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THE ONSET OF LANGUAGE-SPECIFIC PATTERNING
IN INFANT VOCALIZATION

by

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B.Sc., University of Waterloo, 1975

A Thesis

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ABSTRACT

This study presents an acoustic investigation of non-cry vocalizations produced by Cantonese and English infants between the ages of six and eleven months after birth. The purpose is to determine whether there is a significant difference in the intonation contours of the infants that could be attributed to dissimilarities in the suprasegmental patterns of adult speech in these two languages. The infant vocalizations are compared with respect to certain acoustic parameters.

The results show no evidence of language-specific patterning in the intonation contours of the Cantonese and English infants. The findings do however illustrate certain developmental trends in the infant utterances. In addition this study provides some information about the number of utterances required for a representative sample of infant vocalizations. A need is suggested for further research on the acoustic parameters that characterize adult and infant utterances in different languages.

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CHAPTER I

Introduction

1.1 Introduction

"In listening to the recordings of young children there seems to be little difficulty in segmenting utterances into sentencelike chunks, regardless of the intelligibility of the utterance to an adult listener. On the basis of this evidence I have hypothesized that pitch or intonation patterns may be the signals perceived and that these are learned early, perhaps independently of the segmental phonemes."

(Weir 1966:153)

Many people have speculated about the relationship between an infant's early utterances and the acquisition of his native tongue. Most have assumed that during the first year after birth infant vocalizations⁽¹⁾ are not differentiated with respect to any particular language. Lieberman et al. (1972) claimed that the speech articulations of early infancy are highly constrained by the shape of the neonate's supralaryngeal vocal tract. Thus the infant is not capable of producing the articulatory gestures of adult speech in the immediate post-natal period. Jakobson (1968) claimed that by the time the infant reaches the babbling stage (six to twelve months after birth) he is capable of producing all the phonemic segments of adult speech. Yet even at this time language acquisition is apparently unaffected by the particular language that the child is exposed to. As Jakobson (1968:48) said,

"Whether it is a question of French or Scandinavian children of English or Slavic, of Indian or German, or of Estonian, Dutch or Japanese chil-

dren, every description based on careful observation repeatedly confirms the striking fact that the relative chronological order of phonological acquisitions remains everywhere and at all times the same."

This claim suggests that the child's production of segmental phonemes is governed by a universal order of acquisition. According to this hypothesis the infant's early speech productions are not influenced by the language he is exposed to. Thus the child's utterances cannot be identified with any particular language during the first year after birth.

This hypothesis was supported by the results of a study conducted by Preston and Port (1968). They investigated an American infant's production of apical stop consonants (/t/ and /d/) and determined for each consonant a value for voice-onset-time (VOT).⁽²⁾ Preston and Port found that at ten months of age the predominant mode of production for apical stops centered on a value of VOT that is characteristic of the English phoneme /d/. They found that the two modes of VOT that characterize the /t/ vs. /d/ distinction in English, were not clearly evident in the child's production of apical stops until twenty-two months after birth. Thus the infant's acquisition of the phonetic distinction that differentiates these adult phonemes occurred well after the first birthday.

This evidence supports the notion that infant speech production during the first year after birth is not influenced by the particular language that the child is exposed

to. Consequently the claim is made that infant vocalizations during the first year are not language-specific⁽³⁾ with respect to the segmental phonemes of speech.

There is evidence that this claim is not correct with respect to the suprasegmental features of speech. Ruth Weir (1966) was the first to claim that the vocalizations of infants from different linguistic communities could be identified by their language-specific intonation patterns. She reported a study in which she recorded the utterances of Cantonese, Russian and English infants between the ages of five and seven months. Weir claimed that the Cantonese infants could be identified by distinctive pitch patterns. As she said,

"One Chinese infant, recorded first at five-and-one-half and then at six-and-one-half months, shows in the second recording a very different pattern from the Russian and American infants. The utterances produced by the Chinese baby are usually monosyllabic and only vocalic, with much tonal variation over individual vowels... The Russian and American babies, at six and seven months, show little pitch variation over individual syllables..."

(Weir 1966:156)

Thus Weir claimed that the vocalizations of Cantonese infants could be distinguished from those of other languages by distinctive intonation patterns. This led her to ask when these distinctive intonation patterns are acquired..

In answer to this question David Crystal (1973:16) discussed what he called the "onset of language-specific patterning" in infant vocalization. He said that the most likely period for the emergence of such features in production is six to seven months after birth. He claimed that one could test this hypothesis by analyzing the vocalizations of infants from different linguistic communities using a sound spectrograph. Crystal suggested that after seven months of age the spectrograms of Welsh and English children would begin to show regular and quantifiable differences. Furthermore he claimed that these differences could be correlated with adult auditory judgements about the native language of each infant.

Crystal's hypothesis was supported by the claims of Hirsh (1966) and Mehler (1971). Hirsh referred to a study by Tervoort, a Dutch phonetician, who reported that Dutch college students could distinguish the babbling of Dutch from non-Dutch infants at six months of age. No information was provided about the languages of the non-Dutch infants, except that none was a tone language. Mehler (1971:163) referred to a study in which he recorded children of English families living in Argentina and those of families living in the United States. He claimed that as early as six months there were "clear differences in intonation" between children being raised in an English culture and those in a foreign culture. These reports gave credence to Crystal's hypo-

thesis that the onset of language-specific patterning can be detected by adult auditory judgements of infant vocalizations between six and seven months after birth.

The research of Nakazima (1966) presented a different claim about the age at which language-specific patterning is first evident. This study involved the spectrographic⁽⁴⁾ analysis of the vocalizations of six Japanese and four American infants from birth to fourteen months of age. Nakazima claimed to observe differences in intonation between the Japanese and American infants starting at twelve months. However he did not elaborate about the nature of these differences and did not present spectrographic evidence to confirm them. Nevertheless he did claim that it was the influence of the adult language systems that caused the differences in the intonation patterns of the infants at twelve months of age.

A study by Olney and Scholnick (1976) presented evidence to suggest that language-specific patterning is not present in infant speech production even as late as eighteen months after birth. These researchers recorded the vocalizations of a Cantonese and an American infant at six, twelve and eighteen months of age. They presented samples of these recordings to college students and asked them to judge whether they were produced by a Cantonese or an American child. The results showed that the students were not able to judge the linguistic commu-

nity of the vocalizer at any of the three age groups. These findings suggested that language-specific patterning is not evident in infant vocalizations even as late as eighteen months after birth.

It is clear from this cursory review of the literature that there is some controversy concerning the infant's acquisition of the intonation features that are characteristic of the language he is learning. There are some claims that by seven months of age the child has acquired some of the intonation patterns that are unique to his native language. Others state that such language-specific patterning is not evident until twelve months after birth. There are still others who claim that the vocalizations of infants from different language communities are not discriminable even at eighteen months of age.

In view of this controversy it seems appropriate to investigate the intonation patterns of infants from different linguistic environments. This thesis presents such an investigation. More specifically, it is a comparison of the vocalizations of infants from two different language communities -- Cantonese and English. In particular it will deal with two acoustic parameters that play an important role in defining intonation patterns -- the fundamental frequency (FF) of laryngeal pulsation and the duration of an utterance. In this study an attempt will

be made to elucidate the differences, if any, between
the intonation patterns of Cantonese and English infants.

1.2. Review of the Literature

This section presents a brief review of the research that has been conducted to investigate the process of language acquisition in infants. The first topic to be discussed is the infant's ability to perceive linguistic stimuli. Evidence will be presented concerning the child's auditory capacity and his perception of the segmental and suprasegmental features of adult speech. The second topic deals with the infant's ability to produce vocal utterances. Particular emphasis will be given to the development of the infant larynx and its ability to control the fundamental frequency of phonation. The next two topics will be a discussion of research about the acoustic parameters that characterize infant cries and non-cry vocalizations. The final topic of this section will deal with the infant's linguistic environment. An attempt will be made to identify the differences that may exist between the speech used by English and Cantonese parents in addressing their infants. In conclusion, the research discussed in the literature review will be related to the specific problem of determining the onset of language-specific patterning in infant vocalization.

1.2.1 The Infant's Receptive Capacity

Any study of language acquisition in infants must take account of their ability to hear and perceive linguistic stimuli.

1.2.1.1 Auditory Ability

The infant's auditory mechanism, like the adult's, is composed of three basic parts (the outer, middle and inner ear). The outer ear serves to collect sound pressure waves and concentrate them on the tympanic membrane. This membrane converts atmospheric pressure waves into mechanical vibrations which are transmitted via the small bones of the middle ear to the inner ear. At this point the mechanical vibrations are converted into hydraulic pulsations in the fluid-filled cochlea. Fluid waves in the cochlea impinge upon hair cells which are in contact with endings of the auditory nerve. Sound impulses are transmitted to the cerebral cortex via this auditory mechanism.

Eisenberg (1976) reviewed the anatomical and physiological studies that document the pre-natal development of the human auditory system. She claimed that the full-term infant is born with "... at least some of the mechanisms he will need to organize his auditory world" (1976: 11). This claim was based on studies of the hearing mechanism in the human fetus. Eisenberg cited reports that demonstrated cochlear function as early as the fifth fetal month. She also presented evidence that the auditory nerve cells begin to myelinate during the sixth fetal month, and that in the full-term baby even the auditory cortex of the brain is medulated. Furthermore, she said that the fetus has been shown to be responsive to pure tones and other sounds. Based on this evidence Eisenberg claimed that

the normal infant is born with a well developed auditory mechanism.

The ability of this auditory mechanism to perceive linguistic stimuli has been the subject of considerable investigation.

1.2.1.2 Perception of Phonetic Segments

Much research has been done in recent years on the infant's ability to discriminate the phonetic contrasts that are present in adult speech. Jusczyk (1979:60) has claimed that "... infants are able to perceive a wide variety of phonetic contrasts long before they actually produce these contrasts in their own babbling." One of the studies that supports this claim is that of Eimas et al. (1971).

These researchers investigated infant discrimination of voice-onset-time (VOT) in synthetic tokens of initial stop consonants. Eimas et al. examined the discrimination of VOT differences by one-month-old and four-month-old infants. They presented the infants with pairs of synthesized auditory stimuli. For each pair, the two stimuli differed from each other by 20 msec of VOT. The members of one pair of stimuli were chosen from different VOT categories (i.e., +20 msec /ba/ vs. +40 msec /pa/). The other pairs consisted of stimuli chosen from the same VOT category (i.e., -20 msec /ba/ vs. 0 msec /ba/ or +60 msec /pa/ vs. +80 msec /pa/). Eimas et al. used a high-amplitude sucking technique to test the infants'

discrimination of the stimulus pairs. Discrimination was inferred from an increase in sucking rate upon presentation of the second stimulus in each pair. The results showed that both one-month-old and four-month-old infants discriminated the between-categories pair (/ba/ vs. /pa/) but that neither age group discriminated the within-categories stimuli (/ba/ vs. /ba/ or /pa/ vs. /pa/). On the basis of these results, Eimas et al. claimed that the infants could discriminate different values of VOT in a manner approximating the categorical perception of initial stop consonants by adults.

Many studies have been carried out to test the infant's ability to discriminate other phonetic contrasts. In summarizing this research, Jusczyk (1979) claimed that infants as young as two months can discriminate phonetic contrasts in stop consonants, fricatives, liquids and vowels. Consequently he claimed that "...the infant's discriminative capacities for speech are very well developed by the time language learning is thought to begin." (Jusczyk 1979:61). This claim suggests that the infant's ability to perceive the phonetic segments of adult speech is acquired at a remarkably young age.

1.2.1.3 Perception of Suprasegmental Features

Similar claims have been made about the infant's ability to perceive different intonation contours. Lewis (1936:43) stated that "...the child's discrimination of intonation in the speech that he hears is an essential

feature of his acquirement of language." He said that the infant perceives three characteristics of intonation in adult speech: 1) its acoustic quality (whether it is harsh or melodious); 2) its expressive quality (features determined by the speaker's affective state); and 3) the features given to it by convention.⁽⁵⁾ Lewis claimed that these characteristics of adult intonation are perceived by the infant even before the child can discern the phonetic form of an utterance. *

A number of studies have investigated the infant's perception of suprasegmental features. Among the first of these studies was that of Eleanor Kaplan (1970) who conducted an experiment to test infant perception of different intonation contours. The test stimuli consisted of two utterances of the sentence "See the cat." One utterance had a falling terminal pitch contour; the other had a rising contour. Both stimuli had normal stress patterns. The sentences were produced by a "well-practiced female voice." They were presented to groups of four- and eight-month-old infants for discrimination within an habituation-dishabituation paradigm. Discrimination of the auditory stimuli was inferred from dishabituation, which was determined by monitoring the infant's cardiac activity and orienting behaviors. Kaplan found that the eight-month-old infants were capable of discriminating the falling and rising pitch contours. The four-month-old infants, however, did not show evidence of this ability.

Kaplan concluded that by eight months of age infants can discriminate between the falling and rising intonation contours that characterize statements and questions in normal American-English speech.

Similar research was conducted by Morse (1972). He tested the ability of two-month-old infants to discriminate intonation contrasts in monosyllabic words. The test stimuli were synthetic tokens of the word /ba/. One token had a rising terminal FF; the other had a falling terminal FF. Discrimination of the test stimuli was determined by means of the non-nutritive conjugate sucking procedure. Changes in the rate of high amplitude sucking revealed that the two-month-old infants did distinguish between the two stimuli. Morse claimed that this was evidence of the infants' ability to discriminate the acoustic cues for intonation.

Spring and Dale (1977) used a similar method to investigate the discrimination of different stress patterns by infants. They presented one- to four-month-old infants with two artificially synthesized disyllables (/baba/ and /baba/) which differed solely in the location of perceived stress. This perceived stress was a manifestation of differences in FF, intensity and duration between the two syllables of each disyllable. Spring and Dale used the high-amplitude sucking procedure to test discrimination of the two stimuli by sixty subjects. They claimed that their results illustrated the infants' ability to discrim-

minate the acoustic correlates of stress location.

This study, along with those of Kaplan and Morse, illustrated the infant's ability to perceive different intonation contours and stress patterns in adult speech. This ability, in conjunction with the capacity to perceive phonetic segments, is a prerequisite for language acquisition. The aforementioned studies indicated that this linguistic prerequisite may be acquired by the infant during the first few months after birth.

1.2.2 The Infant's Productive Capacity

Since the present study is an investigation of the intonation contours of infant vocalizations, it is important to examine the primary source of sound excitation in the vocal tract. This section will present a brief description of the infant larynx and its role in producing fluctuations in fundamental frequency over the course of an utterance.

1.2.2.1 Productive Capacity of the Infant Larynx

The infant larynx is a relatively soft and pliable organ composed of cartilage, ligament and muscle which rests at the top of the trachea. The vocal folds, situated within the larynx, are the source of phonation.

At birth the vocal folds are relatively small. Yet their rate of growth during infancy is quite rapid. The length of the folds in relation to the antero-posterior diameter of the larynx as a whole is 1 to 2.3 at birth.

This proportion decreases rapidly to 1 to 1.5 at nine months of age. It remains constant thereafter in the female, but lowers still further to 1 to 1.3 in the male at puberty (Préssman and Kelemen 1955:509). The actual length of the vocal folds increases from 3 mm at birth to 5 mm at two months, 5.2 mm at nine months, and 5.5 mm at one year of age (Kaplan 1971:246).⁽⁶⁾ These figures indicate that the growth rate of the folds is quite rapid during the first few months after birth. By the end of the first year, however, this rate of growth has slowed considerably.⁽⁷⁾

The length of the vocal folds is important in determining the fundamental frequency of phonation. Yet it is not the only factor. The frequency of laryngeal vibration is also determined by the thickness and tension of the folds, as well as by the subglottal air pressure.

Lieberman (1967:43) claimed that, in the vocalizations of newborn infants, fluctuations in fundamental frequency (FF) are determined primarily by variations in subglottal air pressure. In a study of the cries of thirty neonates he found that the shape of the FF contours was similar to that of the esophageal pressure (an indicator of subglottal air pressure). He said that during infant cries the fundamental frequency rises initially as the subglottal air pressure builds up. Then the FF remains level or slowly falls until the end of expiration, when it abruptly falls.

Lieberman claimed that the correlation between fundamental frequency and subglottal air pressure accounts for the typical rise-fall FF contour that characterizes infant cries.

These findings suggest that the neonate does not vary the tension of the vocal folds during phonation. Instead the newborn merely maintains the tension of the laryngeal muscles at or near the tension they had at the start of phonation. As a result, fluctuations in FF are controlled by changes in subglottal air pressure.

At some point during the first few months after birth the infant begins to actively manipulate the laryngeal muscles to change the tension of the vocal folds during phonation. This is evidenced by the appearance of vocalizations with a rising terminal FF. In these utterances the subglottal air pressure decreases at the end of expiration while the FF increases. In order to produce such an utterance the infant must increase the tension on the vocal folds while the subglottal air pressure is falling. This increased tension on the folds is caused by the action of various laryngeal muscles (Hardcastle 1976:85).

The age at which the infant gains control over the action of these laryngeal muscles is uncertain. In a study of the vocalizations of thirty Russian infants, Tonkova-Yampolskaya (1969:132) found that utterances marked by final rising FF contours did not appear until the seventh month after birth. Fowlow (1975:163), in a study of eighteen

English infants, reported the occurrence of vocalizations with final rising FF contours as early as ten weeks after birth. This evidence suggests that the infant begins to control the activity of the laryngeal muscles sometime before the end of the third month. This laryngeal control allows the child to vary the FF of phonation independently of the subglottal air pressure. The fact that this ability is mastered soon after birth is an indication of the early onset of cortical control over the speech organs. This cortical control of laryngeal activity is a prerequisite for language acquisition.

1.2.3 The Infant Cry

The neonatal cry is the first utterance produced by the newborn infant. For the first few months after birth the cry continues to dominate the infant's vocal repertoire. Much work has been done on the communicative efficacy of the infant cry. In recent years the cry has also been studied with respect to the clues it may provide about the presence of certain cerebral and auditory dysfunctions in the infant.

1.2.3.1 Studies of Infant Cries

One of the first recorded observations of infant vocalizations was made by Gardiner (1837:193) who claimed that "... children have no difficulty in expressing their wants, their pleasures, and pains by their cries long before they can speak or understand the meaning of a word." He described the calls and cries of both humans and animals

by means of musical notes. According to Gardiner the tones of infant crying generally lie between the notes A and E in the middle of the piano keyboard.

One of the first acoustical studies of infant cry was reported by Fairbanks (1942) who conducted an investigation of the pitch of hunger wails produced by his infant son between the ages of one and nine months. The fundamental frequency of the cries was measured by an instrument that extracted FF from phonograph recordings. The average FF of hunger cries was reported by Fairbanks to be at a relatively low value of 373 Hz at one month of age. It rose to a high of 814 Hz by five months and had dropped to 640 Hz at nine months of age. This study was among the first to analyze infant vocalizations using acoustic instruments.

Lynip (1951) was the first to study infant cries using a magnetic tape recorder and a sound spectrograph. He recorded and made spectrograms of the vocalizations of an infant during its first year after birth. This investigation illustrated the rich amount of information that could be obtained by a spectrographic analysis of infant cries. The spectrograph has been used in many studies since Lynip's pioneering work.

Ringel and Kluppel (1964) used a spectrograph and a sound level recorder to obtain normative data for the following parameters of neonatal cry: fundamental fre-

quency, harmonic spectrum, sound pressure level and duration. They analyzed the cries of ten infants ranging in age between four and forty hours after birth. Their results showed that different cries produced by the same neonate did not differ significantly from each other with respect to FF, sound pressure level or duration. However when comparisons were made between different neonates for FF and sound pressure level, significant differences did exist.

In an effort to investigate different types of neonatal cries, Wolff (1969) made a spectrographic analysis of the vocalizations of eighteen infants during the first month after birth. He identified four basic cries (hunger, anger, pain and frustration), each of which had a unique spectrographic shape. Wolff concluded that neonatal crying patterns were not random expressions of distress. Furthermore, he claimed that in selected instances one could, by direct observation and spectrographic analysis, infer the provoking cause of an infant cry from its spectral shape (Wolff 1969:109).

A similar study of infant cries conducted by Murry et al. (1977) produced somewhat different results. Murry et al. used a visicorder to determine the average FF of the cries of eight infants (four boys and four girls) between the ages of three and six months. The cries were evoked by three different stimuli: the snapping of a

rubber band against the foot (pain); the sudden presentation of a loud noise (startle); and the withholding of food at feeding time (hunger). The results of this study showed no significant differences in mean cry FF as a function of the infant's sex or the cry-evoking stimulus.

These results would seem to contradict Wolff's claim that the provoking cause of infant cries can be determined by their spectrographic morphology. No contradiction exists however, because Murry et al. examined only one of the many acoustic parameters used by Wolff to describe infant cries. Wolff's analysis included measures of duration within and between cries, as well as dynamic fluctuations of FF. The apparent discrepancy between the two studies may be accounted for by the different analyzing techniques used. Wolff's spectrographic analysis yielded rich information about several acoustic parameters. The visicorder used by Murry et al. produced information about only one of the acoustic variables that characterize infant cries.

The pioneering work of Wolff in identifying different types of infant cry by spectrographic analysis led to a number of studies which claimed that infants with certain pathological conditions could be identified by a spectral analysis of their cries.

Wasz-Hockert et al. (1968) were among the first to demonstrate that a spectrographic analysis of pain cries could be used as a diagnostic tool in paediatrics. They

analyzed 419 cry signals from 351 infants, and used a spectrograph to measure fundamental frequency. Using this method they claimed to be able to distinguish the cries of children with cri du chat syndrome from those of normal babies.

This method of paediatric diagnosis was further refined by Vuorenkoski et al. (1971). They constructed a new rating system called a "cry score" in order to assess the normality or degree of abnormality in the pain cry of an infant. The cry score was determined by thirteen different acoustic parameters of the pain cry. Vuorenkoski et al. compared the pain cries of normal neonates to those of infants with diseases affecting the central nervous system (intracranial hemorrhage, meningitis, hydrocephalus), infants with respiratory ailments (neonatal asphyxia, respiration distress syndrome), and infants with chromosomal aberrations (13-15 and 17-18 trisomies, maladie du cri du chat). The cry score was a correct indicator of normal or abnormal neonatal development in ninety percent of the 210 infants whose pain cries were analyzed (Vuorenkoski et al. 1971:74).

The spectrographic analysis of infant cries has also been used to diagnose children with hearing impairment. Jones (1971) studied cry samples from children under the age of four years. The subjects consisted of forty chil-

dren with severe to profound hearing loss and twenty-four normal-hearing children. The cries were analyzed for fundamental frequency, relative intensity and duration. Jones found that the youngsters with significant hearing impairment cried at higher fundamental frequencies than normal-hearing children. These results led her to propose that "... the procedure of analyzing a brief tape-recorded cry sample ... may provide information to aid in differential diagnosis of significant hearing loss during the first year of life" (Jones 1971:315).

This claim was corroborated by the work of Manolson (1972). She studied the intonation patterns of demand cries produced by infants between the first and second year after birth. The subjects consisted of ten infants with a clinical diagnosis of mild to severe hearing loss, as well as ten normal-hearing babies. The cries were analyzed with respect to the contours of fundamental frequency and intensity. The results indicated that for a demand cry the hearing-impaired infants had significantly more and significantly larger FF changes than did normal-hearing children. Furthermore, the hearing-impaired subjects had significantly more intensity variations than normal infants. These results concurred with those of Jones in suggesting that the cries of infants may be a source of information about the integrity of their auditory system.

Thus it can be seen that the acoustic analysis of infant cries yields information about the physical and mental state of the child. In many cases one can determine the underlying cause of an infant cry by examining its spectrographic shape.

1.2.4 Studies of Non-Cry Vocalizations

At some point during the first few months after birth the infant begins to produce non-cry vocalizations. These utterances gradually come to dominate the infant's vocal repertoire. They are the precursors of adult speech. Many investigations have studied these pre-linguistic vocalizations.

1.2.4.1 Phonemic Studies

Many of the early studies of infant vocalization were concerned with describing vocal output in terms of the phonemic system of adult speakers. The aim of these studies was to investigate the infant's acquisition of the articulatory gestures that are characteristic of adult speech.

An example of this research was reported by Irwin and Chen (1946). They studied the vocal output of ninety-five infants between the first and thirtieth month after birth. The infants' speech sounds were recorded by transcription using the International Phonetic Alphabet. The results showed that the phonemic inventory at two months of age was comprised of seven different adult speech sounds. By thirty months after birth the infants could

produce twenty-seven of the thirty-five phonemes present in adult speech.

Much criticism has been levelled at this method of describing infant vocalizations. Truby (1970) claimed that conventional phonetic transcription is inappropriate for describing infant speech sounds. He presented evidence from direct observation, X-ray motion-picture photography and sound-spectrographic records to show that the infant uses a variety of articulatory and sound generation mechanisms to accomplish what seem to be phonetically similar vocal productions. Truby claimed that "... the representation of these performances using conventional phonetic transcription (the basis of which is, as stated, in adult physiology and anatomy) is demonstrably inappropriate to the task of pre-speech sound evaluation." (1970: 945)

Truby's claim was supported by the findings of Lieberman et al. (1971). These researchers made a spectrographic analysis of the vocalizations of twenty normal neonates during the first four days after birth. The results showed that the infants did not produce the range of sounds typical of adult speech. Lieberman et al. (1972) attributed this phonetic inability to limitations imposed by the neonate's vocal apparatus. They claimed that the supralaryngeal vocal tract of the newborn infant lacks the well-formed pharyngeal cavity that is present in adults. Furthermore, they said that this pharyngeal cavity is

necessary for the production of the vowels /a/, /i/ and /u/. Consequently Lieberman et al., concluded that the neonate "... appears to be inherently incapable of producing the full range of human speech." (1971:718).

This fact would support Truby's claim that phonetic transcription, based on adult physiology and anatomy, is inadequate for describing infant vocalizations.

1.2.4.2 Intonation Studies

Many researchers have recognized the inherent weaknesses of phonetic transcription for describing infant vocalizations. They have sought instead to analyze the utterances of infants in terms of suprasegmental features.

Charles Darwin was among the first to claim that intonation is an important component of the communicative repertoire of infants. In a diary describing the language acquisition of one of his own children he wrote the following (1877:293):

"Finally, the wants of an infant are first made intelligible by instinctive cries, which after a time are modified in part unconsciously, and in part, as I believe, voluntarily as a means of communication -- by the unconscious expression of the features, -- by gestures and in a marked manner by different intonations..."

Darwin's observations about the development of communicative ability in infants were supported by the claims of Lewis (1936:151). Lewis said that as early as the first month after birth a child will use different intonation patterns to express different affective states.

He claimed that adults can determine whether an infant is happy or unhappy based on the intonation contour of his utterances. Lewis said that in early infancy intonation patterns are "the chief vocal means by which the child makes us aware of his different moods." (1936:151)

2 This notion of the primacy of intonation features in the vocalizations of infants has been confirmed by the research of Tonkova-Yampol'skaya (1969). She studied the development of intonation in the vocalizations of over three hundred Russian infants under the age of two years. The utterances were analyzed on an electro-acoustical device called an intonograph which extracted fundamental frequency and intensity over the course of each vocalization. In addition to this analysis the emotional state of the infant was noted for each utterance. Tonkova-Yampol'skaya compared the intonation contours of the infants to the structural patterns of intonation in adults.

The results of this study showed that the infants acquired different intonation patterns in a gradual manner during the first year after birth. Furthermore these infant intonation forms approximated the intonation contours of adult speech. The results of the study by Tonkova-Yampol'skaya are summarized in Table 1-1.

Table 1-1

ACQUISITION OF INFANT INTONATION PATTERNS

<u>Infant Intonation</u>	<u>Age of Acquisition</u>	<u>Comparable Adult Intonation</u>
Discontent	Birth	Discontent
Indifference	2 months	Assertion, Enumeration, Comparison
Placid Sound	2 months	
Happiness	3 months	
Laughter	3 months	
Exclamatory Delight	6 months	
Expressive, Calm Cooing	7 months	Affirmation
Request	7 months	Emotional Request
Insistence	10 months	Persuasion, Insistent Command
Question	12 months	Question

(Based on Tonkova-Yampol'skaya, 1969)

As seen in the table the first intonation pattern acquired by infants was one of discontent. This was the typical crying intonation in which the fundamental frequency and intensity varied together over the course of the utterance. Tonkova-Yampol'skaya claimed that this intonation contour retained its meaning of discontent even in adult utterances.

During the first year after birth the infants acquired nine more intonation patterns. In most of these intonations, the fundamental frequency and intensity did not

vary together. This differentiation between these two parameters was seen by Tonkova-Yampol'skaya as evidence of cortical control over the speech organs. In addition, many of the infant intonation contours approximated those of adult speech. This observation was presented as evidence of verbal-auditory feedback in the infant's developing communicative system. On the basis of this evidence Tonkova-Yampol'skaya concluded that speech development in infants begins with the acquisition of intonation contours, and that these intonation contours are modelled on the suprasegmental patterns of adult speech.

Another prosodic analysis of infant vocalizations was reported by Delack (1974, 1976) and Fowlow (1975). The purpose of this study was to provide normative data on infant vocalizations with respect to specific acoustic parameters. An additional aim was to examine the nature of utterances produced in various environmental contexts. The researchers recorded the non-cry vocalizations of ten infants (four females and six males) at bi-weekly intervals from one to twelve months after birth. For each utterance they noted whether the infant was alone, in the company of an adult, or playing with a particular object. The project involved the spectrographic examination and statistical evaluation of the following acoustic parameters for each vocalization:

1. Duration: the time between the commencement and

cessation of phonation.

2. Average FF: the mean value of FF for several points in the utterance.
3. FF Range: the difference between the maximum and minimum values of FF for the utterance.
4. FF Contour: the shape of the FF curve.

The results of this study showed a developmental trend for each of these parameters.

Delack reported that the average FF for each infant remained relatively stable throughout the first year, centering on 355 Hz. Females characteristically exhibited a higher average FF than males. The average duration of vocalizations showed a fifty percent increase during the first year for both males and females. With respect to average FF range, there was an increase from 80 to 100 Hz during the first six months for both sexes. For females FF range continued to rise to 110 Hz while for males it dropped back to 80 Hz by the first birthday. Delack found that different FF contours had similar distributions for both sexes. The simple rise-fall contour was predominant. This contour increased from forty to fifty-five percent of all utterances during the first year. As for the correlation between variations in FF and different environmental contexts, Delack said most infants altered their intonation patterns according to context, although they often did so inconsistently. In

conclusion Delack used these results to suggest that infants use intonation "as a vehicle of expression in terms of 'semantic intent'..." (1974:17). Furthermore he claimed that this study and others refuted the view that language acquisition can only be discussed in terms of the child's segmental phonetic repertoire.

Delack's research provided normative data on the acoustic parameters that characterize the suprasegmental features of infant vocalizations. This investigation and that of Tonkova-Yampol'skaya have shed much light on the child's acquisition of adult intonation contours.

1.2.5 The Infant's Linguistic Environment

It is evident that the child's linguistic environment plays an important role in language acquisition. Indeed the term "mother tongue" is derived from the notion that children acquire the same language as that spoken by their parents. Therefore it is important, in a study of the onset of language-specific patterning, to examine the linguistic environment of the infant.

1.2.5.1 Baby Talk

Charles Ferguson (1975:1) defined the term "baby talk" as a register of adult speech characterized by phonological, grammatical and lexical features that are regarded as primarily appropriate for addressing young children. He claimed that baby talk is a register of adult speech that is present in all linguistic communities.

Among the features of baby talk, Ferguson listed several that are suprasegmental in nature. He said that when adults address young children their speech is characterized by an exaggeration of normal intonation contours. These contours have a greater range in pitch than those of normal adult speech. In addition he claimed that baby talk employs a higher average pitch than speech directed toward older children and adults. Thus the infant's linguistic environment would seem to be a caricature of normal adult speech.

Empirical evidence for Ferguson's claims were provided by Garnica (1975). She compared the speech of female speakers of English in two conversational situations. In one situation each speaker was conversing with another adult; in the other, each subject was speaking to her own two-year-old child. Garnica found that, compared to speech to adults, the speech directed toward the children was characterized by a higher average FF and a greater FF range. Since FF is the primary acoustic correlate of perceived pitch in adult speech (Gandour 1978:41), Garnica's results supported the claim that baby talk is characterized by an exaggeration of adult intonation contours and a higher average pitch. Thus the infant's linguistic environment is characterized by certain differences from normal adult speech.

1.2.5.2 Baby Talk in Cantonese and English

Since the present study is an investigation of language acquisition in Cantonese and English infants, it is appropriate to examine the features of baby talk in these two languages. As noted, Garnica (1975) has studied this phenomenon for English. Unfortunately no such study is available on baby talk in Cantonese. Thus one is left to speculate about the possible differences in the linguistic environments of English and Cantonese infants.

There is evidence to suggest, however, that differences do exist in the baby talk of these two languages. Furthermore, these differences seem to be based on language-specific intonation parameters.

One major difference between Cantonese and English is that the former is a tone language, while the latter is an intonation language. A tone language was defined by Gandour (1978:41) as one in which pitch is used to contrast individual lexical items or words. An intonation language was defined as one in which pitch is used to signal syntactic and semantic distinctions at the phrase or sentence level. According to Li and Thompson (1978:74), Cantonese has six contrastive tones. There are four level tones (high, mid, mid-low and low) as well as two contour tones (high rising and low rising). English, on the other hand, does not have this system of

lexical tones. Thus one might expect that the intonation patterns of these two languages would be different.

The exact nature of the difference in intonation between Cantonese and English is not known. The influence of lexical tone on sentence intonation is rarely mentioned in the literature. Lieberman (1967:102) cited a report that discussed this phenomenon in the Lungtu dialect of Cantonese. The report claimed that in this dialect sentence intonation is superimposed on the individual lexical tones, and determines the absolute pitch and general inflection of the utterance. At the same time, the tones determine the relative difference in pitch and inflection among the syllables. Furthermore, this report claimed that sentence intonation modifies the pitch of the lexical tones but not so that they are imperceptible. Consequently it would seem that the interaction between sentence intonation and lexical tone is such that they are both modified to some extent. Yet despite this modification, the communicative efficacy of each is preserved.

If this is the case, then it seems reasonable to assume that a sequence of lexical tones in a Cantonese sentence would be manifested by a series of fluctuations in the fundamental frequency of the utterance. For example, if a Cantonese sentence consisted of three words with high, low and high tones respectively, one

would expect a relatively high initial FF followed by an abrupt fall and rise in FF as the utterance was spoken. The number of FF fluctuations in a sentence would therefore depend on the type and number of tones. Since all lexical items possess tone, one would expect the intonation contour of a Cantonese sentence to be characterized by a number of rising and falling FF fluctuations.

This would not be the case in a non-tonal language such as English. Fluctuations in pitch are used in English to signal syntactic and semantic distinctions at the phrase or sentence level. Thus it is likely that the intonation contour of an English utterance would not display the numerous FF fluctuations that would be present in a Cantonese sentence.

This difference in the number of FF fluctuations over the course of an utterance is one criterion that could differentiate the intonation patterns of Cantonese and English sentences. Yet there may be some question as to whether this difference in intonation patterns is evident when adult speakers of these languages address young children. It is possible that baby talk in Cantonese is characterized by the same exaggeration of intonation contours that occurs in English. If this is the case, then there may be no significant dissimilarity between the linguistic environments of Cantonese and English infants. Thus there would be no reason to believe that

the vocalizations of infants from these two language communities are discriminable.

This hypothesis is refuted, however, by the fact that Cantonese children start to use lexical tones at a very young age. Li and Thompson (1978:274) cited a study by J. Tse on the acquisition of Cantonese tones by his infant son. Tse claimed that perceptual discrimination of lexical tones began at ten months of age. At sixteen months, the beginning of his one-word stage, the child had mastered the high level and low level tones. By twenty-one months the infant had acquired all six tones of Cantonese. Tse noted that the child still had difficulty with a number of segmental sounds at the age when the tone system was completely mastered. Thus it would seem that the infant was attending to tonal contrasts in adult speech at an early age.

This evidence of the early acquisition of lexical tones in Cantonese is corroborated by research reported in Li and Thompson (1978) for other tone languages. These studies, on the acquisition of Mandarin and Thai, also suggested that the tone system of these languages is mastered before the system of segmental phonemes.

If this is the case, one must assume that Cantonese infants are exposed to tonal variation in the language of their parents. It is by this exposure that they acquire the tone system of the language. Therefore the intonation

patterns used by Cantonese parents to address their children would probably be similar to those used in normal adult speech. These intonation patterns, influenced by lexical tones, would have a number of FF fluctuations over the course of an utterance.

The linguistic environment of English infants, on the other hand, would be characterized by fewer FF fluctuations per utterance. In the absence of lexical tone, English intonation would display significant pitch changes mainly at phrase and sentence boundaries. The numerous FF fluctuations that are apparently evident in Cantonese baby talk would not be present in the linguistic environment of English infants.

This difference in the number of FF fluctuations over the course of an utterance is one criterion that could differentiate the vocalizations of infants from these two language communities.

1.2.6 Summary

This section has presented a review of research that investigates various aspects of language development in infants. Evidence was presented concerning the child's ability to perceive and produce utterances characterized by different intonation contours. Various acoustic studies of infant vocalizations were mentioned. In addition, reference was made to the infant's linguistic environment. These factors will now be discussed with reference to the present study.

1.3 Implications of Previous Research for the Present Study

This study is an acoustic investigation of the vocalizations of Cantonese and English infants between the ages of six and eleven months after birth. The research discussed in the literature review has certain implications for this investigation.

1.3.1 The Infant's Receptive and Productive Capacities

It is clear from the evidence presented that by the first few months after birth, the infant has acquired some of the abilities needed for the perception and production of speech.

The child's ability to hear and perceive speech is undoubtedly a prerequisite for language acquisition. Research indicates that the normal infant is born with a well developed auditory mechanism. Moreover, the child can use this mechanism for the perception of adult speech contrasts at a remarkably young age. Studies indicate that, by as early as two months after birth, the infant can discriminate the linguistic contrasts that differentiate phonetic segments, intonation contours and stress patterns in adult speech. Consequently one can assume that normal infants between the ages of six and eleven months should already have acquired the ability to hear and perceive different adult intonation patterns.

Previous research also suggests that by six months of age the infant should be able to control the intonation

contours of his utterances. Within the first few months after birth the infant begins to exercise cortical control over the laryngeal muscles. This control allows him to change the length, thickness and tension of the vocal folds, and to thus vary the fundamental frequency of phonation. By six months of age the normal infant should be capable of producing different intonation contours.

In summary the infant's receptive and productive capacities for speech seem to be well developed by the time language acquisition is thought to begin. The subjects of the present study should be capable of perceiving and producing the intonation patterns that are present in their linguistic environment.

1.3.2 The Acoustic Analysis of Infant Vocalizations

The studies cited earlier also show that infant vocalizations are a form of communication. An acoustic analysis of these utterances can yield information about the mental and physical state of the infant. Some researchers have claimed that a spectrographic analysis of infant cries can determine their provoking cause. Others have used an acoustic analysis to diagnose auditory dysfunction, and diseases affecting the nervous and respiratory systems. Another study has suggested that infants may alter their vocalizations according to their environmental context; that is, whether they are alone, in the company of an adult, or playing with a particular object. Thus it would seem

that an acoustic analysis of infant vocalizations is sensitive to changes in the child's environmental context as well as to his physical and mental state.

These findings have ramifications for the present study. In order to obtain unbiased results the subjects of this research must all be normal healthy infants with no history of mental or physical disorders. Furthermore the environmental context of the infants must remain relatively constant while the vocalizations are being recorded. Finally, since there may be a difference between the vocalizations of males and females (Delack, 1976), the infants in this study must all be the same sex. If these factors are controlled the acoustic analysis should yield fruitful results.

1.3.3 The Language Environment

The language environment of the infants in this study is also an important factor. The purpose of this research is to investigate the vocalizations of infants who are exposed to different languages. Previous research indicates that the intonation contours of infant vocalizations are modelled on the suprasegmental patterns of adult speech. Since these suprasegmental patterns differ from language to language, it is essential that the linguistic environment of each subject in this study be homogeneous; that is, each infant should be exposed to only one language.

If this stipulation and the requirements mentioned above are satisfied, this study should produce valid results.

1.4 Aim of the Present Study

The purpose of this study is to determine whether there is a significant difference in the intonation patterns of Cantonese and English infants that could be attributed to their different linguistic environments. This study involves the investigation of certain acoustic parameters that were shown by Delack (1976) to be useful for characterizing the suprasegmental features of infant vocalizations. These parameters include the range and contour of fundamental frequency for an utterance as well as its duration.

By examining these parameters an attempt will be made to elucidate the regular and quantifiable differences that may be evident in the vocalizations of infants from different language communities. In view of the claims by Crystal (1973) and Weir (1966) that these language-specific differences should be evident by seven months after birth, the subjects in the present study will range from six to eleven months of age.

Of particular interest to this investigation is the notion that the intonation contours of adult speech may display more numerous FF fluctuations per utterance for a tone language than for a non-tone language. This hypothesis may account for the observation by Weir (1966:156) that the vocalizations of Cantonese infants display "... much tonal variation over individual vowels..." while

those of English infants have "... little pitch variation over individual syllables ...". An attempt will be made in the present study to determine if this qualitative observation about the onset of language-specific patterning is supported by empirical evidence.

CHAPTER II

Method

2.1 Experimental Design

The research method involved the analysis of the vocalizations of six infants. There was one English subject and one Cantonese subject in each of three age groups: six months, nine months and eleven months. The vocalizations were recorded on magnetic tape in the home of each infant. The recorded utterances were then analyzed with respect to fundamental frequency and duration. An attempt was made to determine if the intonation patterns of the Cantonese infants differed from those of the English subjects.

2.2 Subjects

2.2.1 Biographical Information

The subjects for this study were all full-term, healthy male infants whose names were obtained from two pediatricians in Ottawa. The biographical data for each infant is shown in Table 2-1.

2.2.2 Linguistic Environment

The linguistic environment of each infant was judged to be homogeneous in nature. The parents of the English babies were all native speakers of Canadian English. The parents of the Cantonese infants were all immigrants to Canada from Hong Kong. They spoke only Cantonese to their children.

TABLE 2-1

BIOGRAPHICAL INFORMATION

SUBJECT	E6	C6	E9	C9	E11	C11
Native Language	English	Cantonese	English	Cantonese	English	Cantonese
Age (weeks)	27.9	29.3	39.7	38.3	48.3	48.0
Birth Weight (pounds)	8.0	6.3	9.3	6.5	7.8	7.0
Weight at Recording (pounds)	16.0	14.5	21.0	18.0	26.0	18.0
Motor Development:						
Sitting	Yes	Yes	Yes	Yes	Yes	Yes
Crawling	Yes	No	Yes	Yes	Yes	Yes
Standing	No	No	No	No	Yes	Yes
Walking	No	No	No	No	No	No
Siblings	1 Sister	1 Brother	None	1 Sister	None	1 Brother

2.3 Procedure

2.3.1 Data Collection

2.3.1.1 Recording Equipment

The infant vocalizations were recorded on BASF magnetic tape using a Sony TC105 portable tape recorder and a Sony ECM16 microphone. The recording speed of 4.8 cm/sec yielded a frequency response of 50 Hz to 6000 Hz.

2.3.1.2 Taping Situation

The recordings were made in the home of each infant. The researcher had as little contact as possible with each subject, and an attempt was made to preserve the natural home setting. Most of the vocalizations were recorded when only the mother and infant were present in the room. The mother was asked to play with the infant in order to elicit vocalizations. The microphone was placed near the subject, and the recordings were monitored by the researcher in another room.

If the child was too fussy or too sleepy for a good recording to be obtained, a new taping session was scheduled. All recording sessions lasted between one and two hours. Each of the six-month- and nine-month-old infants was recorded once. The eleven-month-old infants were both recorded twice with no more than six days between taping sessions.

2.3.2 Instrumental Analysis

The vocalizations of each infant were re-recorded onto a master tape to eliminate extended periods when the subject was not vocalizing. For the instrumental analysis the master tape was played on a Uher 5000 tape recorder. The signal from the tape recorder was passed through a band-pass filter set at a high-pass frequency of 330 Hz and a low-pass frequency of 560 Hz with a filter slope of 36 dB/octave. The filtered signal was fed into a Kay Visi-Pitch 6087A fundamental-frequency analyzer⁽⁸⁾ which was set at frequency scale C (200-800 Hz). The output of the Visi-Pitch was fed into a Mingograf 804 oscillograph which produced a strip-chart oscillogram. All vocalizations for each subject were reproduced on a single continuous oscillogram. At the end of each run a frequency calibration scale was recorded on the oscillogram by means of a frequency calibrator designed and built at the University of Ottawa Phonetics Laboratory.⁽⁹⁾ The oscillogram displayed four different parameters: time (in seconds); acoustic energy⁽¹⁰⁾; relative intensity; and fundamental frequency (Hz). A sample oscillogram is shown in Figure 2-1.

The vocalizations of each infant were analyzed twice. On the first run the master tape was played at normal speed (4.8 cm/sec), and the Mingograf paper-feed was set at 50 mm/sec. In this configuration the Visi-Pitch, set

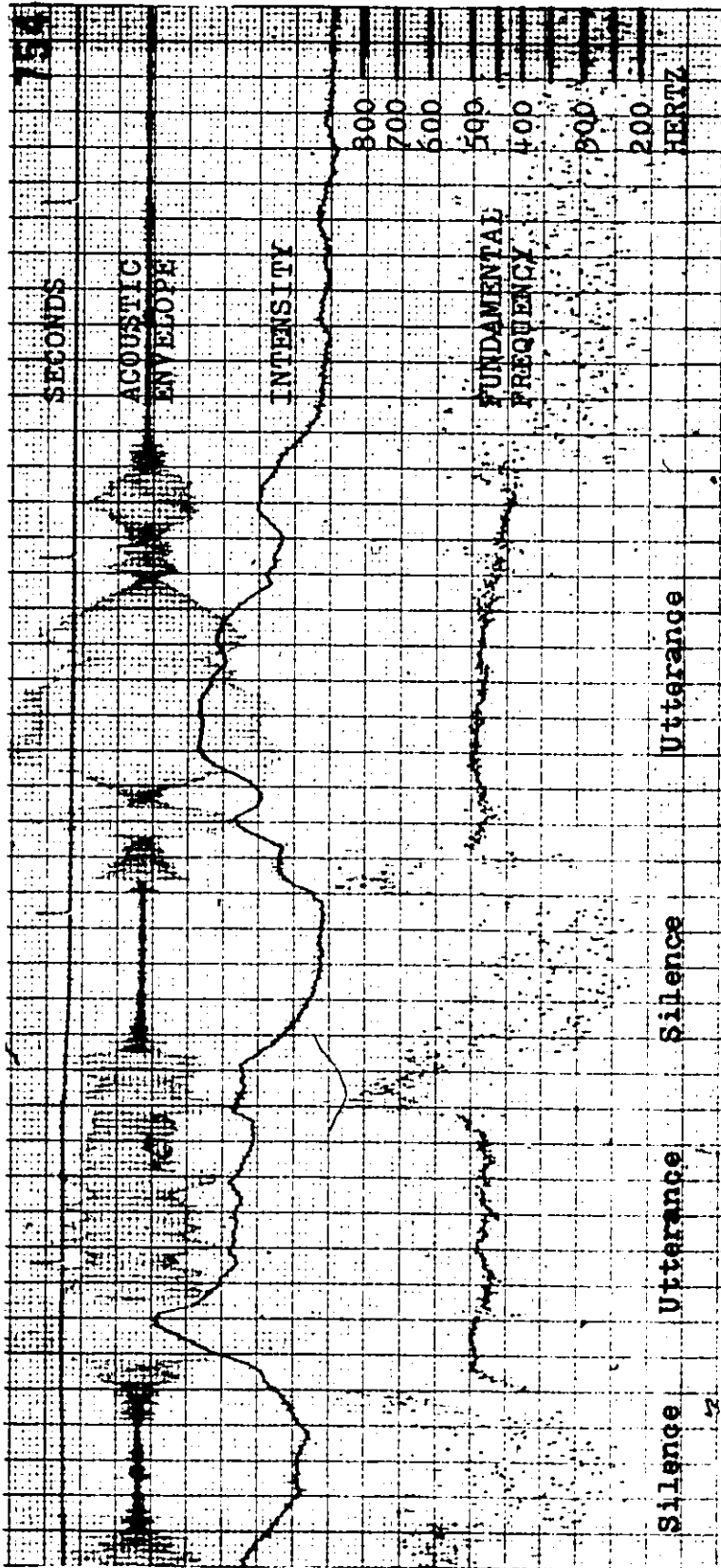


FIGURE 2-1: An oscillographic display of two vocalizations produced by Subject E6. The scale on the right was produced by the frequency calibrator.

at scale C, extracted FF between 200 Hz and 800 Hz. On the second run the master tape was played at half-speed (2.4 cm/sec), and the Mingograph was set at 25 mm/sec. This manipulation allowed the Visi-Pitch, still set at scale C, to extract FF between 400 Hz and 1600 Hz. Thus the effective frequency range for the FF analysis was 200-1600 Hz.

2.3.3 Measurements

After the instrumental analysis was complete, each vocalization on the master tape was identified with its image on the oscillogram. A number of vocalizations were eliminated from further analysis. The following types of utterances were discarded:

- 1) Those produced when the subject was laughing or crying.
- 2) Those that were masked by loud noises or adult voices.
- 3) Vocalizations that contained voiceless consonantal segments. (11)
- 4) Vocalizations that were less than 100 msec. in duration. (12)
- 5) Utterances that exhibited voice break, vocal fry or abrupt changes in vocal register.
- 6) Utterances that were produced by ingressive laryngeal phonation, bilabial phonation, gurgling or grunting.

All other vocalizations were measured with respect to duration. Measures of FF were made for a subset of these utterances.

2.3.3.1 Measurement of Duration

All vocalizations that were not discarded were measured with respect to duration. Duration was defined as the time between the initial and final points of phonation for any given utterance.

On the oscillogram, the initial point of phonation was determined to be the first point in an utterance at which the oscillographic trace of acoustic energy, relative intensity and FF all showed evidence of laryngeal activity. Similarly the final point of phonation was designated to be the last point at which these three parameters showed evidence of laryngeal activity. (13)

The oscillogram paper was divided into sections of 1 mm along the horizontal time axis. The oscillograph paper speed of 50 mm/sec meant that 1 mm of paper was equal to 20 msec of duration. (14) Thus the distance in millimeters between the initial and final points of phonation was multiplied by a factor of twenty to obtain the duration in milliseconds. A conservative estimate of measurement error using this method would be plus or minus 20 msec.

2.3.3.2 Measurement of FF

For each utterance whose duration was greater than 500 msec (15), FF was measured at several points: initial point of phonation (INITIAL), final point of phonation (FINAL), maximum FF (MAX) and minimum FF (MIN). The FF values were determined by measuring the oscillographic

trace with a template inscribed on a T-square. This template was a duplicate of the frequency scale that had been produced on the oscillogram by the frequency calibrator at the end of each run.

The accuracy of this method was tested by measuring a series of random constant tones recorded on a test tape. Measurement error was defined as a disagreement between a reading made from the oscillogram using the T-square template, and the Visi-Pitch's own digital read-out, which was confirmed by a Hewlet-Packard frequency counter. In 44 random test tones the measurement error ranged from 0-12 Hz. Thus the standard error using this method was in the realm of 15 Hz.

2.3.3.3 Calculation of Within-Utterance Range

The value of FF range (RANGE) for each utterance over 500 msec was equal to the difference between the values for MAX and MIN.

2.3.3.4 Classification of FF Contours

Each utterance with a duration of over 500 msec was classified according to its FF contour. If the FF did not fluctuate more than 25 Hz throughout an utterance, then that utterance was classed as level (L). An increase of more than 25 Hz over a period of at least 100 msec was classified as a rise, while a decrease of more than 25 Hz over a period of at least 100 msec was classified as a fall. Thus the following contours were generated:

rise (R), fall (F), rise-fall (RF), fall-rise (FR),
rise-fall-rise (RFR), fall-rise-fall (FRF), etc.

2.3.4 Statistical Analysis

2.3.4.1 Continuous Variables

For each subject the mean and average deviation was calculated for all six continuous variables (INITIAL, FINAL, MAX, MIN, RANGE and DUR). The average deviation for a variable was defined as the average of the differences between the mean and each of the subject's scores for that variable. In addition, the overall mean and overall average deviation for all subjects was calculated for each of the six continuous variables.

2.3.4.2 Discrete Variables

In order to make the continuous variables discrete the vocalizations of each subject were classified as high, low or average with respect to the overall mean for each variable. For example, the durations (DUR) of all utterances for each subject were compared with the overall mean duration for all subjects. If an utterance had a duration that was within 20 msec⁽¹⁶⁾ of the overall mean, then it was classed as average (AVG). Utterances that were longer than the overall mean plus 20 msec were classed as HIGH; those that were shorter than the overall mean minus 20 msec were classed as LOW.

The same classifying procedure was performed for each utterance with respect to the other continuous variables

(INITIAL, FINAL, MAX, MIN, and RANGE). In these cases an utterance was classed as ~~AVG~~ if it had a FF within 15 Hz ⁽¹⁷⁾ of the overall mean. Utterances with FF greater than the overall mean plus 15 Hz were classed as HIGH; those that were less than the overall mean minus 15 Hz were classed as LOW. In this way each of the continuous variables was divided into three discrete categories: HIGH, LOW and AVG.

At this point the number of utterances classed as HIGH, LOW and AVG were counted for each subject. For each variable, Chi-square tests were performed to test the null hypothesis that the utterances were produced by infants from the same population. The level of significance for these tests was 0.05.

2.3.4.3 FF Contour

For each subject all FF contours were classified into four discrete categories:

- 1) Zero Slope-Changes (LEVEL, F, R)
- 2) One Slope-Change (FR, RF)
- 3) Two Slope-Changes (FRF, RFR)
- 4) Many Slope-Changes (FRFR, RFRF, FRFRF, etc.)

For the purposes of this classification, a slope-change was defined to be any point at which a falling FF changed to a rising FF, or vice versa. ⁽¹⁸⁾ The total number of utterances in each of the four categories was counted for each subject. Chi-square tests were performed to determine

whether the difference between subjects could be attributed to chance variation. The level of significance for these tests was 0.05.

2.3.4.4 Test of Sampling Error

Calculations were performed to determine the minimum number of vocalizations that would be required from each subject in order to obtain a representative sample for that subject. For each of three variables (DUR, INITIAL and FINAL), a mean score was calculated after each group of ten vocalizations produced by a subject. Each of these mean scores was subtracted from the overall mean for that subject. The resulting values, called the "sampling error", were plotted on a graph as a function of the number of vocalizations produced by each subject.

For this test it was assumed that the total number of vocalizations obtained from each subject was indeed large enough to be representative of that subject's utterances. Insofar as this was the case, the test would determine the average error that would have occurred if the mean had been calculated using a smaller number of vocalizations for each subject.

CHAPTER III

Results

3.1 Introduction

This section presents the results of the statistical analyses that were described in Chapter II. The tables and figures referred to in this section are shown at the end of the chapter.

3.2 Analysis of FF Range

Table 3-1 presents the mean and average deviation for all FF variables. This table displays the average RANGE for each subject as well as that for all subjects combined.

Table 3-2 is a classification of the RANGE of each subject's utterances. The three classes (HIGH, LOW and AVG) were determined with respect to 112 Hz (the mean RANGE for all subjects) plus or minus 15 Hz. The number of utterances in each class is expressed as a percentage of the total number of vocalizations for each subject.

The results of the chi-square tests for RANGE are shown in TABLE 3-6. As seen in the table, FF RANGE did not differ significantly between the Cantonese and English infants except at six months of age. Subject E6 had a significantly lower RANGE than did C6. The older subjects did not exhibit this dichotomy. There was no significant RANGE difference between E9 and C9, nor between E11 and C11. However, when the utterances of the

Cantonese and English subjects were combined at these two age-groups, the eleven-month-old infants displayed a significantly higher RANGE than the nine-month-old subjects. Comparison with the younger infants showed that E6 had a RANGE comparable to that of E9 and C9; similarly, the RANGE of C6 did not differ significantly from that of E11 and C11.

Thus with respect to RANGE the six subjects could be divided into two groups. For this variable E6, E9 and C9 had a relatively low value compared to C6, E11 and C11.

3.3 Analysis of Utterance Duration

Table 3-1 shows the mean and average deviation of DUR for each subject and for all subjects combined. The results are expressed in milliseconds.

Table 3-3 presents a classification of DUR for the utterances of each subject. The three classes were determined with respect to 735 msec (the mean DUR for all subjects) ± 20 msec. The number of utterances in each class is expressed as a percentage of the total number of vocalizations for each subject. (19)

The results of the chi-square tests for DUR are displayed in Table 3-6. A comparison of the Cantonese and English infants showed a significant difference at eleven months of age. The utterances of C11 were significantly longer than those of E11. There was no differ-

ence in DUR between E6 and C6, nor between E9 and C9. However, when the utterances of the Cantonese and English subjects were combined at these two age groups, the six-month-old infants had a significantly greater DUR than the nine-month-old subjects. Comparison with the older infants showed that E11 had a DUR similar to that of E6 and C6; furthermore, the DUR of C11 was significantly greater than both the six-month- and nine-month-old subjects.

Thus with respect to utterance duration, the six subjects could be divided into three groups. The duration of E9 and C9 was relatively low; that of C11 was relatively high; the duration of E6, C6 and E11 had a value between these two extremes.

3.4 Analysis of FF Contour

Table 3-4 displays the number of utterances that occurred in each FF contour category for all subjects. Table 3-5 is a reclassification of these results with respect to the number of slope-changes that are present in each contour. The number of utterances in each category is expressed as a percentage of the total number of vocalizations for each subject.

The results of the chi-square tests for FF contour are displayed in Table 3-6.

3.4.1 Zero Slope-Changes

A comparison of the Cantonese and English infants for FF contours with no slope-changes (LEVEL, R, F) showed no significant difference at any of the three age-groups. When the utterances of the two infants in each age-group were combined, there was no significant difference between the six-month- and nine-month-old subjects, nor between the six-month- and eleven-month-old infants. However E11 and C11 did have significantly more FF contours with zero slope-changes than did E9 and C9.

3.4.2 One Slope-Change

The chi-square tests for FF contours with one slope-change (FR, RF) showed a significantly greater number for E9 than for C9. There was no significant difference between E6 and C6, nor between E11 and C11. However, when the scores of the two subjects in each of these groups were combined, the six-month-old infants had significantly more FF contours with one slope-change than did the eleven-month-old subjects.

3.4.3 Two Slope-Changes

A comparison of the Cantonese and English infants for FF contours with two slope-changes (FRF, RFR) showed no significant difference at any of the three age-groups. Furthermore, there was no significant difference between the six-month- and nine-month-, the six-month- and ele-

ven-month-, nor the nine-month- and eleven-month-old subjects. Thus all subjects had a similar percentage of FF contours with two slope-changes.

3.4.4 Three or More Slope-Changes

The chi-square tests for FF contours with three or more slope-changes (FRFR, RFRF, FRFRF, etc.) showed a significantly greater number for C9 than for E9. There was no significant difference between E6 and C6, nor between E11 and C11. However when the scores of the two subjects in each of these groups were combined, the six-month-old infants had significantly fewer FF contours with three or more slope-changes than did the eleven-month-old subjects.

3.5 Analysis of Sampling Error

Tables 3-7, 3-8 and 3-9 display the sampling error for each subject for DUR, INITIAL and FINAL. The error is expressed as a function of the number of vocalizations which were used to determine the mean whose value was in error. The sampling error for all six subjects was used to calculate an average error for DUR, INITIAL and FINAL. Graphs of the average error appear in Figures 3-1, 3-2 and 3-3.

As seen in the graph for DUR, the average sampling error did not fall below 100 msec until at least ninety vocalizations had been elicited from each subject. Thus, if only eighty vocalizations had been collected from each

subject, the error in estimating the average utterance duration would have been at least 100 msec. Similarly, in order to obtain a mean duration within 50 msec of the "true" mean for each subject, one would have to analyze a minimum of one hundred and forty vocalizations.

From the graphs of sampling error for INITIAL and FINAL it can be seen that, in order to obtain mean values of FF that were within 30 Hz of the actual value, one would have to obtain forty vocalizations from each subject. In order to reduce the error to 15 Hz (the estimated measurement error for FF), one would have to elicit between sixty and seventy utterances from each infant.

TABLE 3-1
MEAN AND AVERAGE DEVIATION FOR FF VARIABLES AND DURATION

SUBJECT	E6	C6	E9	C9	E11	C11	ALL SUBJECTS
INITIAL							
Mean (Hz)	449	408	395	373	412	411	406
A.D. (Hz)	128	162	47	56	160	68	113
FINAL							
Mean (Hz)	463	421	402	366	404	369	399
A.D. (Hz)	143	74	57	62	179	61	127
MAX							
Mean (Hz)	504	538	453	430	498	453	447
A.D. (Hz)	139	257	55	59	262	84	170
MIN							
Mean (Hz)	424	364	375	342	373	352	367
A.D. (Hz)	120	111	46	48	146	46	94
RANGE							
Mean (Hz)	83	174	79	88	131	101	112
A.D. (Hz)	57	209	43	40	148	67	119
DURATION							
Mean (msec)	665	792	609	550	795	912	735
A.D. (msec)	380	657	458	455	912	634	596

TABLE 3-2

CLASSIFICATION OF FF RANGE*

SUBJECT	NUMBER OF UTTERANCES	% HIGH	% AVG	% LOW
E6	63	15.9	14.3	69.8
C6	109	37.6	12.8	49.5
E9	93	10.8	17.2	72.0
C9	95	14.9	26.6	58.5
E11	114	29.8	18.4	51.8
C11	172	30.2	11.6	58.1

*Utterances were classified with respect to 112 Hz (the mean RANGE for all subjects) \pm 15 Hz (the estimated measurement error).

TABLE 3-3

CLASSIFICATION OF UTTERANCE DURATION**

SUBJECT	NUMBER OF UTTERANCES	% HIGH	% AVG	% LOW
E6	98	41.8	1.0	57.1
C6	189	39.7	0.0	60.3
E9	183	20.8	3.8	75.4
C9	227	24.7	2.2	73.1
E11	212	38.2	2.4	59.4
C11	269	51.7	3.3	45.0

**Utterances were classified with respect to 735 msec (the mean DUR for all subjects) \pm 20 msec (the estimated measurement error).

TABLE 3-4
FF CONTOURS

SUBJECT	E6	C6	E9	C9	E11	C11	ALL SUBJECTS
LEVEL	5	11	4	2	8	17	47
F	4	9	7	16	17	48	101
R	12	10	14	4	12	6	58
FR	11	9	2	3	7	5	37
RF	16	43	46	33	37	46	221
FRF	4	9	4	7	7	20	51
RFR	7	8	6	3	2	4	30
Many Slope- Changes*	4	10	10	27	24	26	101
TOTAL	63	109	93	95	114	172	646

*This category was comprised of the following FF contours:
FRFR, RFRF, FRFRF, RFRFR, FRFRFR, FRFRFR, etc.

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TABLE 3-5
CLASSIFICATION OF FF CONTOURS*

SUBJECT	E6	C6	E9	C9	E11	C11 ^o
Number of Utterances	63	109	93	95 ₃	114	172
% Zero Slope-Changes	33.3	27.5	26.9	23.2	33.0	41.0
% One Slope-Change	42.9	47.7	51.6	37.9	37.5	30.0
% Two Slope-Changes	17.5	15.6	10.8	10.5	8.0	13.9
% Three or More Slope-Changes	6.3	9.2	10.8	28.4	21.4	15.0 ^u

*Columns do not always total 100% because some values have been rounded to the nearest tenth of a percent.

TABLE 3-6
RESULTS OF CHI SQUARE TESTS

VARIABLE ENGLISH VS. CANTONESE 6 MOS. VS. 9 MOS. VS. 11 MOS.

FF RANGE E6 < C6 (9 MOS. = E6) < (C6 = 11 MOS.)

E9 = C9

E11 = C11

DURATION

E6 = C6 9 MOS. < (6 MOS. = E11) < (C11)

E9 = C9

E11 < C11

FF CONTOUR

Zero

E6 = C6

6 MOS. = 9 MOS.

Slope-Changes

E9 = C9

6 MOS. = 11 MOS.

E11 = C11

9 MOS. < 11 MOS.

One

Slope-Change

E6 = C6

11 MOS. < 6 MOS. = E9

E9 > C9

6 MOS. = C9

E11 = C11

11 MOS. = C9

Two

Slope-Changes

E6 = C6

6 MOS. = 9 MOS. = 11 MOS.

E9 = C9

E11 = C11

Three or More

Slope-Changes

E6 = C6

6 MOS. < 11 MOS. < C9

E9 < C9

6 MOS. = E9

E11 = C11

E9 = 11 MOS.

TABLE 3-7
DURATION: SAMPLE ERROR (msec)

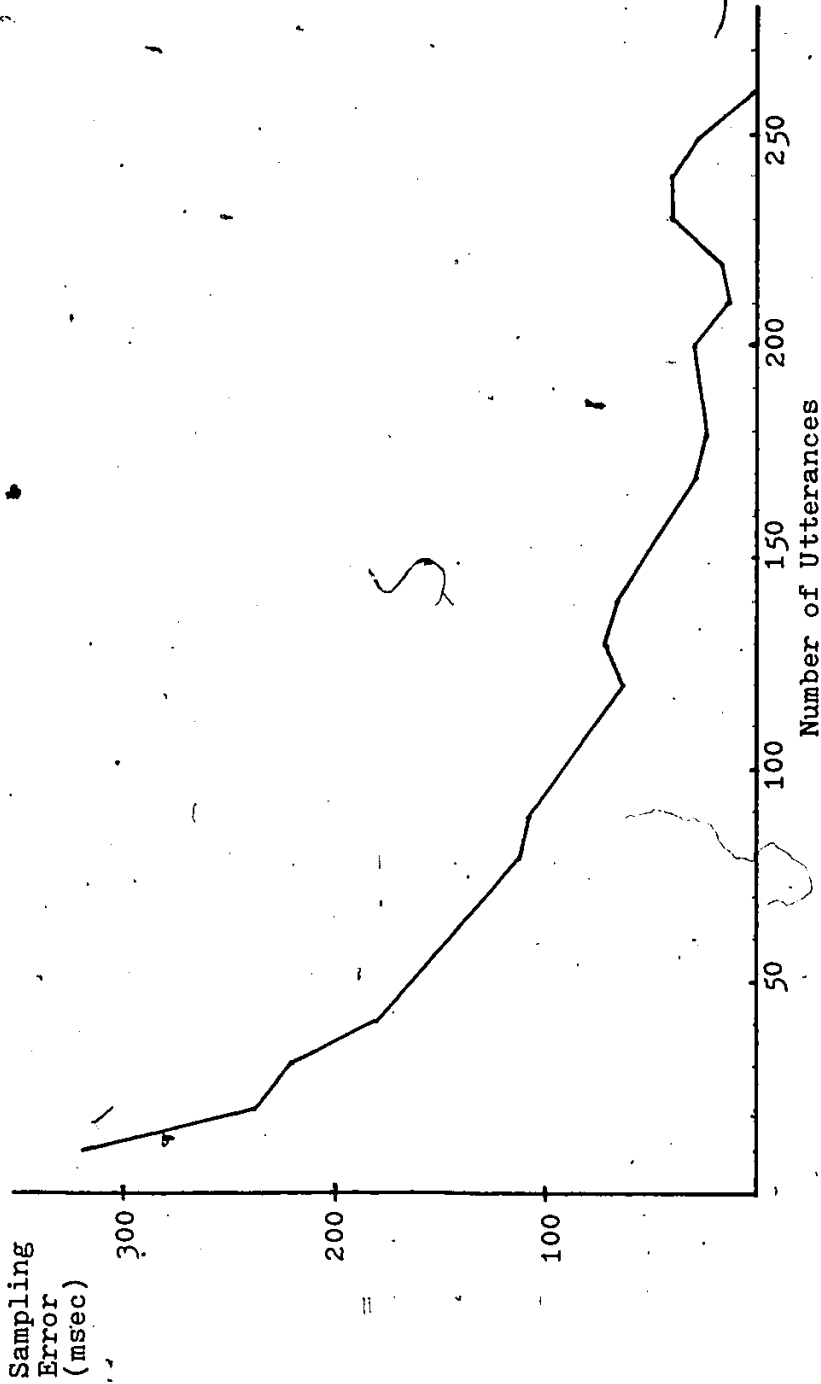
SUBJECT	E6	C6	E9	C9	E11	C11	Average Error
10	433	258	342	186	215	310	291
20	238	219	276	140	284	150	218
30	128	36	240	174	287	350	203
40	97	31	140	123	252	351	166
50	37	93	98	121	152	389	148
60	16	115	78	131	130	325	132
70	9	96	33	127	126	324	119
80	2	121	21	92	129	244	102
90	5	99	24	87	156	217	98
100		74	24	88	82	160	86
110		85	15	77	92	90	72
120		76	5	68	78	65	58
130		63	11	81	105	73	66
140		54	2	98	107	42	60
150		27	2	94	105	15	49
160		27	5	67	86	16	40
170		9	4	19	96	7	27
180		0	4	11	91	2	21
190				12	63	0	25
200				11	50	23	28
210				7	6	28	13
220				4		32	18
230						38	38
240						38	38
250						26	26
260						2	2

TABLE 3-8
INITIAL FF: SAMPLE ERROR (Hz)

SUBJECT	E6	C6	E9	C9	E11	C11	Average Error
10	83	25	4	58	7	14	32
20	32	11	8	60	29	13	26
30	23	25	4	38	91	22	34
40	18	30	3	22	67	18	26
50	21	4	1	14	68	14	20
60	4	17	1	11	45	10	15
70		4	2	9	36	11	12
80		12	0	3	30	12	12
90		4	0	1	17	12	7
100		3			3	11	6
110					1	8	5
120						7	7
130						6	6
140						3	3
150						1	1
160						1	1
170						1	1

TABLE 3-9
FINAL FF: SAMPLE ERROR (HZ)

SUBJECT	E6	C6	E9	C9	E11	C11	Average Error
10	67	36	15	73	49	58	50
20	26	6	1	66	15	17	22
30	19	24	9	40	93	4	31
40	18	32	5	20	63	10	25
50	23	0	1	14	76	18	22
60	2	8	1	9	59	12	15
70		4	2	5	44	6	12
80		14	1	0	31	1	9
90		6	1	1	18	3	6
100		1			5	5	3
110					2	5	3
120						5	5
130						5	5
140						3	3
150						2	2
160						1	1
170						0	0



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FIGURE 3-1-1: A graph of the average sampling error for utterance duration (DUR).

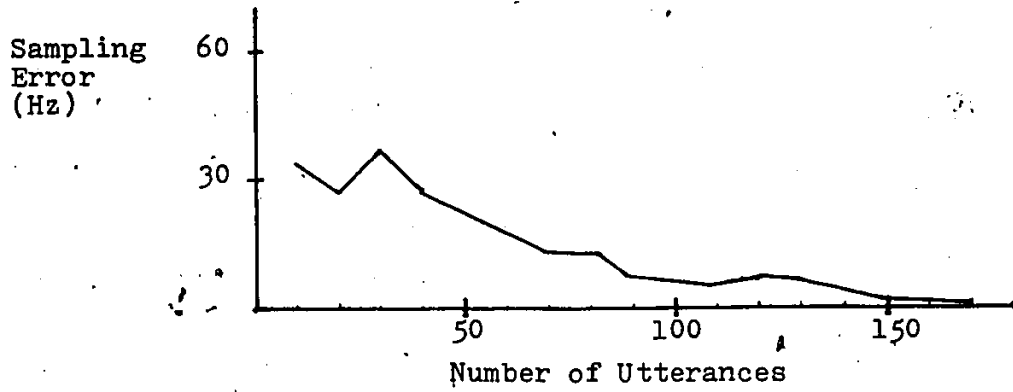


FIGURE 3-2: A graph of the average sampling error for initial FF (INITIAL).

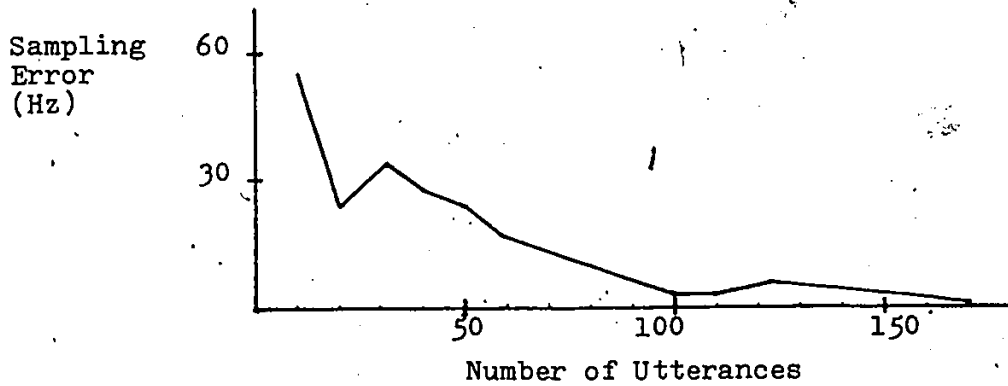


FIGURE 3-3: A graph of the average sampling error for final FF (FINAL).

CHAPTER IV

Discussion

4.1 Discussion of the Results

The most important result of this study was that it did not show a significant difference in the intonation patterns of Cantonese and English infants that could be attributed to their different linguistic environments. According to the hypothesis of Crystal (1973) regular and quantifiable differences should have been evident in the vocalizations of the two languages after seven months of age. Consequently there should have been significant differences in the utterances of the nine-month-old and eleven-month-old subjects that would not appear for the six-month-old infants. The results did not show evidence of this trend.

4.1.1 FF Contour

Of particular interest to this study was the question of whether the intonation contours of Cantonese infants would display more FF fluctuations per utterance than those of English subjects. This trend was not evident in the vocalizations of the infants in this study.

The number of FF fluctuations per utterance was proportional to the number of slope-changes in the oscillographic display of each vocalization. The analysis of FF contour showed that a difference in the number of slope-changes between the Cantonese and English infants

was evident only at nine months of age. Subject C9 had significantly more vocalizations with three or more slope-changes than did his English counterpart. This finding might be interpreted as evidence of language-specific patterning at nine months of age.

This hypothesis is refuted however by the fact that there was no such difference in the intonation contours of the eleven-month-old subjects. If the differences at nine months were indeed caused by the infants' linguistic environments, then similar results should have been obtained for the older subjects. Indeed, since the influence of language-specific patterning should become more evident with age, the differences in the intonation patterns of the eleven-month-olds would be even greater than those at nine months. The lack of these differences at eleven months suggests that language-specific patterning is not acquired before this age.

4.1.2 FF Range

The results of the analysis for FF Range also showed no evidence of language-specific patterning. For this parameter the only significant difference between the Cantonese and English subjects occurred at six months of age. Because this difference was not evident in the vocalizations of the older infants it cannot be attributed to dissimilarities in the FF Range of adult utterances in Cantonese and English.

4.1.3 Utterance Duration

The analysis of utterance duration showed that there was no significant difference between the Cantonese and English infants except at eleven months of age. The vocalizations of Subject C11 were longer than those of Subject E11. These results might be interpreted as evidence of language-specific patterning since the difference in duration was not apparent for the younger infants. It is possible that sometime between the ages of nine and eleven months the vocalizations of Cantonese and English infants are differentiated due to the influence of different utterance durations in the baby talk of the two languages. The paucity of information on baby talk in Cantonese prevents a definitive statement about this hypothesis.

Consequently the results of this study show no evidence of language-specific patterning in infants as old as eleven months:

4.1.4 Developmental Trends

It is possible to compare the results of the present study to previous research on infant vocalizations. The most comprehensive report of the developmental trends in infant vocalization during the first year was presented by Fowlow (1975) and Delack (1976). That study analyzed the vocalizations of six English infants at two-week intervals from birth to one year of age. It reported certain developmental trends for the acoustic parameters used to describe infant utterances.

With respect to FF contour Delack stated that during the first year the child's vocal repertoire is dominated by the simple rise-fall intonation. This FF contour accounted for forty to fifty-five percent of all vocalizations. In the present study this intonation curve was also predominant. As seen in Table 3-4, the RF contour accounted for 221 of the 646 vocalizations that were analyzed. This is equivalent to thirty-four percent of all utterances produced by the infants. The correlation between the two studies is significant in pointing out the dominance of the rise-fall contour in infant utterances.

Another correlation between the Delack study and the present investigation was evident for the developmental trend in average utterance duration. For this parameter Delack reported an average increase of fifty percent throughout the first year after birth. For the present study, Table 3-1 illustrates that the mean utterance duration was higher for the eleven-month-old subjects than for the younger infants. Thus both studies illustrated a trend toward longer infant utterances as age increased during the first year after birth.

With respect to FF Range the Delack study showed a different trend from the present investigation. Delack reported a decrease in FF Range from 100 Hz at six months to 80 Hz at eleven months of age. In the present study FF Range increased from an average of 80 Hz at six months

to 115 Hz by eleven months of age. This discrepancy represents a departure from the correlation between the study by Delack and the present investigation. The similar developmental trends for FF contour and utterance duration do not coincide with the different trends for FF Range.

4.1.5 Sampling Error

In this thesis an effort was made to collect enough vocalizations from each subject so the sample would be representative of the infant's normal vocal productions. To this end a total of 1178 vocalizations were analyzed for six subjects. This was an average of almost 200 utterances per infant. For the analysis of sampling error it was assumed that this number was sufficient to be representative. That is, it was assumed that the analysis of an even greater number of utterances would not have significantly altered the results.

If this assumption was valid then the analysis of sampling error indicated that a fairly large number of vocalizations would be required to obtain representative values for the acoustic parameters in question. For the parameters of fundamental frequency a minimum of sixty to seventy utterances were required before the sampling error dropped below 15 Hz (the estimated measurement error). For utterance duration a total of 140 vocalizations were required in order to obtain a sampling error below 50 msec.

It is interesting to apply the results of this analysis to the study reported by Delack and Fowlow. That research involved the recording of six infants for a period of fifteen minutes every two weeks during the first year after birth. On average, a total of forty vocalizations were recorded per session (Fowlow 1975:169). In the present study this number of vocalizations produced a sampling error of 26 Hz for FF parameters and 160 msec for utterance duration. If the variability in the infant vocalizations was similar to that in the present study, Delack could expect a sampling error of similar magnitude. He expected to compensate for the small number of utterances by combining the results of all six subjects. Nevertheless there is some doubt that the elicitation of only forty utterances per recording session was sufficient to yield representative values for the acoustic parameters in question.

The results of the present study have provided some information about the number of utterances required for a representative sample of infant vocalizations. It is hoped that this information can be used in future investigations.

4.2 Limitations of the Present Study

The main limitation of this study was that it analyzed the vocalizations of only six infants. It is difficult to make generalizations about a whole population based on the

results of this small number of subjects. An attempt was made to compensate for this limitation by collecting large numbers of vocalizations from each infant. Nevertheless it would have been better to analyze the vocalizations of more subjects.

The reason for this limitation was the great amount of time required to edit, analyze and measure each utterance. Over 4000 individual measurements of FF and duration were made for just six subjects. Since these measurements were all made by hand it was a very time-consuming process.

Yet the results for the analysis of sampling error indicated that a large number of vocalizations is required to yield representative values for the acoustic parameters that characterize infant utterances. This fact suggests a need for more sophisticated instrumentation that can analyze and measure large numbers of utterances in a relatively short time. This instrumentation would allow for the investigation of language-specific patterning in a large number of infants.

4.3 Directions for Further Research

The results of this study raise certain questions about the onset of language acquisition in infants. The apparent absence of language-specific patterning in eleven-month-old infants suggests a need to examine the vocalizations of older subjects. It would be interesting to compare the utterances of Cantonese and English infants during the

second year after birth when the lexical tones of Cantonese are said to be acquired.

Yet even before undertaking such a study, it is imperative to investigate the language-specific intonation patterns of adult speech in these two languages. For the present study, the differences between Cantonese and English were determined by subjective judgements about the intonation contours of adult speech. An experimental investigation would yield an objective measure of the differences between these two languages. After determining the acoustic parameters that differentiate adult utterances in Cantonese and English one could follow the developmental trends of these parameters in infant vocalizations. In this way the onset of language-specific patterning could be more accurately assessed.

4.4 Summary

This thesis has presented an investigation of the intonation patterns produced by Cantonese and English infants between the ages of six and eleven months. An attempt was made to determine whether there was a significant difference in the infant vocalizations that could be attributed to the different linguistic environments. The utterances were compared with respect to certain acoustic parameters.

The results of this investigation did not show evidence of language-specific patterning in the intonation

contours of the Cantonese and English infants. The results did, however, illustrate certain developmental trends in the infant utterances. This study also provided some information about the number of utterances required for a representative sample of infant vocalizations.

In conclusion this study suggested a need for further research on the acoustic parameters that characterize adult utterances in different languages. A thorough analysis of language-specific patterning in adult speech will allow a more accurate assessment of the onset of language acquisition in infants.

FOOTNOTES

1. The terms "vocalization" and "utterance" are used throughout this thesis to denote a continuous stretch of vocal activity.
2. Voice-onset-time was defined by Lisker and Abramson (1964) as the time between the release burst of a stop consonant and the onset of laryngeal pulsing.
3. The term "language-specific", as used in this thesis, does not refer to something that is characteristic of human language in general, but rather to something that is characteristic of one or another language in particular.
4. The term "spectrographic" refers to an analysis by a sound spectrograph.
5. It is not clear what Lewis meant by the "conventional" features of intonation.
6. This compares to a vocal fold length of 17-23 mm in the adult male and 12-17 mm in the adult female.
7. This fact probably accounts for the observation by some researchers (Tonkova-Yampol'skaya, 1969; Delack, 1976) that infant vocalizations become more stable and controlled as the child approaches the first birthday. This stability and control over laryngeal activity is maintained by the male until he reaches puberty, when rapid growth of the vocal folds is once again evident.

8. The Visi-Pitch extracts two acoustic parameters from the speech signal: FF and relative intensity. The FF is extracted on a cycle-to-cycle basis.
9. The frequency calibrator was designed and built by Mr. R.D. Fournier to be used in conjunction with the Visi-Pitch.
10. The oscillographic trace for acoustic energy was produced by a direct line from the tape recorder to the oscillograph. This trace was not subject to filtering or Visi-Pitch analysis.
11. These were discarded due to the difficulty of interpreting the abrupt cessation and resumption of phonation in the middle of an utterance.
12. These utterances were too short to make reliable FF measurements.
13. In fact the oscillographic trace of FF was seldom used for this purpose due to the unstable nature of laryngeal vibration at the onset and cessation of voicing. In most cases the initial and final points of phonation were determined by the oscillographic traces of acoustic energy and relative intensity.
14. On the second run for each subject the paper speed was 25 mm/sec. However, since the master tape was being played at half speed, the same relationship held; that is, 1 mm of paper was equal to 20 msec of duration.

15. For most utterances with duration less than 500 msec. the FF values were difficult to measure due to the unstable nature of laryngeal vibration in vocalizations of such short duration.
16. This "buffer zone" on both sides of the overall mean was equivalent to the estimated measurement error for duration.
17. This value was equivalent to the estimated measurement error for FF.
18. The number of slope changes was a measure of the number of FF fluctuations in an utterance.
19. Note that the number of vocalizations for each subject was greater for DUR than for RANGE. This is because RANGE was determined only for utterances in which DUR was greater than 500 msec.

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