carefully synthesised and manipulated utterances. In Chapter Four, the acoustic properties of stress and emphatic stress were investigated, concentrating primarily on monosyllabic words. Chapter 5, followed the same vein as that of Chapter Four, investigated the acoustic properties of stress, but this time, in polysyllabic words. Lexical stress placement in two- and three-syllable words was also discussed. This chapter will summarise the findings and discuss their implications. Limitations of this research and suggestions for further research will also be discussed.

6.2 Summary of Findings

6.2.1 Perceptual Cues of Prominence

Past research on English, Polish, Czech and various other languages suggest that pitch is the most important perceptual cue, when compared to intensity and duration. Though studies were done rather extensively on stress in SE, no research has yet to establish the perceptual cues of stress in SE. Most of these studies assume that SE speakers would judge a higher pitched syllable as the prominent syllable. There is, therefore, a need to question if this assumption about the perceptual qualities of prominence in SE is true. Additionally, there is also a need to investigate if the three ethnic varieties of SE have different perceptual cues of prominence.

Chapter Three presented the results of the experiment carried out to investigate the perceptual properties of prominence in the Chinese, Malay and Indian varieties of SE. The experiment was intended to show to what extent each of the three parameters (pitch, intensity and duration) is, or may be responsible for the impressions identified by these Singaporean listeners as prominence. The experiment was in two main parts. For the first part of the experiment, the main purpose was to establish if the Chinese, Malay and Indian subjects use (i) higher or lower pitch, (ii) greater or less intensity and (iii) shorter or longer vowel duration to determine prominence. This was done by manipulating one parameter at a time, in one syllable.

The results show that it is generally consistent that all three groups of subjects use higher pitch, longer vowel length and increased loudness to determine prominence. For the Indian subjects though, when the difference in vowel length between the two test words is only 0.05 sec, their responses are split, showing that small durational changes do not have a clear effect on the Indian subjects' judgements of prominence .

The second part of this chapter concentrated on determining the relative strengths of the perceptual cues. In other words, when faced with a choice between two syllables, one of which is longer and the other, louder, for example, which syllable would the subjects feel is more prominent. The experiment consisted of utterances that had both test words synthesised, with one parameter manipulated in each test word, at the same time.

When it comes to the relative strength of the perceptual cues for each group of subjects, differences can be observed. Furthermore, there seems to be a hierarchy in the dominance of the parameters of pitch, intensity and duration.

The results show that for the Chinese subjects, intensity seems to be the most dominant perceptual cue for stress. They would pick the test word containing the louder vowel as the more prominent item, even when the other item is higher pitched or longer. When made to choose between a higher pitched but shorter test word and a longer but lower pitched test word however, this group of subjects would pick the word containing the longer vowel as the prominent item, as opposed to the higher pitched one. Therefore, for the Chinese subjects, in their perception of stress, they would first use intensity, followed by duration, and lastly, pitch.

For the Malay subjects however, the situation is slightly different. When asked to decide between a longer but softer test word and a louder but shorter test word, the choice of the more prominent item is the one containing the louder vowel. When asked to choose between a higher pitched but softer test word and a louder but lower pitched test word, however, when the difference in amplitude is only 5 dB, the subjects would choose the test word containing the higher pitched vowel. When given a choice between a higher pitched vowel and a longer vowel, the subjects would pick the word containing the higher pitched vowel to be the more prominent item. Therefore, what can be concluded for this group of subjects is that duration is the weakest perceptual cue for stress. While pitch and intensity seem to be equally dominant, the subjects seem to be less sensitive to smaller changes in amplitude compared to smaller changes in pitch, and thus, one could conclude that this group of subjects tends to use pitch as the dominant perceptual cue, followed by intensity, and lastly, duration.

For the Indian subjects, intensity seems to be the most dominant cue. They would pick the test word containing the louder vowel as the more prominent item, even when the other item is higher pitched or longer. When made to choose between a higher pitched but shorter test word and a longer but lower pitched test word however, the choice is for the former. This group of subjects would pick the word containing the higher pitched vowel as the stressed item, as opposed to the longer one. Therefore, for the Indian subjects, in their perception of stress, they would first use intensity, followed by pitch, and lastly, duration.

6.2.2 Acoustic Correlates of Stress

6.2.2.1 Background

Various studies on different languages were carried out to determine the acoustic properties present in stressed syllables. Researchers on languages such as English and Polish note that the stressed syllables in these languages have a higher F_0 compared to the unstressed syllables. In Danish, it is found that stressed syllables are longer and louder, and in contrast to the above examples, have lower F_0. In Hungarian, Fónagy (1966) notes that an unstressed syllable is longer, has higher F_0 and amplitude than that of a stressed syllable. Different varieties of the same language can also have different phonetic properties for stress. In the English spoken in Southern England, the stressed syllables are "louder, longer and higher" (Lass, 1987: 108) than unstressed syllables. In Northern Irish English however, stressed syllables are louder, longer but lower than unstressed syllables.

Though it is established by these above studies that different languages, or even different varieties of the same language can have different acoustic properties of stress, no extensive study has been done to establish the acoustic correlates of stress in SE. Researchers on SE stress, especially in the investigation of stress placement in SE, assume that the stressed syllable in SE must surely be the syllable that has a higher pitch. There is therefore a need to question if this assumption about the acoustic qualities of stress in SE is true. Additionally, similar to the investigation of the perceptual nature of prominence, it is necessary to determine if speakers of the three ethnic varieties of SE have different acoustic correlates of stress.

6.2.2.2 Monosyllabic Words

Chapter Four presented the results of the experiment carried out to investigate the acoustic properties of stress in the Chinese, Malay and Indian varieties of SE, in monosyllabic words. The experiment was intended to show if the three parameters (fundamental frequency, duration and amplitude) are different in the stressed, unstressed and emphatically stressed words. The difference in the phonetic properties present in the stressed, emphatically stressed and unstressed syllables was the target of investigation. The difference between the stressed and unstressed syllables in sentence-final positions and non sentence-final positions was also looked into.

The findings show that the Chinese, Malay and Indian speakers of SE have different acoustic correlates of stress. The Chinese speakers use increased amplitude and longer vowel length to indicate stress. In other words, intensity and duration are the Chinese speakers' acoustic correlates of stress. The Malay speakers, on the other hand, use higher F_0, increased amplitude and longer vowel length to indicate stress. All three parameters – pitch, intensity and duration, are the Malay speakers' acoustic correlates of stress. However, as the Malay speakers only use lengthened vowel length for stressed words at sentence-final positions, this correlate is weaker than the other two. The Indian speakers use higher F_0 and increased amplitude to indicate stress. In other words, pitch and intensity are the Indian speakers' acoustic correlates of stress.

The three groups of speakers also show differences in the acoustic manifestation of emphatic stress. For emphatic stress, the Chinese speakers use higher F_0 and increased amplitude to indicate the emphatic nature of the stress. Therefore, in addition to duration and intensity, pitch is also an acoustic correlate of stress for the Chinese speakers, but for emphatic stress. The emphatically stressed words will also be louder than the words that are normally stressed. The Malay speakers, for emphatic stress, use higher F_0 and longer vowel length to indicate the emphatic nature of the stress. The emphatically stressed words will therefore also be higher and longer than the words that are normally stressed. The Indian speakers use longer vowel length to indicate the emphatic nature of the stress. Therefore, in addition to pitch and intensity, duration is also an acoustic correlate of stress for the Indian speakers, but for emphatic stress.

In terms of differences in acoustic correlates of stress with regard to position within the sentence, there is no difference in the acoustic correlates of stress for the Chinese speakers for words in both sentence-final and non sentence-final positions. For the Malay speakers, sentence-final words are significantly lengthened when compared to unstressed words in the same position. Duration is only used as an acoustic correlate of stress for words in sentence-final position, and not so for words in the non sentence-final position. For pitch and intensity, both correlates are used regardless of position. Duration therefore, for the Malay speakers, can be considered to be the weakest acoustic property of stress. For the Indian speakers, pitch is used as an acoustic correlate of stress for words only in the sentence-final position, and not so for words in the non sentence-final position. This is, as mentioned earlier in Chapter 4, probably due to the boosted pitch on the words (stressed or unstressed) that happens in non sentence-final positions, diminishing the differences between the stressed and unstressed words in this position. This could also be caused by possible interferences from Tamil, which sees a rise-fall pitch contour at the sentence-final position (Tan, 1999). Intensity is used as a correlate regardless of position. Duration is not used as an acoustic correlate of stress for the Indian speakers, regardless of position. For the Indian speakers, pitch is most likely a weaker acoustic correlate of stress compared to intensity, as pitch is only used as an acoustic correlate in sentence-final positions, while intensity is used regardless of position.

6.2.2.3 Polysyllabic Words

For polysyllabic words, the results are similar. In Chapter 5, the acoustic correlates of stress in polysyllabic words were investigated. Emphatic stress was not investigated. For both two-syllable words and three-syllable words, it is confirmed from the results that the Chinese speakers do not use pitch as an acoustic correlate of stress. Intensity and duration, on the other hand, are phonetic properties that are used to distinguish between the stressed and unstressed target words, confirming that these two properties are acoustic correlates of stress for the Chinese speakers, regardless of the number of syllables a word has.

For the Malay speakers, all three phonetic properties, pitch, intensity and duration are used to distinguish the stressed target words from the unstressed ones. However, pitch is a particularly strong acoustic correlate of stress, showing itself as a dominant phonetic property in for the words in all four sets of words. Intensity and duration, on the other hand, are shown to be weaker. While intensity and duration are used to distinguish the stressed target words from the unstressed ones for the two-syllable words, these two phonetic properties are not used for both sets of three-syllable words.

For the Indian speakers, the results do not provide evidence to show that duration is used as an acoustic correlate of stress. Intensity and pitch, on the other hand, are phonetic properties that are used to distinguish between the stressed and unstressed target words, confirming that they are the acoustic correlates of stress for the Indian speakers.

6.2.2.4 Hierarchy of Acoustic Correlates

Looking at the acoustic correlates of stress for the three groups of subjects, monosyllabic as well as polysyllabic, a hierarchy in terms of the dominance of the parameters can be observed.

		1-syllable		2-syllable		3-syllable	
		Non sent-final	Sent-final	SET A	SET B	SET C	SET D
Chinese Speakers	**Pitch**						
	Intensity	✓	✓	✓	✓	✓	✓
	Duration	✓	✓	✓		✓	✓
Malay Speakers	**Pitch**	✓	✓	✓	✓	✓	✓
	Intensity	✓	✓	✓	✓		
	Duration		✓		✓	✓	
Indian Speakers	**Pitch**		✓	✓	✓	✓	✓
	Intensity	✓	✓	✓	✓		✓
	Duration						

Table 6.1: Acoustic correlates of stress in the monosyllabic and polysyllabic words of the three groups of speakers.

For the Chinese speakers, it has been established in the analyses of both the monosyllabic and polysyllabic words, that intensity and duration are acoustic correlates of stress for this group of speakers, while pitch is not. As can be seen from Table 6.1, duration is not used as an acoustic correlate of stress for SET B words. Intensity, on the other hand, is used as an acoustic correlate for every single instance, from one- to three-syllable words. Intensity, therefore, can be regarded as the most dominant acoustic correlate of stress, followed by duration, for the Chinese speakers of SE.

For the Malay speakers, all three parameters – pitch, intensity and duration are used as acoustic correlates for all the words, monosyllabic and polysyllabic. As can be seen from

Table 6.1, pitch is used by the Malay speakers for every instance, from one-syllable words to three-syllable words. While intensity and duration seem to be equally matched, intensity is perhaps more dominant than duration as an acoustic correlate of stress for the Malay speakers. Intensity is an acoustic correlate of stress for the Malay speakers in the monosyllabic words regardless of sentence position. It is also an acoustic property of stress for both sets of two-syllable words. Though it does not show itself as an acoustic correlate for three-syllable words, it is felt that the consistency of which it appears as a phonetic property in one- and two-syllable words make it a slightly more dominant acoustic property compared to duration, which shows itself as a phonetic property only in sentence-final monosyllabic words, and words in SET B and SET C. The most dominant acoustic correlate of stress for the Malay speakers therefore is pitch, followed by intensity, and lastly duration.

For the Indian speakers, it has been established in the analyses of both the monosyllabic and polysyllabic words, that intensity and pitch are acoustic correlates of stress for this group of speakers, while duration is not. As can be seen from Table 6.1, intensity and pitch seem to be equally dominant. It is extremely difficult to determine which is more dominant than the other, as intensity is used as an acoustic correlate of stress in every instance, except in SET C words. Pitch, on the other hand, is used as an acoustic property of stress in every instance except for the monosyllabic words in sentence-final position. However, it is felt that intensity could be considered as a slightly more dominant acoustic correlate of stress for the Indian speakers, compared to pitch, based on the consistency it shows itself as a phonetic property of stress. Its absence in SET C words could be due to the small sample size. Pitch, on the other hand, does not show itself to be an acoustic correlate of stress for the monosyllabic words in non sentence-final position, and it is consistently so. Based on this therefore, if one were to force a hierarchical structure based on their dominance as phonetic properties of stress, one would say, albeit with some reservation, that intensity could be slightly more dominant than pitch as an acoustic correlate of stress for the Indian speakers.

6.2.3 Correlation between Acoustic and Perceptual Properties

What have been shown so far are two sets of hierarchy – one for the perceptual cues and another for the acoustic correlates of stress. It is interesting to note that the hierarchical structure for the both the perceptual and acoustic properties of stress are the same for each group of speakers.

Table 6.2 shows the correlation between the acoustic and perceptual properties of stress for the Chinese, Malay and Indian speakers of SE.

Chinese Speakers	
Perceptual cues for prominence:	INTENSITY > DURATION > PITCH
Acoustic correlates of stress :	INTENSITY > DURATION > (PITCH) – not a property.
Malay Speakers	
Perceptual cues for prominence:	PITCH > INTENSITY > DURATION
Acoustic correlates of stress :	PITCH > INTENSITY > DURATION
Indian Speakers	
Perceptual cues for prominence:	INTENSITY > PITCH > DURATION
Acoustic correlates of stress :	INTENSITY > PITCH > (DURATION) – not a property.

Table 6.2: Correlation between the acoustic and perceptual properties of stress for the Chinese, Malay and Indian speakers of SE.

As can be seen, the perceptual properties of prominence correspond to the acoustic correlates of stress for each ethnic variety of SE, showing a match between the perception and acoustic manifestation of stress.

6.2.4 Lexical Stress Placement

As mentioned repeatedly in the earlier chapters, all the studies done on SE stress focus on word stress. Most of these studies are concerned with where the main stress is within a polysyllabic word. The early studies of Tongue (1974), Platt and Weber (1980) and Tay (1982) report that there is a rightward shift of stress on words, which, in BrE, have initial syllable stress. Sng (1991) reports that in polysyllabic words, the stress moves away from the initial syllable.

Having established the acoustic and perceptual nature of stress in the three ethnic varieties of SE, Chapter 5 also sought to look into the location of lexical stress in a small sample of polysyllabic words, and to determine if lexical stress placement differs between these three ethnic varieties of SE. The method of analysis involved comparing each syllable in the stressed polysyllabic word with the corresponding syllable in the unstressed polysyllabic word. The syllable that exhibits significant differences in one or more of the three parameters of pitch, intensity and duration is considered to have received the main lexical stress.

The polysyllabic words were grouped into four categories. The results show that the Chinese, Malay and Indian speakers of SE have different lexical stress placement patterns. Differences are also observed in the lexical stress placement patterns across the four categories of polysyllabic words.

For two-syllable words like *dinner*, *mirror*, *ribbon*, *riddle*, *linen* and *lily*, the Chinese and Indian speakers place the main lexical stress on the second syllable. For the Malay speakers however, both syllables receive lexical stress. For the Indian speakers, the main lexical stress falls on the second syllable.

For two-syllable words like *goggle*, *model*, *body*, *dolly*, *lorry* and *robin*, the location of stress is different. For the Chinese speakers, the lexical stress falls on the first syllable. For the Malay speakers, the lexical stress falls on the second syllable. For the Indian speakers, both syllables receive lexical stress.

For three-syllable words like *mineral*, *minister* and *millipede*, for both the Malay and Indian speakers, the lexical stress falls on the second syllable. For the Chinese speakers however, the first and second syllables receive lexical stress.

For words like *beginning*, *manila*, *gorilla*, the Indian speakers still retain the lexical stress on the second syllable. For the Malay speakers however, the lexical stress now moves to the third syllable. For the Chinese speakers, while the second syllable still receives the lexical stress, instead of the first syllable, the third syllable now also receives lexical stress.

6.3 Implications

6.3.1 Locating this Study within SE Stress Research

The findings in this dissertation have implications for SE prosodic research. As mentioned in the first chapter of this dissertation, there are research gaps in the studies on SE stress, and they are:

(1) the determination of the acoustic correlates of stress in SE – examining the acoustic properties present in a stressed syllable that are not present in unstressed syllables;

(2) the determination of the perceptual cues of SE – examining the properties present in a syllable that SE listeners would judge as stressed.

This dissertation has, in some ways, contributed to the research on stress in SE by addressing these gaps.

Additionally, sentence stress and emphatic stress are the types of stress that have yet been investigated in SE. This dissertation, by looking at the acoustic correlates of stress, on the sentential level, as well as emphatic stress, opens up the avenue for stress research beyond the word-level.

Furthermore, as most research on SE do not control the ethnic groups of the subjects as a variable, this dissertation has shown that there are indeed differences to be seen within the ethnic varieties, and that future researchers on SE need to take these differences into consideration. SE, perhaps, is not as homogenous as most researchers have assumed it to be.

The results also have implications on previous research conducted on SE stress. As highlighted in Chapter Two, one of the assumptions researchers of stress in SE make is that the acoustic correlate(s) of stress in SE is the same as that of BrE, namely, pitch. The biggest gap in these past studies is that the acoustic correlate(s) of stress in SE is not first determined before identifying the stressed syllables. Researchers like Chua (1989) and Low (1998) readily assume that that a higher pitched syllable is a stressed syllable in their investigation of lexical stress placement patterns in SE, using the acoustic correlate of stress in BrE to apply to that in SE.

Taking a higher pitched syllable as the stressed syllable, these researchers would have identified the ‘incorrect’ stressed syllables, and therefore would have come to a wrong conclusion about stress placement in SE, unless of course, their subjects were Malay. Most of their subjects however were Chinese subjects. Their analyses on the stress placement in SE could therefore have erroneous conclusions.

Other researchers like Tongue (1974) and Platt and Weber (1980), in their experiments, use their own judgements, to determine the stressed syllables in their sample. It is to be noted of course that Tongue, Platt and Weber are not native speakers of SE. They use BrE perception to perceive prominence in SE, in which case, the higher pitched syllable is perceived to be the stressed syllable. As the results from Chapter Three show, the most dominant perceptual cue of prominence for the Chinese and Indian subjects is intensity, not pitch. These past researchers have misrepresented the perception of stress for most speakers of SE.

The results presented in this dissertation on the perceptual and acoustic nature of stress in SE have shown that these past research and their findings need to be re-examined, and that an analysis of stress without first determining the acoustic and perceptual properties of stress could lead to wrong conclusions about stress placement.

6.3.2 Theoretical Implications: The British Model

In the analysis of prosodic systems, especially intonation and rhythm, the model adopted is usually the ‘British’ approach (e.g. O’Conner and Arnold, 1961; Couper-Kuhlen, 1986; Cruttenden, 1997). This approach involves the division of speech into ‘tone units’, each of which has a characteristic pitch movement. The tone unit is an utterance that consists of an obligatory nucleus, and three optional elements – the prehead, head and tail. The nucleus consists of a ‘nuclear syllable’ which is the last accented syllable in the tone unit upon which there is a pitch change; the ‘accented’ syllable being the most prominent syllable within the utterance which involves a pitch obtrusion.

The findings of this study suggest that the British tradition of analysing intonation using the tone unit approach is not suited for the analysis of SE. In Chapter 4, it has been established that SE speakers' stressed syllables do not necessarily consist of a pitch obtrusion. In other words, the term 'accented syllable' probably does not exist in SE, at least for the Chinese speakers. This being the case therefore, the identification of the nucleus would become difficult and problematic. The model cannot be applied to SE. The application of this pitch-dependent model therefore becomes meaningless in SE, which, in terms of stress and prominence, does not necessarily involve changes in pitch movements.

Indeed, Low (1994, 1998) and Deterding (1994c) have suggested that employing this British traditional model of intonation analysis for the description of intonation patterns in SE is inappropriate, primarily because there is no clear nucleus to be identified. Deterding (1994c) further suggests that there is a nucleus in SE, but is simply cued differently. The findings in this study show that this suggestion might indeed be a possibility. With the perceptual cues of prominence and acoustic correlates of stress in SE more clearly spelt out, which makes it easier to identify stressed and unstressed syllables, it would perhaps be possible to look for the 'nucleus', though it could be that the 'nucleus' does not involves pitch obtrusions. This being the case, it is hoped that a theoretical prosodic model could be built to suit SE, and that this study's findings on the acoustic and perceptual nature of stress in SE could contribute to the building of this model.

6.3.3 Inter- and Intra-ethnic Communication

It is apparent from the results that the Chinese, Malay and Indian subjects use different perceptual and acoustic of stress. Though the first part of the experiment shows that all three groups use higher pitch, longer vowel length and increased loudness to determine stress, it is the relative importance of these three parameters that are different for these three groups of SE speakers. In normal occurring speech where all three parameters are at play, it is certain that stress will be determined by the most important phonetic property. In this case therefore, the Chinese and the Indian speakers of SE would most likely listen out for a louder syllable in the judgement of stress. For the Malay speakers however, a higher pitched syllable will be the more prominent one. In the same vein, the way the three groups of speakers produce stressed syllables are different. Emphatic stress production is also different. Different acoustic properties of stress are present in the stressed and emphatically stressed syllables for all three groups of speakers.

These differences in the perceptual and acoustic correlates of stress between these three groups of subjects have implications for inter-ethnic communication. A Chinese speaker for example would use increased vowel duration to stress a syllable. An Indian speaker however would not have thought that the syllable that contains the longer vowel is stressed. This Indian speaker would however judge a higher pitched syllable as the stressed syllable, yet this same syllable, in the Chinese speaker's speech repertoire is merely an effect of intonation, and not a product of stress. This means therefore that there are possibilities of misunderstandings between the ethnic groups should these differences in the nature of stress be ignored. Comprehension and understanding between these three groups of speakers could be enhanced if they are aware of how stress is perceived and produced by the different speakers of SE.

6.3.4 Pedagogical Implications

Although Singapore ceased to be a British colony more than 30 years ago, the teaching of English in Singapore schools is still holding on to the model of British English. This is made more so by the fact that Singapore students take the GCE 'O' and 'A' Level examinations set by the Cambridge Examinations Syndicate. Singapore teachers being trained at the National Institute of Education are therefore made to perpetuate this ‘British tradition’, since they are at the forefront of educating the young. This is done so by getting the trainees to undergo an oral examination known as the “Use of English in Teaching”. This examination requires all the trainee teachers to ‘speak’ like the ‘British’, and they are graded upon whether or not their pronunciation, intonation and stress patterns ‘deviate’ from the British norm.

This colonialist mentality certainly comes about because of linguistic insecurity, and this insecurity would undoubtedly become more severe if teachers are made to believe that British English is the ‘correct’ variety of English to be used in the classrooms. Teachers and students, and more importantly, the governing body of the country, need to understand and accept that SE is a legitimate variety of English, and that it is in no way inferior to the variety spoken by our past colonial master.

What this present study has shown is that the prosody of SE speech is a system of its own, and that it needs not be a copy or a deviation from the British model. This study presents how Singaporean speakers produce and perceive stress. If teachers can be made to understand these differences, it would be easier for them to allow themselves, and their students, to see that the Singapore English that they speak is indeed a variety worth speaking, and a ‘tradition’ that a Singaporean can be proud of. As Professor Tommy Koh, then Singapore’s permanent representative to the United States once pointed out,

> “… when one is abroad, in a bus or train or aeroplane and when one overhears someone speaking, one can immediately say that this is someone from Malaysia or Singapore. I should hope that when I’m speaking abroad, my countrymen will have no problem recognising that I’m a Singaporean.” (1974).

Certainly, the speech of a person is a mark of one's cultural identity. It is therefore important to recognise our own variety of English. It is hoped that the findings in this study has contributed towards the understanding of how Singaporeans speak, and that it could allow for teaching in the local variety without the feeling of inferiority.

6.3.5 Applications: Speech Synthesis

As mentioned in Chapter 3, there is so far no speech synthesis programme for SE. The findings of this study can contribute to building a speech synthesis and speech recognition model for SE. Understanding the prosodic nature of stress in the ethnic varieties of SE, the speech synthesis programme can be modelled more naturally. These prosodic differences could also build a more effective speech recognition programme that would allow for the ethnic varieties to be clearly distinguished from each other. Besides, artificial speech could be made more natural and realistic with the knowledge of the acoustic properties of stress in SE. The understanding of the perceptual and acoustic nature of stress in the three ethnic varieties of SE can certainly enrich areas of speech recognition, speaker recognition and forensic phonetics.

6.4 Limitations

6.4.1 Subjects

The SE subjects used in this research consisted only of undergraduates. This sample can at best only represent the younger and more educated population in Singapore. The findings therefore are not generalisable to the population of Chinese, Malays and Indians as a whole. One would expect differences to be seen should less educated or older subjects were chosen.

The choice of subjects for recording, as mentioned in Chapter 4, was limited only to speakers who spoke their respective Mother Tongues at home. One might expect therefore that other SE speakers who speak other indigenous languages like Hokkien, Teochew, or Hindi and Punjabi would show different speech patterns to those subjects recorded in this experiment. Furthermore, as the subjects recorded were male, the findings are not necessarily generalisable to females.

Given the constraint of time, space and energy, and the need to keep subject sampling as controlled as possible, the limitations were unavoidable. Future research therefore could possibly look into these areas to include speech samples of these other groups not represented in this dissertation.

6.4.2 Corpus

The method of recording and experiment materials were described in detail in Chapter 4. The subjects were given materials to look at, and were asked to say the utterances as indicated in the experiment material. Even though the pictures and question-answer style of recording was meant to emulate natural, spontaneous speech, they were nonetheless still controlled to a very large extent. The unclear nature of the area of research required carefully designed and controlled experiments that would allow for comparability. This need for control therefore did not allow for spontaneous speech to be analysed. Thus, it is certainly to be expected that results might differ should spontaneous speech be recorded and analysed. Future research ought to look into more natural modes of speech.

The need for high quality recording for instrumental analysis required the recordings to be done in the laboratory. The strict atmosphere in the laboratory setting could affect the speech patterns of the subjects, resulting in a more unnatural and perhaps more formal mode of speaking. Future research could certainly move away from the laboratory to collect more naturally occurring speech samples.

The experiment for the investigation of the acoustic correlates of stress concentrated primarily on monosyllabic words. The sample of polysyllabic words is small, and the results therefore cannot provide a full picture of lexical stress placement patterns in SE. Future research could concentrate and expand on the sample size of polysyllabic words for a more comprehensive study.

6.4.3 Test Materials for Perception Test

6.4.3.1 Permutations

As described in Chapter 3, the synthesised utterances were manipulated, four step manipulations for each parameter. Due to the constraint of time and the need to keep the length of the perception test manageable, more step manipulations could not be done. Further research could certainly look into increasing the number of step manipulations.

For the second part of the test, which looked at the relative strengths of the parameters, both syllables were synthesised, one parameter in each syllable. As mentioned in Chapter 3, the permutations were done systematically, with each step manipulation of each parameter paired with the same for another parameter, for example, *D1* (length manipulated to 0.1 sec) in the first vowel and *F1* (F_0 manipulated to 100 Hz) in the second vowel. Due to the constraint of time and energy, as well as the need to keep the listening test short for the subjects, not all possible permutations of the variations for each parameter was done. Different permutations of the parameters, for example *F1* (F_0 manipulated to 100 Hz) with *D4* (vowel length manipulated to 0.3 sec) or *I2* (amplitude manipulated to 65 db) with *D1* (vowel length manipulated to 0.1 sec) may lead to different results. The interactions between the different step manipulations in each permutation could lead to interesting or different findings. The large number of permutations however makes it an impossible task for this research. It is hoped that this research has therefore provided a starting point for future research in this area.

In addition, the size of the manipulations could not be made to correlate with each other. It would be an ideal situation if one could determine how much a change in one parameter, e.g. intensity, is equivalent to a change in another parameter, e.g. pitch or duration. In this research, the step manipulations were done in a systematic fashion – 5 dB for intensity, 10 Hz for pitch and 0.05 sec for vowel length. It is not clear if 5 dB in intensity is actually equivalent to 10 Hz in pitch or 0.05 sec in vowel length. It is hoped that future research could establish this important correlation between the correlates, and thus provide a more complete picture for the perception of stress in SE.

6.4.3.2 Declination

Also missing from the test materials for the investigation of perceptual cues of stress was the effect of declination. Declination refers to the downward slope of F_0 as the utterance progresses. Figure 6.1 shows the effect of declination across an utterance.

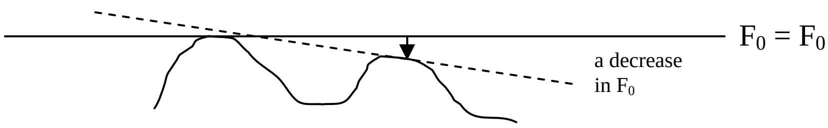


Fig. 6.1: The effect of declination across an utterance.

To factor in the effect of declination was to have both the target words in the basic form. In other words, no manipulation was to be done for each target word. In the test sentence, for example,

I	*saw*	*saw*	*blade*
↓	↓	↓	↓
F_0 = 98 Hz	F_0 = 120 Hz	F_0 = 120 Hz	F_0 = 98 Hz
Amplitude = 60 dB	Amplitude = 70 dB	Amplitude = 70 dB	Amplitude = 60 dB
Duration = 0.08 sec	Duration = 0.2 sec	Duration = 0.2 sec	Duration = 0.08 sec

though both the target words have exactly the same acoustic properties, the effect of declination would have the first *saw* more prominent, because presumably, the second *saw*, due to one's natural anticipation of declination, would not have a higher F_0. To have both the two target words in the basic form would give answers to the possibility of declination affecting the judgements of the subjects.

6.4.3.3 Pitch Movements

The F_0 modifications in the synthesised speech samples involve changes in level pitch. In other words, the F_0 of the vowel is modified on a constant level – e.g. 120 Hz for the entire duration of the vowel. Pitch movements within the vowel, or even between adjacent syllables might show a different finding on how the listeners perceive stress. Though it seems that majority of the Chinese speakers in Singapore do not tend to use pitch as an indication of stress, compared to intensity and duration, this could be due to the fact that the pitch level in the test materials is static, and that pitch movements within the test words could possibly produce different results. Future research expanding into the manipulation of pitch with pitch movements could shed light on the role of pitch as a perceptual cue for stress.

6.4.3.4 Sentence-types

In both the investigation of the acoustic correlates of stress and the perceptual cues of prominence, the experiments consist only of declarative sentences. Interrogative utterances, for example WH-questions and Yes-No questions could present different results in terms of both perceptual cues and perhaps more so, for the acoustic correlates of stress in SE. This area is certainly worthy of further research, such that the findings would not be merely restricted to declaratives, and thus provide a more comprehensive picture.

6.5 Future Research

6.5.1 Substrate Influence

It has been established that there are differences in the nature of stress in the three ethnic varieties of SE. The next obvious question to ask is: why these differences? Future research could certainly look to answering this question. One could intuitively guess that the differences observed between these three ethnic varieties are caused by the different Mother Tongues that they speak. However, more should be done to establish the exact cause of these differences, and determine the extent to which these differences in the perceptual and acoustic nature of stress in the ethnic varieties of SE are results of transference from the respective Mother Tongues. One could establish the perceptual and acoustic correlates of stress in Mandarin, Malay and Tamil, and to see if they are the same as that found in the Chinese, Malay and Indian varieties of SE.

Looking into the acoustic and perceptual nature of stress in substrate languages like Hokkien, Teochew, Cantonese, Hindi, Punjabi and many others could also afford a clearer and more comprehensive picture of how stress is, and how features in these languages are transferred to influence the nature of stress in Singapore English. This would also provide an insight into how the Substrate Theory could apply to the prosodic systems of languages.

6.5.2 Inter-ethnic and Intra-ethnic Stress Perception

As described in Chapter 3, the perception test was based on utterances ‘spoken’ by a speech synthesis programme, which provided the speech patterns of a British male who spoke Standard Southern British English. This provided a picture of how each group of subjects judge the stress perception of this same 'neutral' speaker.

Future research could look into how each group perceive stress both inter- and intra-ethnically. In other words, the experiments would have test materials composed by utterances spoken by Chinese, Malay and Indian subjects. These utterances in turn would be played to the three groups of subjects to determine how stress is perceived when one listens to utterances produced by someone of the same ethnic group compared to utterances produced by someone from another ethnic group. The results of such an experiment will definitely shed light on the inter- and intra-ethnic intelligibility issues. It would also show the perception of stress and the interference of other factors such as accent and inter- and intra-group understanding and comprehension.

6.6 Concluding Remarks

It is beyond the scope of this research to address the limitations and answer the many more questions about the nature of stress in the ethnic varieties of SE. This present study has however taken the first steps toward addressing the fundamental basic questions about the properties of stress in SE, and perhaps it is no longer difficult to identify stress in SE. It is hoped that the groundwork for SE stress studies has been laid, so that future researchers of SE stress no longer need to look to a foreign variety to base their study on. Hopefully, this dissertation has, in small ways, made the building of a full-fledged theoretical model of the prosodic nature of SE and its varied and distinct subvarieties a real possibility.

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APPENDIX I

The first page of the response sheet used for perception test, as described in Chapter 3.

You are going to hear 80 sentences in this test. Each sentence will be played TWICE. Pay particular attention to the words in *Italics*.

Please **tick** in the box under the more **prominent** word. If you cannot decide which word is more prominent, please leave both boxes blank.

This is an experiment on your responses to these test stimuli. There is no right or wrong answer.

---

1) He'll *sue Sue* later. ☐ ☐

2) I *saw saw* blades. ☐ ☐

3) I *see sea* creatures. ☐ ☐

4) I *saw saw* blades. ☐ ☐

5) He'll *sue Sue* later. ☐ ☐

6) I *see sea* creatures. ☐ ☐

7) I *saw saw* blades. ☐ ☐

8) He'll *sue Sue* later. ☐ ☐

9) I *see sea* creatures. ☐ ☐

10) I *saw saw* blades. ☐ ☐

11) He'll *sue Sue* later. ☐ ☐

12) I *see sea* creatures. ☐ ☐

13) I *saw saw* blades. ☐ ☐

14) He'll *sue Sue* later. ☐ ☐

15) I *see sea* creatures. ☐ ☐

16) I *saw saw* blades. ☐ ☐

17) He'll *sue Sue* later. ☐ ☐

18) I *see sea* creatures. ☐ ☐

19) I *saw saw* blades. ☐ ☐

20) He'll *sue Sue* later. ☐ ☐

21) I *see sea* creatures. ☐ ☐

22) I *saw saw* blades. ☐ ☐

23) He'll *sue Sue* later. ☐ ☐

24) I *see sea* creatures. ☐ ☐

25) I *saw saw* blades. ☐ ☐

26) He'll *sue Sue* later. ☐ ☐

27) I *see sea* creatures. ☐ ☐

28) He'll *sue Sue* later. ☐ ☐

29) I *see sea* creatures. ☐ ☐

30) I *saw saw* blades. ☐ ☐

31) He'll *sue Sue* later. ☐ ☐

32) I *see sea* creatures. ☐ ☐

Questionnaire given to the subjects to obtain information about their linguistic profile before the perception test.

Questionnaire

Please answer the questions below:

1) Are you a Singaporean? **YES** / **NO**
2) What is your ethnic group? **CHINESE / MALAY/ INDIAN / OTHER**
3) Gender: **MALE / FEMALE**
4) Besides English, what other languages do you speak?

____

5) What language(s) do you speak at home? ____________________
6) If you speak languages other than English at home, what is the percentage of English usage at home, compared to the other language(s)? ______________
7) Have you ever lived outside Singapore for more than 5 years? **YES / NO**
8) If yes, where, and for how long? ______________________

APPENDIX II

List of sentences elicited and analysed in the acoustic experiment (in Chapter 4 and Chapter 5):

Monosyllabic (Sentence-final)	**Monosyllabic (non sentence-final)**
1. I want the bib. 2. I want the ring. 3. I want the mill. 4. I want the bin. 5. I want the rig. 6. I want the doll. 7. I want the log. 8. I want the dog. 9. I want the rod. 10. I want the knob.	11. The bib is cheap. 12. The ring is cheap. 13. The mill is cheap. 14. The bin is cheap. 15. The rig is cheap. 16. The doll is cheap. 17. The log is clean. 18. The dog is clean. 19. The rod is clean. 20. The knob is clean.
Poly-syllabic (2-syllable words)	**Poly-syllabic (3-syllable words)**
21. The dinner is cheap. 22. The mirror is cheap. 23. The lily is cheap. 24. The ribbon is cheap. 25. The riddle is difficult. 26. The linen is cheap. 27. The dolly is cheap. 28. Her body is strong. 29. The lorry is cheap. 30. The robin is clean. 31. The goggle is cheap. 32. The model is rich.	33. The mineral is cheap. 34. The minister is rich. 35. The millipede is clean 36. The beginning is difficult. 37. The manila is cheap. 38. The gorilla is clean.