THE DEVELOPMENT OF PROSODIC CONTRASTIVITY DURING THE FIRST YEAR OF LIFE

by

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ABSTRACT

The relationship between the infant's early vocal development and subsequent speech and language development has been generally a matter of speculation, largely based upon anecdotal evidence, despite the voluminous literature on the subject. Included in the existing data on infant prosodic development are descriptions of differentiated crying behaviour ostensibly expressive of different internal states such as pain, hunger and pleasure. Instances of differential vocalization to objects and people have likewise been alluded to in the literature, but no systematic studies of the phenomenon have been made.

The present study examines certain aspects of vocal differentiation and differential vocalization, primarily with respect to familiar environmental objects. Nineteen normal, healthy, 'first-born' infants served as subjects. All were being raised in an exclusively monolingual English home environment, where all data were collected at biweekly intervals from five weeks to approximately one year of age. The vocalizations of ten of the infants were studied longitudinally over an entire year, the remaining subjects from five weeks to approximately six months.

Intonation patterns of non-cry vocalizations occurring in two basic situations (i.e., infant alone and infant in the context of various objects) were analyzed spectrographically for fundamental frequency, within-utterance range, duration and contour. Each variable was examined longitudinally and in different contexts.

A number of age trends are evident: Duration and within-utterance range increase with age, whereas fundamental frequency remains relatively stable over the first year. Females exhibit a higher F_o than males at all age levels examined. Peak values of the variables are commonly observed at 4-6, 9 and (to a lesser degree) 11 months. The RF intonation contour increases in frequency of occurrence during the first year, while the other contours demonstrate little change.

Contrasts of utterances occurring in different categories reveal essentially no difference between contexts for the variables studied. Examination of the distributions of the different intonation contours for each context indicates that the infants could be manipulating contour differentially in a given context.

In sum, it is felt that the infants exhibit a very real, albeit circumscribed, capacity for vocally differentiating environmental events. It is felt that there exists sufficient evidence to refute the parochial view that linguistic acquisition can only be relevantly discussed when the child's segmental phonetic output begins to resemble that of the adult standard. The evidence presented corroborates the hypothesis of continuity from babbling to speech.

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CHAPTER 1

Introduction

1.1. Introduction

> '...the wants of an infant are at 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, -- lastly by words of a general nature invented by himself, then of a more precise nature imitated from those which he hears; and these latter are acquired at a wonderfully quick rate.'
>
> (Darwin, 1877, p. 8)

It is generally agreed that the infant's cry is a primitive mode of expression. Many people have offered hypotheses regarding the role of early cry and non-cry utterances in the continuum of language development, but relatively few have studied the subject systematically. Those who have undertaken studies of infant vocalization during the first year of life have been faced with ostensibly insurmountable problems in data collection, analysis, and interpretation of results. The researcher is further confronted by a multitude of uncontrollable variables, such as genetic make-up, rate of development, and environmental factors. All of these variables must ultimately be taken into account in any theory of language development which claims to be comprehensive.

Early investigators in language acquisition acknowledged that the infant cry acquired an expressive function very soon after birth (Lewis, 1951). The newborn was thought to oscillate between two states: discomfort and indifference: Discomfort was denoted by the cry, indifference by silence. Later, a comfort cry would emerge. Comfort and discomfort were differentially expressed, while the state of indifference continued to be indicated by silence. As the infant grew older, the state of hunger also became differentiated vocally. Today, this idea of progressive differentiation of the cry is widely accepted. Not only is it compatible with a maturational approach to language acquisition, but it can be explained by certain learning theory approaches as well.

Wasz-Höckert et al. (1968) demonstrated that cries arising in different situations (viz., birth, pain, hunger and pleasure) exhibited different acoustic characteristics; cf. Table I. Wolff (1969) discussed this phenomenon of differential crying at length. In the Wasz-Höckert study, adults who had varying degrees of experience in caring for young babies, were asked to judge the different types of cry in a perceptual test. The subjects were able to identify different cry types, but it was found that the amount of experience with young babies influenced the number of correct judgments: midwives, children's nurses, and mothers were best able to identify the different cry types;

pleasure cries were most easily identified, followed by hunger, pain and birth cries in that order.

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Insert Table I about here.

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In contradiction to Wasz-Höckert et al., a recent study of cry identification abilities of mothers (Müller et al., 1974) found that mothers were usually unable to identify the situation of the cry. Three types of cry-evoking situations were examined: pain stimulation (elastic band snapped against child's foot), auditory stimulation (loud clap of wooden blocks) and hunger stimulation (feeding was begun and then suddenly halted). With the exception of the pain stimulation, these cry situations are not comparable to those employed by Wasz-Höckert et al. The cry produced in response to auditory stimulation might be described as a form of startle response, as might the pain cry. The Wasz-Höckert 'hunger cry' was produced about four hours after the infant's last feeding; all other reasons for discomfort were discounted. The Müller 'hunger cry', on the other hand, was elicited after feeding had begun; this cry could thus be interpreted as a cry of frustration or anger rather than hunger. The authors recognized this possibility but argued that the term 'hunger stimulation' was operationally defined for the purposes of their research and that the cry was hunger-related (Müller et al., p. 92). The four cry categories of Wasz-Höckert et al.

TABLE I

A SUMMARY OF THE CHARACTERISTICS OF INFANT CRIES

Type / Features	BIRTH	PAIN	HUNGER	PLEASURE
Length	approx. 1 sec	long; variation in length; longer with increase in age	approx. 1 sec	approx. 1 sec
Melody	Level or Falling	Falling; Rising-falling is rare	more than two-thirds are Rising-falling	Level - often nasal
Tense	always	usually	approximately one-half are tense	never
Glottal Plosives	rare	0-1 mo. - present in 50% the cries; decrease with age	present; after 1 mo. occur in two-thirds of cries	rare
Vocal Fry	rare	in more than half of the cries	rare	rare
Subharmonic Break	rare	in about 50% of cries; increase with age	rare	occurs in about one-fifth of the signals
Shift	present in approx. 20% of signals	often present (30-40%)	rare	occurs, usually in Rise-fall
Voice	60% voiceless	0-1 mo. - 65% voiced 1-7 mo. - 72% voiced	0-1 mo. - 60% voiced 1-7 mo. - 68% voiced	always
Maximum Pitch	550 ± 70 Hz	high; increases with age	few marked changes with age	more variable pitch

(based on Wasz-Höckert et al., 1968)

encompass a wide variety of situations. Müller's categories could be described as subsets of one major category, namely 'pain'. It is possible that cries within this major category may not be acoustically different even though their evoking stimuli may be different (e.g. loud noises, bright lights, pinches, frustration). Müller et al. did not include any spectrograms with their results, and consequently it is difficult to judge whether the three types of cries were actually acoustically different.

Thus far we have discussed the infant's ability to signal major internal states by different types of utterances. It appears that changes in the child's external environment can also be signalled by a change in the child's vocal output. The vocal behaviour that occurs in these situations has been variously labelled 'imitation', 'role-playing', and 'response to a novel situation'. Lieberman (1967) cited evidence based on two children, a 10-month-old boy and a 13-month-old girl, both of whom altered their fundamental frequency in the presence of a parent. A lower fundamental frequency was used in the presence of the father than in the presence of the mother. The boy used a higher fundamental frequency when playing alone than he did when playing with either his father or his mother. Unfortunately, Lieberman gives no information as to how he obtained the data or how many observations were made, nor does he specify the nature of the adult stimulus in more than anecdotal fashion.

After studying the babbling of his twin daughters, Cruttenden (1970) was unconvinced that 'meaningful or indeed "delimitative" pitch patterns' occurred during the babbling stage (p. 112). Some patterns were imitated and put into use. Both twins experimented with pitch register. One co-twin employed two pitch registers, one very high and the other low and creaky. The author did not note whether these two registers were being employed in different situations.

Crystal (1973b) refers to a child who employed a falsetto voice when playing with his rabbit, and a chest voice when playing with his panda; both of these were ostensibly toy animals. He suggests that this type of behaviour could be construed as role-playing.

Recently, a study of vocalizations in infants from five weeks to four months of age, was carried out (Handford, 1972) in which it was found that the children generally did not alter their fundamental frequency or within-utterance range (of fundamental frequency) in response to different objects or situations. However, twenty percent of the statistical tests carried out were significant, demonstrating that the children were at least capable of altering their vocal output in different situations.

The intent of the present study is to examine, in acoustical terms, the intonation patterns of non-cry vocalizations of the infant in two basic situations: (1) infant alone, and (2) infant in the context of various objects. Ten subjects were studied longitudinally from five weeks to one year of age. An additional eight subjects were studied from five weeks to six months of age.

The results are examined and discussed, keeping in mind the child's developing physical and cognitive capacities.

1.2. Literature Review

1.21. Receptive capacity of the infant

In any study of an individual's speech and language development, one is first concerned with that person's receptive capabilities. How then might the infant be equipped to receive and process the speech signal? What kinds of perceptual tasks can the infant perform? Although we are far from being able to answer these questions, some data are available.

During the first two years of life, about sixty percent of brain development occurs (Lenneberg, 1967, p. 179). Structural, chemical and electrophysiological changes take place at a rapid rate, during which time the infant develops an ever-expanding repertoire of gross and fine motor skills. Paralleling this physical growth is the rapid growth of receptive and expressive language, as well as other cognitive skills.

Myelin, a substance which envelops the axons of many nerve cells in the body, aids in accelerating the transmission of nerve impulses. Myelination, the process by which nerve cells acquire a myelin sheath, is incomplete at birth. In the brain, myelination occurs in an ordered sequence, and in the direction of the pathway concerned. The medulla is myelinated first, followed by the basal ganglia, mesencephalon and finally the cortex (Peiper, 1963, pp. 539-541; Yakovlev and Lecours, 1967; Lecours, 1972ms). The auditory nerve is fully myelinated at birth; however, myelination of the two classical speech and language areas of the brain, Broca's area and Wernicke's area, takes place more slowly over the first two years of life. Thus, given the status of the auditory tract, the infant could rapidly become a sophisticated listener, whereas overt speech and language skills would emerge more slowly.

The asymmetry of the left and right hemispheres, which is evident in most adults and generally indicates hemispheric dominance for speech and language, is demonstrable in fetuses as early as twenty weeks gestational age (Wada, 1974). A study by Molfese (1973) indicates that the brain processes speech and music differentially at birth: auditory evoked responses to speech, syllables, words, music and speech noise were recorded from the temporoparietal areas in both the right and left hemispheres in infants, children and adults. In all subjects, verbal stimuli elicited the greatest amount of AER activity from the left hemisphere, while non-verbal stimuli elicited more activity from the right hemisphere.

The structures of the ear are fully developed at birth. Traditionally, it was believed that the middle ear was filled with mucous at birth. The resultant conductive loss would then interfere with the infant's response to sound. Tympanometry and measurements of the compliance of the tympanic membrane have revealed that neonates have normal middle ear function and that mucous is not present (Keith, 1974). The few W-shaped tympanograms (usually indicating hypermobility of the eardrum but not observed with a 220-Hz probe tone) that were observed were thought to be indicative of unresolved embryonic connective tissue pressing against a part of the eardrum.

Wertheimer (1961) demonstrated auditory localization in an infant less than ten minutes old. Eisenberg et al. (1964) reported that neonates were differentially responsive to signals within the speech range (250-4000 Hz). Signals below 4000 Hz elicited responses two to three times more often than signals above 4000 Hz. High frequency signals tended to cause distress, whereas low frequency signals tended to inhibit it. Low frequency stimulation evoked gross motor responses when the infant was dozing. High frequency stimulation elicited the highest proportion of arousal and orienting quiet reflexes and was most effective when the infants were in wakeful states.

Kearsley (1973) reports that newborns are differentially responsive to auditory stimulation. Further, they are capable of integrated orienting and defensive behaviour. The onset of the auditory event is apparently the most important factor in determining a response. As with Eisenberg et al., the studies of both Kearsley (1973) and Pomerleau-Malcuit and Clifton (1973) recognize the importance of the state of the organism in its response to a stimulus. Pomerleau-Malcuit and Clifton (1973) found less variability in neonatal response to tactile, auditory and vestibular stimulation before the infant was fed.

Friedlander (1968) has attempted to examine the listening preferences of young infants, using an automated behaviour analysis toy which can be attached to a standard playpen. The toy allows the children to select between pairs of auditory stimuli which have been recorded on tape loops. A study of three infant boys, aged eleven to thirteen months, demonstrated a preference for the mother's voice over music. When presented with a choice of listening to the mother's monotone voice or a stranger's voice with bright inflection, the youngest subject showed a preference for the stranger's voice, whereas the 15-month-old subject showed a shift from preference of the stranger's voice with bright inflection to the mother's voice with flat inflection. The third subject (12-months-old) was given the task of discriminating a sample of his mother's speech in which she employed familiar phrases and a bright inflection, and a sample of the mother reading in a flat, monotonous voice. At first, the child showed a preference for the mother's bright voice, but this was followed by a shift in preference for the monotone version of the mother's voice. This same subject was given a further task involving selection of speech samples which differed in message redundancy. The low redundancy message repeated itself every 240 seconds, while the high redundancy message was a 20-second sample edited from the longer message. During the initial sessions, the infant showed a preference for the repeating 20-second message. Finally, there was a switch to preference for the longer message. These results were subsequently duplicated using 40-second and 120-second repeating messages. In a later study employing more subjects (Wisdom and Friedlander, 1971), almost one-half of the infants preferred the low-redundancy, high-inforamtion message. Six of the subjects showed a distinct shift in preference from low-information, high redundancy to high-information, low-redundancy.

There are parallels between Friedlander's observations of shifting preference from the familiar to the novel, and observations on infant visual behaviour (recorded at a somewhat earlier age). Infants fixate on complex visual patterns more than simple patterns, and on complete faces rather than scrambled ones. Wetherford and Cohen (1973) obtained response habituation to a familiar pattern at ten to twelve weeks but not at six to eight weeks. The older subjects preferred novel patterns, while the younger ones preferred familiar patterns.

Evidence to supplement the observations regarding infant listening preferences exists in the realm of speech perception. At two weeks, infants are capable of discriminating vocal and non-vocal stimuli (Wolff, 1969). Between two and four months, discrimination of the affective qualities of voices occurs (Lewis, 1951; Lieberman, 1967; Wolff, 1969). Familiar and unfamiliar voices are also distinguished at this age (Kaplan and Kaplan, 1971). Turnure's (1971) three-month-old subjects exhibited more mouth movements during the presentation of the mother's voice than during the presentation of a stranger's voice. Kaplan (1970) mentioned that, in preliminary testing, four-month-old infants were able to discriminate between a male and a female voice repeating the same utterance: "See the cat." Variability in both heart rate and orienting responses increased when the voice 'changed from male to female, and vice versa' (p. 10).

Kaplan and Kaplan (1971) suggest that the young infant (under seven months of age) is more attuned to the suprasegmental components of speech. After six months he/she is supposedly more aware of segmental information. Several studies have been devoted to the young infant's perception of segmental information. The high amplitude sucking paradigm (HASP) has been used as the response measure in the majority of these studies.

Eimas et al. (1971) found that one- to four-month-old infants were able to discriminate synthesized versions of /b/ and /p/; these sounds had the acoustic properties associated with the syllables /ba/ and /pa/. The results indicated a tendency towards categorical perception, i.e. discrimination across phoneme boundaries rather than within phoneme categories. Moffitt (1971) demonstrated discrimination of /ba/ and /ga/ in infants from twenty- to twenty-four-weeks of age. Trehub and Rabinovitch (1972) found that infants could discriminate between the synthetic speech stimuli /ba/ and /pa/, as well as the natural speech stimuli /ba/ vs /pa/ and /da/ vs /ta/. The subjects in their study were between four- and seventeen-weeks old.

Morse (1972) tested the ability of 40- to 54-day-old subjects to discriminate cues for place of articulation (/ba/ vs /ga/) and intonation (/ba-/ vs /ba+/, where the "-" denotes a falling intonation contour and "+" a rising intonation contour). In addition to the control group which was presented only with /ba-/, there was a non-speech control group which was presented with a stimulus consisting of the acoustic cues which differentiate /ba/ and /ga/. The infants were able to discriminate the cues for place and intonation. Moreover, a comparison of the non-speech control condition and the place condition indicated that the infants responded to the acoustic cues for place in a manner that was considered linguistically relevant.

Eilers and Minifie (1974) used the HASP to study infants' discrimination of fricatives between four and seventeen weeks of age. The subjects were found to be able to detect differences between /s/ and /v/ and between /s/ and /š/, but not between /s/ and /z/. One drawback to the HASP and similar paradigms is that the instances in which the infant perceives the stimuli to be different but does not find the difference reinforcing cannot be differentiated. Thus, the infant may have perceived a difference between /s/ and /z/, but the results of HASP would not necessarily demonstrate this. If the results of HASP experiments do give reliable evidence of the infant's discriminative capacities, then Eilers and Minifie's results would indicate that discrimination is dependent on the nature of the acoustic cue rather than on the number of cues available.

Eleanor Kaplan (1970) used a cardiac habituation-dishabituation paradigm to measure the ability of four- and eight-month-old children to discriminate rising and falling, stressed and unstressed terminal contours of American English. The four-month-old infants apparently could not discriminate between the stressed or the unstressed versions of the contours. The eight-month-old infants were able to discriminate the rising stressed and falling stressed contours, but they were unable to discriminate the unstressed contours.

Both the HASP and the heart rate paradigms (HRP) have advantages and disadvantages (Butterfield and Cairns, 1974). The HRP requires less active participation on the part of the subject than the HASP. The criterion for habituation in the HASP is stringent, whereas the HRP criterion must be decided in advance and occasionally involves a certain amount of arbitrariness. Changes in the state of the infant are of considerable importance in the HRP but of lesser importance in the HASP. The intensity of the stimulus is important in the HRP but is of less consequence in the HASP. Furthermore, the HRP is only applicable to very young subjects. The HRP method has been studied in some detail; on the other hand, information regarding the HASP method is limited, and therefore the results of experiments employing this method must be interpreted with caution.

There is debate as to whether infants perceive sound differences in a linguistically relevant manner, as suggested by Morse (1972). Chinchillas have been trained to respond differentially to presentations of /i/ vs /a/ (Burdick and Miller, 1974), /t/ vs /d/ (Kuhl and Miller, 1974), /pa/ vs /ba/ and /ga/ vs /ka/ (Kuhl and Miller, 1975). The method employed in these experiments was a variation on the HASP technique, which required the animals to jump across a cage and lick on a water tube. These studies suggest that what may be actually being tested in infants is an ability that is something other than previously claimed and which somehow relates to the way in which the brain processes sound.

Another recent study of stop discrimination in Kikuyu children (Streeter and Landauer, 1975) casts further doubt on some of the findings of infant speech perception research. The Kikuyu language distinguishes prevoiced and voiced stops but has no stop comparable to the English /p/. Kikuyu children were able to discriminate not only prevoiced from voiced labials, but also voiced from voiceless labials, even though the latter are not phonemically distinct in the Kikuyu language. After the children received formal teaching in English, the voiced/voiceless discrimination improved. If experience with a language is of major importance in discrimination, then the theory that infants are discriminating voiced and voiceless stops on the basis of voice onset time alone is likely to be incorrect; in fact there is evidence to indicate that formant transition frequencies and rates are more important than voice onset time. It would seem that Kaplan and Kaplan's suggestion that the infant's perception of suprasegmental information precedes that of segmental information is probably correct.

A recent kinesic study purports to demonstrate that neonatal movement is in synchrony with adult speech (Condon and Sander, 1974). A frame-by-frame analysis of infant movement occurring as an adult (either live or taped) spoke to the infant was said to reveal correspondences between the movement of the infant and the sound patterns of the speech of the adult. The authors' conclusions are questionable for a number of reasons: They make no mention of the coarticulatory effects which are present in speech; simply put, in connected speech, while one phoneme is being produced, the articulators are moving into position for the production of the next phoneme. The phoneme being produced is thus influenced to a certain degree by the succeeding phoneme. As a result, inter alia, no two phonemes are ever produced in exactly the same manner. The infant listener is exposed to a constantly changing stream of speech; changes are occurring not only across but also within phoneme boundaries. The authors' representation of similar sounds over several film frames is therefore not as accurate as it could have been had a finer transcription been used. Another criticism of the study involves different movement configurations of the infant and their relationship to the adult speech. In some instances it appears that movements are sustained over a number of successive sounds, while in other cases some or all of the movements may change ith each sound. In the one sample presented in the paper, these changes appear to be of a random nature. For example, the word 'over appears twice in the sample given: [ovɨr] first and [ovɚ] second. During the presentation of [ovɨr], the child's movements change with each phoneme, yet during the next [ovɚ], the child's movements remain constant. The results and authors' discussion leave many questions unanswered and raise others in addition. An examination of kinesic factors should prove very valuable in the study of language acquisition, but the results need to be examined and evaluated more thoroughly than is the case in the report by Condon and Sander.

1.22. Productive capacity: The infant larynx

In the previous section we noted that the hearing mechanism is well developed at birth. On the other hand, as will now be discussed, the vocal apparatus is not fully developed at birth. Its immature status places some limitations on the infant's vocal output but acts beneficially in ways that are important for survival.

The infant larynx can be simply described as a single-tube resonating system rather than as a two-tube responating system (as is found in the adult). In a recent article, Lieberman, Crelin and Klatt (1972) compared the skull features and vocal tracts of the human neonate, the adult human, the chimpanzee and a reconstruction of Neanderthal man. A number of anatomical features were found to be similar in newborn, chimpanzee and Neanderthal man, but different in the adult human.

In the adult human, the posterior third of the tongue rests in a vertical position and forms the anterior wall of the pharyngeal cavity. In the other three vocal tracts, the tongue is entirely within the oral cavity when in its neutral position. At the same time, the hard palate is relatively flat, whereas it is arched in the adult human. In the newborn, chimpanzee and Neanderthal man, the epiglottis can articulate with the soft palate. Since the opening of the larynx into the pharynx is immediately behind the oral cavity, there is virtually no supralaryngeal portion of the pharynx. The high position of the epiglottis makes closure of the oral cavity possible during feeding to allow for breathing through the nose. In the adult, there is no such approximation of the epiglottis and soft palate, and the opening of the larynx into the pharynx is such the one-half of the supralaryngeal cavity is formed by the pharyngeal cavity.

At birth, the larynx is tilted in a posterior direction (Kirchner, 1970). With the growth process, it becomes more in line with the trachea and more angulated with respect to the nasal passages and the mouth. As these modifications occur, the larynx evolves into a two-tube resonating system. Due to its tilt, the infant larynx is actually a more efficient respiratory organ, since the pathway to the lungs is more direct than in the adult.

The infant larynx, then, is not a miniature adult larynx: It is softer, more pliable than the adult larynx and is proportionately smaller in relation to the size of other structures in the body. Moreover, it is situated in a higher position in the neck relative to the adult larynx; descent of the larynx begins during embryonic life and continues until the adult position is reached at about ten years of age (Wind, 1970).

The vocal folds, which are approximately 3 mm long at birth, reach a length of 5.5 mm by the age of one year. The ratio of vocal fold length to anteroposterior diameter of the larynx is

1:2.3 in the infant as compared to 1:1.5 in the adult female and 1:1.3 in the adult male (Kirchner, 1970). The adult female ratio of 1:1.5 is reached in the infant by nine months. The high ratio in the infant indicates that there is some constriction of air flow. When an adult inhales deeply, the opening of the glottis is almost equal in size to the lumen of the trachea; there is no obstruction of air. In the infant, the glottal opening cannot approximate the size of the lumen of the trachea during inspiration. Since the infant can only take in a small volume of air with each breath, the rate of respiration is rapid. In vocalization, only a small area of the vocal folds is available for vibration. The sounds so produced by the infant are therefore much higher pitched than those of the adult. Further, it is possible that until an approximation of the adult female ratio of 1:1.5 is reached, the ability of the infant to build up and release subglottal pressure, as for stop consonants, may be somewhat restricted.

Studies of the motions of the infant vocal tract during crying suggest that mature patterns of movement are very rapidly established and some are present even at birth (Menyuk, 1971, pp. 45-47). The rudiments of coarticulatory activity are seen in the infant's anticipation of the cry: the structures are in position before the crying begins. The infant gradually learns to use the tongue, lips and soft palate to modify the configuration of the vocal tract and produce different sounds.

1.23. Cognitive development and imitation in the Sensorimotor Period

Traditionally, the infant has been regarded as a helpless human being, incapable of any form of intellectual activity. Piaget was one of the first to put forth strong theoretical notions regarding the infant's cognitive development. Central to his theory is the idea that intellectual development is a 'continual process of organization and reorganization of structure, each organization integrating the previous one into itself' (Phillips, 1969, pp. 10-11). The structural units of the theory are known as schemata. Sensory input is fed into the schemata which are, in turn, modified by the input.

Integral to Piaget's theory are three major periods of cognitive development, roughly delimited as follows: the Sensorimotor Period (birth to 2 years), the Concrete Operations Period (2 to 11 years), and the Formal Operations Period (11 to 15 years). For the purposes of this thesis, we are concerned with the Sensorimotor Period.

The Sensorimotor Period is composed of six stages, each of which is named for the process which has most recently become operative. It is recognized that each child will pass through these stages at his/her own rate.

The first stage is a brief one, lasting from birth to about one month. During this time, the infant's activity is largely reflexive in nature, whereby the built-in schemata are exercised.

The second stage, which begins at one month and lasts until about four months, involves egocentric activities which are continually repeated. New stimulus patterns are established and incorporated into the existing schemata. At first, the infant would appear to respond to all objects in an indiscriminate manner. In time, differential responses such as smiling at some objects, and touching or sucking others, begin to appear. The behaviour of the infant begins to become object-centered, but there is no general space or time, and no object permanence; there are only events. In other words, when an object disappears from view, it no longer exists for the infant.

In stage three, occurring between four and eight months, there is continual development and refinement of the schemata developed in stages one and two. Motor responses become more brief. The action appears to represent the object itself. This is motor meaning: the responses that the child makes to an object are effectively, the meaning of that object. New objects are incorporated into the existing schemata. The child begins to engage in brief searching for absent objects. This stage then, marks the beginning of object permanence.

The fourth stage represents a continual refinement of stage three and application of refined responses to new situations. This stage begins when the child is about eight months of age and lasts until approximately one year. There is the beginning of 'context-bound object permanence'. That is, the reality of the object begins to be dependent on the surrounding rather than on the infant's actions. In the realm of causality, the infant is now capable of perceiving agents other than self as causes of events.

Between twelve and eighteen months of age (stage five) the infant begins to experiment; he/she manipulates the environment in order to determine the result of his/her actions. Object permanence, space perception, and time perception continue to develop. Means that are found to be ineffective are dropped from the existing schemata.

The sixth and final stage of the Sensorimotor Period is a transitional stage to the pre-operational subperiod of the Concrete Operational Period. During the latter half of the second year of life, the child increases his/her use of internal symbols. On the basis of past experience he/she invents new methods of dealing with the environment and is able to anticipate the results of his/her actions.

Sinclair (1971) puts forth a strong argument for the use of cognitive structures in explaining language acquisition rather than the reverse. She states that once the child has established spatial displacement and object permanence, he/she is now an active person. That the child manifests the ability to foresee future results on the basis of present actions is indicative of symbolic thought.

The features of language which express affective states (stress, melody, duration and intensity) are present in the child's language at a very early stage. Sinclair believes that these features are incorporated by imitation 'before the first discrete, meaning-bearing elements occur' (p. 126).

Piagetian theory attempts to trace the development of imitation which Furth (1969) defines as

> 'The figurative correspondence of motor activity to an internal event. Imitation has three stages: (1) sensory-motor imitation, identical with perceptual accommodation, (2) deferred imitation (gesture) in the absence of the model, the beginning of symbol formation, (3) internalized imitation, the image'. (p. 261)

Although this definition encompasses many forms of imitation, we are concerned here with the development of vocal imitation. According to Piagetian theory, true imitation is pure accommodation. The appearance of 'pseudo-imitation' in stage two is thought to be a stage preliminary to the development of 'true' imitation. When an individual repeats an action that the child has just performed and then the child repeats that action, pseudo-imitation has occurred. In stage three, the infant imitates movements and sounds that are within his/her repertoire and visible on his/her own body. Mounoud (1974) cites the work of Olga Maratos, whose four-month-old subjects were able to imitate mouth movements. By stage four, the restrictions involving the imitation of only visible movements and certain sounds are lifted. The infant becomes interested in novel activities and their imitation. The imitation in stage five is of a more precise nature than before. Furthermore, patterns that are less similar to the established schemata are reproduced. Stage six marks the beginning of imitation of non-human, even non-living objects, as well as the imitation of absent objects, known as deferred imitation. Imitation of complex actions is carried out with less difficulty than previously.

Lewis (1951) cites Guernsey's (1928) study of imitation involving 200 children aged two months to twenty-one months. Using Guernsey's study and observations from five other records, Lewis divides the child's progress into three stages. These stages are, to a certain extent, compatible with Piaget's framework of imitation. The first year is divided into three stages, the first one lasting from birth to four months, the second occurring from four months of age to nine months, and the third stage beginning at about nine months. During the first stage, the infant responds to human speech by making sounds that are within his/her own repertoire. Occasionally, the child's imitated version resembles the intonational and phonetic form of the original. During stage two, vocal responses to speech either disappear completely or occur rarely, and do not reappear until stage three. In stage three, the child seems to focus on the activity of imitation itself. There is a gradual change from the imitation of familiar to unfamiliar sounds and sound groups. Intonational forms are reproduced in a more precise manner than previously, since the infant seems to be attending to pitch and stress patterns.

1.24. Biologically based theories of infant vocalization

In addition to Piaget's ideas on language development which are cognitively based, there are theories about the nature and development of speech and language which have a physiological basis. Lieberman (1967) postulates that the infant's cries have as their basis a 'hypothetical innate referential breath-group'. The adult counterpart is the archetypal normal breath-group which produces an intonational pattern that is characteristic of the unemphatic declarative sentence in English, whereby fundamental frequency and acoustic amplitude fall at the end of the sentence; the notation [-BG], designating the unmarked breath-group, is used to denote this rising-falling pattern.

Experimentally, the measurement of esophageal pressure is used to infer the relative level of subglottal air pressure. When the esophageal pressure falls, subglottal pressure falls; and when esophageal pressure rises, subglottal pressure can also be inferred to have risen. The shape of the fundamental frequency contour of the infant's cry approximates that of the typical esophageal pressure contour which rises initially, levels off somewhat and then falls abruptly. In conclusion, 'the gross variations of the fundamental frequency contour thus seem to be a function of the subglottal air pressure during infant cries' (1967, p. 43).

Kim (1968) has strongly criticized Lieberman's hypotheses. He claims that respiration is innate, but that the infant's cry is not innate to speech. He argues that controlled subglottal pressure, which can only come about as a result of the development of muscular control, is a prerequisite to speech phonation. Since the infant does not yet have the ability to control subglottal air pressure, the infant cry cannot be regarded as a speech phonation. The evidence of Wolff (1969) would tend to refute Kim's claims.

In a phonetic study of babbling in his twin daughters, Cruttenden (1970) noted that his results did not support Lieberman's breath-group hypothesis or the final fall of fundamental frequency within the breath-group. He found that as early as three months, falling-rising intonation patterns were included in the repertoires of both babies; some other variations occurred, but Cruttenden did concede that falling patterns predominated.

The results of Wasz-Höckert et al. (1968) lend partial support to Lieberman's claims. Falling and rising-falling contours were the most frequent patterns in pain and hunger cries, respectively. The birth cry was marked by a relatively high proportion of falling patterns. From one to seven months, the pleasure cry was characterized by level and rising-falling contours.

It is generally agreed that intonation is one of the first features to appear in children's speech (Shvachkin, 1948; Raffler Engel, 1965; Lewis, 1951; Lenneberg, 1967; Lieberman, 1967; Tonkova-Yampol'skaya, 1969; Crystal, 1972, 1973a, 1973b). The first patterns are similar to those occurring over whole sentences (Raffler Engel, 1965; Lenneberg, 1967; Tonkova-Yampol'skaya, 1969). Later on, patterns, such as may occur over a word, appear (Raffler Engel, 1965).

Shvachkin (1948) states that '"the meaning" represented by the complex experience of denotative, affective, and functional similarity of perceived objects is a semantic unit of the earliest child speech' (p. 93). He cites several instances of the semantic function of intonation in both comprehension and expression. Rhythm is said to acquire a special semantic function at about six months.

Lenneberg, Rebelsky and Nichols (1965) suggest that crying and the appearance of cooing are governed by maturational factors. A comparison of the vocalizations produced by children of hearing parents and children of deaf parents revealed no essential differences up to the age of three months. This was even true of one subject who was later discovered to be deaf. A wider range of crying behaviour was reported in the children of deaf parents. It was thought that this was likely a reflection of the acoustic stimuli present in the homes of the deaf families and of the inconsistencies in the response of the deaf parents to the cries of their infants. Although all of the deaf families had sound-to-light transducing devices, the arrangement differed from home to home. These devices would cause a light to flash if the noises made by the baby were greater than a given intensity level. In some homes a light would flash only in one room, whereas in one home lights were set up at different places within the house. In two other homes, the light would flash illuminating the baby's room, as well as his face. Ramey and Hieger (1972) discuss the possibility of the flashing light acting as a reinforcing stimulus for the babies' vocalizations.

There are many theories which have been developed to explain why the infant vocalizes (e.g. Mowrer's autism theory, feedback theories). Since there is little definitive evidence bearing on explanatory principles, an examination of these theories will not be attempted here.

1.25. Methods used in the study of infant vocalizations

While some investigators have chosen to theorize about language acquisition in the infant, others have chosen to collect data on the subject. Several approaches have been employed in the past for the collection of data on infant utterances. Early observations were contained in diaries (Darwin, 1877; Lewis, 1951). Much of this data is extremely valuable from a descriptive standpoint; however, in many cases the author's own child was involved, and thus some of the accounts are not as objective as they might otherwise have been.

Irwin and Chen (1946) conducted a longitudinal study of phonemic development in infants. The subjects were observed in their homes, and vocalizations that occurred on thirty breaths or respirations were transcribed using a modification of the International Phonetic Alphabet. This method was likely the best possible in view of the recording equipment that was available at the time; however, now that efficient, high-quality equipment is available, other methods of data collection have become more popular. Furthermore, the study was criticized by Lynip (1951) for the use of the IPA, a system used to transcribe mature speech, in describing infant utterances:

> '...it is totally impractical to try to express in adult sounds an utterance of an infant prior to his speech maturation. Infant utterances are not like any of the well defined values of adult language. They are produced differently and they are shaped differently, their relationships with adult sounds are at first only fortuitous. Infant sounds cannot be described except in terms of themselves. There is no International Phonetic Alphabet for the utterances of a baby.' (p. 226)

In order to overcome some of the problems of human error in the analysis of speech, Lynip used a magnetic tape recorder in combination with the sound spectrograph for the analysis of one infant's vocalizations throughout the first year of life. Winitz (1960) contended without reasonable cause or corroborative evidence, that Lynip's assumption regarding the use of phonetic transcription systems and the fallibility of the human ear was 'illogical and unwarranted' [sic] (p. 179). Ten graduate students in speech pathology were asked to transcribe a sample of infant vowel sounds. Thirty-one vowels agreed on by more than seven judges were subjected to spectrographic analysis.

Graphic plots of Formant 1 _vs_ Formant 2 revealed a displacement of the thus constructed vowel triangle upward and to the right of the standard adult triangle. There was some overlap of formant frequencies of the different vowels, and considerable variation was observed. Winitz appears to have misunderstood Lynip's basic tenet regarding the fallacy of describing infants' sounds in terms of an adult model.

It is generally recognized by present-day linguists that the production of an IPA for infant utterances is a formidable task, and many have been experimenting with more descriptive frameworks (Gruber, 1966; Bullowa, Jones and Bever, 1964; Ringwall, Reese and Markel, 1965; Stark and Rose, 1974; Bush et al., 1973). Ringwall, Reese and Markel (1965) analyzed the vocalizations of forty three-day-old infants using distinctive features: The reliability of this method was high (although its validity may be suspect), and its use appears justified since it does not impose a rigid adult model on a developing system.

Bullowa, Jones and Bever (1964) utilized a somewhat different method: Developmental observations were made of neurological and sensory responses to visual, auditory, tactile and kinesthetic stimuli, all observations being documented on film. Half-hour sessions of spontaneous activity of the subjects in their homes were tape- and film-recorded; an observer dictated the finer details of the infants' behaviour that could not be captured by the camera. These data were to have been re-synchronized in the processing stage. Additional information regarding recent events occurring in the household and about the infants' condition was collected. The authors hoped to determine the development of paralinguistic features such as tone of voice, loudness and rhythm, as well as the development of phonemic features (for which a linguist was devising a notation). They also wished to determine the mutual influence of the mother's and child's patterns of speech. A further aim was to discover whether there were any consistent relationships between the development of vocal to verbal behaviour and other behaviour patterns. The results of this study have not been published to date; it appears that such a mass of information was assembled that analysis and ultimate synthesis of the data became too formidable, and the study was essentially abandoned.

The sound spectrograph, as noted earlier, provides an objective method for examining speech and is invaluable for the analysis of infant vocalizations. Nevertheless, its use with large samples is laborious and time-consuming. Alternatively, computerized analog-to-digital devices have been used successfully by Sheppard and Lane (1968) in the analysis of utterances collected in a sound-proof setting; however, their technique is not applicable to data gathered in a normal home environment, since available instrumentation is incapable of filtering out background noise.

1.26. Studies of infant vocal output

Irrespective of method, there is an ever increasing amount of information available on infant vocalizations. These studies can be divided into two major categories: (1) acoustic attributes, and, specifically, (2) intonation patterns.

1.261. Acoustic studies

A great number of studies have been devoted to the characterization of crying utterances, since it has been established that the quality of the newborn infant cry can be used in determining the presence or absence of abnormalities such as brain damage and certain genetic disorders such as Down's Syndrome and the Cri du Chat Syndrome (Wasz-Höckert et al., 1968). Infants who have experienced anoxia at birth also exhibit abnormal crying patterns for some time after birth.

Vuorenkoski et al. (1971) established a rating system for infant pain cry responses which could be used to assess the degree of abnormality of the cry. There was a strong correspondence between the cry score and diagnosis. Measures of the cry score over time revealed the possibility of the use of the rating system in following the clinical course of certain diseases.

Fairbanks (1942) analyzed the fundamental frequency characteristics of the hunger cries of his infant son. On each monthly birthdate for the first nine months of his life, the baby was deprived of his regular two o'clock feeding; the ensuing cries were recorded and analyzed. The mean fundamental frequency recorded was 556 Hz, and a range in frequency from 63 Hz to 2631 Hz was observed over the nine-month period. A rapid increase in fundamental frequency occurred during the first half of the nine-month period. This was followed by smaller, irregular changes in the second half of the observation period. The author plotted frequency distributions of the fundamental frequencies produced by the infant at each month. The distribution at one month resembled a normal curve, but the subsequent distributions were more irregular and of higher variability.

In his account of the natural history of crying based on observations of eighteen infants, Wolff (1969) describes a basic cry, from which he contends all other cry and non-cry vocalizations evolve. A rhythmical cry, often called the hunger cry, is observable within one-half hour of birth and consists of a cry (600 msec), a period of silence (200 msec), a short inspiratory whistle (100-200 msec) of a higher fundamental frequency than the first cry, and then a brief rest before the initiation of the next cry cycle (p. 82). The fundamental frequency of this cry ranges from 250 to 450 Hz with a strong band of energy between 350 and 400 Hz. Fundamental frequency rises slightly at the beginning of the cry and then tapers off towards the end.

A variation on the basic cry is the 'mad' or 'angry' cry, which has the same temporal sequence but is turbulent due to excess air being forced through the vocal folds. The pain cry is characterized by a sudden onset of long, loud crying, and an 'extended' period of 'breath holding in expiration', followed by an inspiratory gasp (p. 85). Subsequent cries vary in duration, and the infant eventually cries according to the basic pattern previously described. The cry of frustration, such as may occur following the removal of a pacifier, is characterized by a cry (initially long and drawn out) followed by an inspiratory whistle.

While knowledge of the crying behaviour of infants has advanced considerably over the past decade, the topic of non-crying utterances has been seriously neglected. In an investigation of speech development in Japanese infants, Murai (1960) noted that the first non-crying utterances appeared at 1.5 months. Spectrograms of these utterances revealed considerable energy at the lower frequencies, while the higher frequencies sometimes contained no energy whatsoever. The average duration of such utterances was under 400 msec. These early utterances were closely related to respiratory rhythms. Later, in the babbling stage, utterances became shorter in length and thus somewhat independent of respiratory activity. A study (Nakazima, 1962), involving Japanese and American infants, confirmed the appearance of non-crying utterances at the age of about one month. The rhythm of phonation was observed to be greater than that of respiration with one period of phonation lasting from 600 to 800 msec, while one period of respiration lasted from 400 to 600 msec.

Wolff (1969) observed that new non-cry patterns first appear just before the infant begins to fuss. These patterns are later practiced when the infant is in a contented state, 'but until at least the end of the third month, vocal novelties appear as if they were discovered only in the context of moderate discomfort, became autonomous from a particular state by repeated practice, and then were incorporated into the ensemble of non-cry vocalizations' (p. 99). Non- cry vocalizations are characteristically more complex and of longer duration than rhythmical cries. The fundamental frequency may be doubled or halved in the middle of the utterance and the terminal portion usually has a level or a rising fundamental frequency according to Wolff's description.

Sheppard and Lane (1968) investigated the prosodic features of fundamental frequency, duration and amplitude in the vocalizations of two infants, one male and one female. Continuous recordings of the infants' vocalizations were made from the time of birth until the age of five months. The material collected was sampled and processed using analog electronic devices.

The fundamental frequency of the male infant dropped from 438 Hz at birth to 411 Hz at twenty-one days, then rose again to 455 Hz by forty-five days, and stabilized at approximately this value for the remainder of the study. The fundamental frequency of the female infant dropped from 401 Hz at birth to 384 Hz at twenty-one days and then rose to 420 Hz by forty-five days, where it likewise stabilized for the duration of the study.

Coefficients of variation were computed between and within utterances for each of the prosodic parameters. The coefficients of variation in fundamental frequency both between and within utterances remained essentially constant. Thus, the fundamental frequency of the infant did not vary more (or less) between or within utterances with age. In fact, approximately two-thirds of the readings of fundamental frequency for a particular utterance were within ten percent of the mean value. The average coefficient of variation in amplitude within utterances stayed nearly constant; however, the variability in amplitude within utterances was greater than the variability in fundamental frequency within utterances. The arithmetic and geometric means for duration were, respectively, 550 msec and 290 msec for the male and 552 msec and 286 msec for the female. The differences between the two means for each subject were present ostensibly as a result of the highly positive skewness of the frequency distributions of the utterance durations. The coefficient of variation in duration between utterances decreased with age, indicating that the average duration of utterances within a sample stabilized with age.

The values for the duration of the average utterance reported by Sheppard and Lane correlate fairly well with those of Murai (400 msec) and Nakazima (600-800 msec). Ringwall, Reese and Markel (1965) found that the average infant utterance was shorter than 350 msec. Any variation in these values is due to the difference in age of the subjects and the frequencies of occurrence of different lengths of cries. Handford (1972) found that the duration of non-cry utterances increased exponentially with age.

A drawback to the Sheppard and Lane study is that the recording environment was not a natural one. The infants were kept in plexiglass air cribs, since these afforded a more optimal environment in terms of attenuation of outside noises. Many of the interactional sequences which might have occurred in a more normal situation were therefore not possible to obtain. Furthermore, since there were only two subjects involved in the experiment, one must be wary of generalizing with respect to the results. Moreover, no attempt was made in the computer analysis to distinguish cry and non-cry vocalizations. Yet, in explaining the possible sources of developmental trends, the authors attribute the initially high fundamental frequency to the frequency of unconditioned-reflex crying responses. It is suggested that this type of crying decreases in frequency with age, as does the fundamental frequency. Following this, a new class of operant cries appears, controlled by environmental events. One would have to separate the results for the two types of vocalizations in order to determine whether this idea is tenable.

A second explanation regarding a possible source of a developmental trend involves the idea that increases in area, thickness, and length of the vocal folds with age would lead to an initial drop in fundamental frequency. The successive occurrence of an increase in subglottal pressure with age would result in an increase in fundamental frequency. Fairbanks (1942) postulated that the increase in fundamental frequency must be due to 'variation in vocal fold tension rather than of variation in length and thickness' (p. 231). He suggests that this may be related to psychological conditions or, those being constant, to an increased capability to exert muscular tension in and adjacent to the larynx. This, he notes, is in agreement with the rapid neuromuscular development which takes place during the first year of life. He postulates that the plateau in fundamental frequency could be attributed to the negative acceleration of neuromuscular growth coincident with the less negatively accelerated continuation of dimensional growth. In view of what is known of the mechanisms of laryngeal action and of laryngeal development during early life, any explanation of the fluctuation of fundamental frequency in the first year would have to be based on a combination of the ideas presented above.

Handford (1972) studied the development of fundamental frequency, within-utterance range and duration in the non-cry utterances of six five to 15-week-old infants. Two trends were evident in her data: the first was an exponential increase of duration with age, and the second was a linear increase of within-utterance range with age. Within-utterance range was found to be dependent on the amount of fluctuation and the duration of the utterance. A criticism of these findings is that utterances were analyzed irrespective of the intonation contour which they exhibited. This may well have obscured some important trends with respect to the variables studied and to the statistical tests (noted above) carried out. Furthermore, the variable of duration was not included in the statistical analysis; this variable may be important in terms of infants' vocal reactions to objects.

1.262. Intonation studies

Thus far we have discussed some of the isolated acoustic features of the speech signal of the infant. Given a certain behavioural context, the infant modifies his/her vocal output, such that different states appear to be characterized by specific 'groupings' of acoustic features. Information regarding actual intonation contours and their development during the first year of life is relatively sparse. Crystal's (1973a) review discusses this problem and notes that in many instances the available information is anecdotal, at best.

Pike (1949) purports to have demonstrated that infants model their intonation patterns after the patterns employed by their parents. Pike and her husband avoided the use of the rising intonation contour ('baby talk') in the presence of their daughter, Barbara, who was 'taught' to produce a falling intonation contour on the words 'baby', 'Daddy', 'Mommy', and 'Judy'. The experiment was begun at the time Barbara was 'ready to learn to speak' (p. 22). Since no age is mentioned, we might assume from the data given that the child was between nine and fifteen months of age. At one point in the experiment, the family had occasion to leave Barbara in the care of neighbours for a period of four days. Because the neighbours were unaware of the experiment, they employed rising intonations in their speech to Barbara, who in turn began using them in her own speech. When the parents returned and the experiment resumed, Barbara again employed falling intonations in her speech, although she frequently employed the rising intonation patterns as well. The situations in which the different patterns were employed were not specified by the author. This anecdotal account would indicate that children are capable of mimicking pitch at a very early age and that those intonation patterns employed by the individuals having the most social contact with the child will be learned first.

Weir (1966) notes that the utterances of young children can be segmented into 'sentence-like chunks, regardless of the intelligibility of the utterance to an adult listener' and hypothesizes that intonation patterns are perceived and learned early in life 'perhaps independently of the segmental phonemes' (p. 153).

Regarding the effect of different linguistic environments on language acquisition, Weir and Maccoby recorded four infants: one Chinese, two Arabic and one American, between six and eight months of age. They were able to identify the Chinese infant on the basis of 'distinct pitch patterns' but could not distinguish the Arabic babies from the American baby (p. 155). A further study involving fifteen babies (five Chinese, five Russian and five American) was in progress at the time Weir's paper was presented. Preliminary results indicated that at 6.5 months of age the Chinese subject used a different suprasegmental pattern from the Russian and American babies: whereas the Russian and American babies showed little variation in pitch over individual syllables, the Chinese infant exhibited much variation over single vowels. The pitch of the Russian and American babies' utterances varied 'over a number of syllables' (p. 156).

In contrast, Nakazima (1962, 1966) found no meaningful differences in the speech of Japanese and American infants before the age of one year. During the 'Repetitive Babbling Stage' (six to eight months) the use of whispers and high pitch was common, as were variations on a single sounds. Imitation of parental intonation patterns occurred, but there was no pitch shift as suggested by Lieberman (1967). Between nine months and one year conversation-like changes in pitch and stress were noticeable. From about one year of age, differences in intonation were observed between the Japanese and American infants. It was contended that the prosodic system of the parents' speech was beginning to influence the infants' speech development.

A cross-sectional study on the development of speech intonation in the first two years of life was carried out by Tonkova-Yampol'skaya (1969) employing 170 subjects. Utterances were recorded on magnetic tape and analyzed using an intonograph. Each sound intonogram contained a sound oscillogram (with 2-msec time divisions) and tracings of fundamental frequency and intensity. Behavioural observations made during the data collection stage were used as an aid in the interpretation of the results. Throughout the first month of life, cries indicated discomforts such as hunger, pain and wetness. In the second month, comfort and discomfort sounds could be distinguished. During the third month, sounds of happiness and laughter appeared. From this time until the sixth month, vocalizations indicated discontent, happiness, placid cooing and laughter. During the second half year of life, new expressional forms appeared, such as exclamatory delight and calm satisfaction. Although a requesting form of intonation appeared at about seven months, a questioning intonation did not appear until well into the second year.

Since the intonograms of the infants revealed a gradual approximation to adult intonation patterns, it was decided to compare the infant intonation patterns obtained with those of adults. Four basic adult intonation pattern configurations were classified as follows:

(1) fundamental frequency and intensity varying together and rhythmically:
e.g., offense, remonstration, threat.

(2) fundamental frequency rises and then remains at a certain level: intensity increases and then decreases;
e.g., assertion, enumeration.

(3) fundamental frequency rises, falls and then rises again: intensity falls, rises and then falls again;
e.g., surprise, consternation, questioning.

(4) fundamental frequency rises sharply, falls abruptly at the end of the sentence;
e.g., command, persuasion, invitation, request

based on Tonkova-Yampol'skaya (p. 131, 1969)

Table II shows the infant intonation patterns and their adult counterparts.

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Insert Table II about here.

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Tonkova-Yampol'skaya claims that the newborn cry, at first lacking in meaning, quickly acquires the meaning of discomfort. Fundamental frequency and intensity are initially undifferentiated. The intonation of discomfort in the child fully coincides with that of the adult. It is further suggested that

TABLE II

INFANT INTONATION PATTERNS AND

THEIR ADULT COUNTERPARTS

Infant Intonation Pattern	Age of Appearance	Adult Counterpart
indifferent	2-7 months	assertion / enumeration
happiness, differentiated into exclamatory delight and contented noises	before 6 months after 6 months	consternation
expressive calm cooing	7 months sharp increase in occurrence at 9 months	affirmation
requesting	7 months to end of 2nd year	adult emotional request
insistent	10 months occurrence increases with age	persuasion, insistent command
questioning	2nd year	questioning

based on Tonkova-Yampol'skaya (1969, p. 133-135) this primary intonation structure may be of a biological nature. Adult speech is characterized by differentiations of fundamental frequency and intensity. That this differentiation occurs is taken as evidence for cortical control of the speech apparatus. Furthermore, since the intonation patterns used by children appear to be based on those of adults, one could infer the 'establishment of conductive pathways between verbal-auditory and vocal-motor cortical analyzers and speech organs' (p. 137).

Wasz-Höckert et al. (1968) classified their data into five different intonation contours: rise-fall, fall, rise, level and fall-rise. An additional category called 'no form' was added for classification of those cries which were voiceless, or contained glottal plosives or sounds of less than 400 msec duration. The intonation contours were defined by a 'change in the pitch level, when exceeding 10 percent of the pitch during more than 10 percent of the length of the cry' (p. 10). Table III shows the percentage of each type of contour which appeared for the different cry types.

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Insert Table III about here.

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It should be evident that the studies mentioned above vary considerably with respect to age of the subjects and parameters examined. In the present study we hope to either verify or refute the claims made by researchers in previous studies

TABLE III

PERCENT OCCURRENCE OF EACH INTONATION CONTOUR
FOR BIRTH, PAIN, HUNGER AND PLEASURE SIGNALS

Age	0 - 1 month			1 - 7 months		
Cry type	Birth	Pain	Hunger	Pain	Hunger	Pleasure
Contour RF	13	23	78	18	81	31
F	31	62	1	77	4	10
R	3	8	-	2	-	8
L	36	2	11	3	1	46
FR	-	-	-	-	-	6
No form	16	5	9	-	14	-

based on Wasz-Höckert et al. (1968, p. 40) regarding fundamental frequency and duration. It will not be possible to directly compare our results for specific intonation contours with those of past studies, since we have not defined our contours in the same manner as either Tonkova-Yampol'skaya or Wasz-Höckert et al., for example; cf. Chapter Two. It should, however, be possible to compare the results of our study with these latter studies in a general fashion.

1.27. Extralinguistic factors in language development

1.271. Conditioning studies

There have been a number of studies concerned with the social and non-social conditioning of infant vocalizations. Rheingold, Gewirtz and Ross (1959) showed that vocal behaviour in three-month-old, institutionalized infants could be conditioned by simultaneously smiling, clucking, and touching the infant's abdomen after each vocalization. These three activities combined, acted as a reinforcing stimulus which very quickly raised the rate of vocalization above the baseline level. The disappearance of the reinforcing stimulus during extinction caused the rate of vocalization to return to the baseline level.

As a sequela to Rheingold's study, Weisberg (1963) demonstrated the effects of contingent and non-contingent social and non-social reinforcement on rates of vocalization in three-month-old institutionalized infants, whereby he controlled for the presence of the experimenter (E). The resulting six experimental groups were: (1) No E present, (2) E present but expressionless,

(3) non-contingent social stimulation, (4) non-contingent non-social stimulation, (5) contingent social stimulation, and (6) contingent non-social stimulation. A door chime served as the non-social reinforcing stimulus, whereas social reinforcement consisted of E rubbing the infant's chin, smiling and saying "yeah". Conditioning occurred in the two groups which had undergone contingent reinforcement, with the socially reinforced group being the most vocal.

Todd and Palmer (1968) reinforced infant vocalizations using a tape-recorded message. In one group, conditioning was carried out with an adult present, while in the other group no adult was present. Both groups showed significant increases in the rate of vocalization; however, extinction was more pronounced in the 'adult present' group. Thus it was demonstrated that although the presence of a human increases the effectiveness of vocal reinforcement, it is not a necessary prerequisite. Contrary to the results of Todd and Palmer, Ramey and Ourth (1971) found no difference in the rate of vocalization, whether or not the experimenter was present. They argue that since Todd and Palmer obtained baseline results with no experimenter present, 'it was impossible to determine from their data if the presence of an adult would, in and of itself, tend to increase the rate of vocalization during the conditioning phase' (p. 296).

Routh (1969) conducted a study involving both home-reared and institutionalized infants between the ages of two and seven months. Consonants and vowels were selectively reinforced using the procedure of Rheingold et al (1959). The three groups -- (1) consonants only reinforced, (2) vowels only reinforced, and (3) vowels and consonants reinforced -- all showed an increase in vocalization. More significantly, however, the groups which were selectively reinforced for a particular sound category showed an increase in the production of the sounds in the reinforced category.

Ramey and Ourth (1971) examined the effect of delay of reinforcement on rate of vocalization in infants aged three months, six months and nine months. Infants were randomly assigned to one of three delay of reinforcement intervals: 0 sec, 3 sec, and 6 sec. Only the 'no delay' condition was effective in producing an increase in the rate of vocalization at all ages. There was no developmental trend in the ability of the infants to cope with a delay of reinforcement.

Several people have attempted to determine the effectiveness of the various components of reinforcement employed in these conditioning studies. In a study by Schwartz et al. (1970), visual, tactile and auditory stimulation were examined separately, in combinations of two, and all together. Although conditioning occurred, there were no significant differences among the groups, indicating that no one event was more reinforcing than another. Ramey and Watson (1970; cited in Ramey and Hieger, 1972) used either a light alone or a light plus a one-kHz tone as reinforcers of vocal behaviour in ten- and sixteen-week-old infants. At ten weeks, no change from the baseline occurred. At sixteen weeks, there was a significant increase in mean vocalization which was found to be largely a result of the males' response to the light; females were not conditioned in either case.

A study by Watson (1969) involving a different modality, vision, indicated that males condition under visual reinforcement while females condition under auditory reinforcement. Hutt (1972) noted that, in her experience, female subjects were more interested in auditory patterns, while males were more interested in visual patterns. Although there are some discrepancies (such as exists between the Schwartz et al. study and Ramey and Hieger's study) among the studies mentioned, there are also some interesting consistencies (such as the males' response to visual stimuli noted above). It would be of interest to determine whether any of these findings would be borne out in the child's preference for certain toys. For example, if females are more interested in auditory patterns, perhaps they would prefer to play more with noisemakers, such as rattles or squeakers. Males, being more visually oriented, may show a preference for toys which are visually stimulating, such as mobiles.

Attempts have been made to determine whether male or female voices are differentially reinforcing for young infants. Banikiotes et al. (1972) found no significant difference in either number or fundamental frequency of vocalizations, between vocalizations that were reinforced by a taped male voice and vocalizations that were reinforced by a taped female voice. An inspection of suppression of infant vocalizations as a function of parental voice selection revealed that the preferred voice brought about a greater suppression of vocalization than did the non-preferred voice (Barrett-Goldfarb and Whitehurst, 1973). There were no significant differences in the selection of the father's or the mother's voice, except in one subject who chose the father's voice in twelve out of fifteen sessions. The subjects in this study were one year of age.

1.272. <u>Parent-infant studies</u>

Jones and Moss (1971) state that at two weeks the amount of infant vocalization is positively related to the amount of maternal speech, whereas at three months it is positively related to the amount of maternal speech following the vocalizations. This relationship is also dependent on the infant's state. There was an increase in the amount of vocalization with age, with more vocalizations occurring when the infant was in an active state: if the infant was in an active state, he/she vocalized more alone than in the presence of the mother. These findings are similar to those of Nakazima (1962, 1966), who also found that his subjects tended to vocalize more when they were alone.

Jones and Moss (1971) suggest that the change in the relationship between infant and maternal vocalizations that occurs from two weeks to three months may be related to the increase in frequency of vocalization with age (p. 1029). At two weeks, the infant vocalizes relatively infrequently. The occurrence of vocalization is novel, and the mother responds vocally. The infant may vocalize more in order to elicit more responses from the mother. By three months, the novelty effect has abated. Further, both the infant and the mother may elicit vocal responses from each other by the use of non-vocal, as well as vocal stimuli.

Bateson (1971) observed that mother and infant typically vocalize by turns: the mother vocalizes and waits for her infant to respond before vocalizing again. The results of Jones and Moss (1971) seem to indicate that this type of conversational situation occurs at three months of age, when the degree of socialization between mother and infant has increased.

The location of the infant in the home environment has been shown to have a significant effect on the amount of vocalization (Lewis and Freedle, 1973). Vocalizations occurred most often when the infant was free of physical restraint (e.g., in the playpen, on the floor, or in an infant seat). Fewer vocalizations occurred when the infants were on their mothers' laps, in their cribs, on changing tables, or in the bathtub. The mothers' relative vocalizations were greatest when the infant was on the floor, on the changing table, in the bathtub, or on the sofa, and least when the infant was in the playpen, crib or jumper. It is worth noting that while the mother vocalized least when the infant was in the playpen, the infant vocalized most in that location. This situation is non-social and conforms with the findings of Jones and Moss (1971) and Nakazima (1962), whose subjects tended to vocalize more in similar non-social situations.

The quality of maternal care is another significant variable in the child's development. Beckwith (1971) found that infants whose mothers restricted environmental exploration and gave less verbal and physical contact, scored lower on the Cattell Scale and Motor Gesell Scale than infants who were given much verbal and physical contact and freedom to explore. Those infants who had more social contact with people other than their parents tended to have higher scores on the Cattell Scale.

The alert and sensitive mother tends to have the more responsive baby and vice-versa (Osofsky and Danzger, 1974). These researchers found consistencies in infant state and behavioural measures across situations. Similar results were obtained by Eckerman and Rheingold (1974). A comparison of the responses of ten-month-old infants to a passive person and to a responsive person revealed that the latter was physically contacted by the infant more frequently.

Moss (1967), who observed the interaction of mother and first-born infant over the first three months of life, remarks that the 'state of the infant affects the quantity and quality of maternal behavior' (p. 34). As the infant matured, there tended to be a decrease in feeding behaviour and close physical contact and an increase in attending and affectionate behaviour on the part of the mother. A number of sex differences were noted in both the infant and maternal variables studied, but when control was made for the state of the infant, most of the differences were no longer significant. Moss notes that infant's cry seemed to determine the mother's behaviour. There was a relative instability in the mother-infant system over the three-month period which was thought to reflect the uncertainty of mothers of first-born children. With time, the mother's confidence increased as she became more familiar with her infant and attachment behaviours began to develop.

Cross-cultural studies of caretaking styles have borne out some interesting claims with respect to language development. Caudill (1972) compared the caretaking behaviours of Japanese and American mothers, the latter of whom responded more quickly to their babies, irrespective of the type of vocalization, and encouraged activity and vocal responsiveness in their babies. Consequently, the American babies uttered many more 'happy' sounds than did the Japanese babies. Japanese mothers, on the other hand, were more concerned with soothing and quieting their babies; they tended to view their babies as an extension of themselves and placed more importance on physical contact and less importance on vocalization than did the American mothers, who tended to view their infants as potentially independent beings.

Although the role of the mother in the vocal development of the infant has gathered a considerable amount of attention, the role of the father has been neglected. In a study of infants up to three months of age, Rebelsky and Hanks (1971) found that the average father spent 37.7 seconds per day in contact with his infant. During this time, a mean of 2.7 vocal interactions took place. Although large individual differences were observed, even the father with the most interactions spent only about 10.5 minutes per day with his child. Just over one-half of these interactions occurred during caretaking activities.

In view of the results of Rebelsky and Hanks (1971), it does not seem surprising that the father has been ignored, given his minimal role in the child's early life. However, an observation made by Friedlander et al. (1972) cautions against overlooking the father's role no matter how minimal it may seem. In a study of infants' natural language environment in the home, it was noted that one female subject ultimately learned Spanish as a result of her father's speaking only Spanish in her presence; the subject's mother spoke to her in English. The language environment of this family had been sampled from 7 AM to 9 PM every day for a week, resulting in a 3-hour recording. The child's exposure to her father accounted for only five percent (351 sec) of the total language listening opportunities. In terms of direct address, the child was exposed to her mother 59 percent of the time and her father only 37 percent of the time. No figures are reported for the actual length of time that the child was directly addressed by her father, but we do know that it could only be a portion of the 351 seconds overall exposure to the father's speech. We must also assume that the sample obtained was truly representative of the child's exposure to her father's speech. In spite of the comparatively small amount of time that the child was exposed to her father, she had developed a grasp of Spanish by one year of age. In an informal follow-up session six months later, the child was able to name objects, follow simple directions, answer questions and could carry on a simple conversation in Spanish.

Observations such as Friedlander's cause one to question the emphasis on mother-infant interaction in child language acquisition research. It is apparent that for Friedlander's subject, the minimal exposure to the father was very important. In many families, the father is away from home during the child's waking hours. His presence therefore becomes novel to the child. In this event, the child may be more attentive to his/her father during the limited time that the father is available for interaction. This explanation is illustrative of the 'discrepancy principle' discussed by Kagan (1971) whereby:

> '...an event that is moderately discrepant from the one that generated a schema (e.g., alterations in the temporal and spatial configuration of the original stimulus) will elicit longer fixations than minimally discrepant events or events that bear no relation to the schema. A curvilinear relation is hypothesized between fixation time, on the one hand, and degree of discrepancy between the perception of an encountered event and the schema for the original event, on the other...' (p. 62)

The father in Friedlander's study could be equated to a discrepant stimulus. The discrepancy principle may account for fixation time on the part of the infant but it does not explain the quantity or quality of learning that occurs while the infant is attending to the stimulus. This would be valuable information in terms of language acquisition as well as other forms of cognitive development.

This section has attempted to describe some of the salient extralinguistic factors which are thought to influence language development. It is contended that some of these factors such as type of object (e.g. visual or auditory), or whether an object is novel to the child, may be of importance in the ultimate explanation of the results of this study. Although the aspects of parent-child interaction are not being specifically examined here, they may influence some of the results of this study and will be discussed as deemed appropriate.

1.3. Summary and statement of the problem

The literature regarding the so-called prelinguistic stage of development includes a number of studies concerning the development of the child's phonemic system. Since we are primarily concerned with suprasegmental development, these studies were not discussed in this review. In contrast, information regarding the development of intonation and the influence of the child's ecosystem on this development is scarce and in many cases anecdotal. Studies of the crying behaviour of infants have shown that these latter areas deserve exploration, since many of the findings could be of value in diagnostic procedures, as well as providing additional information on language acquisition and the development of communicative competence in general.

Linguists have traditionally applied the adult terms 'phoneme', 'syllable' and 'word' to infant utterances, even though these terms have little relevance to infant speech (Crystal, 1973b). A concern with the articulatory correlates of speech has led many students of child language to ignore any developmental trends occurring in the realm of intonation and meaning. The tendency to dismiss the whole first year as the 'prelinguistic' stage has meant that many important milestones in language development may have gone unrecognized. We have yet to adequately explain why, by the end of the first year, the infant appears to have mastered many of the prosodic nuances of his/her language. Furthermore, many questions with regard to semantic development in the first year remain unanswered.

The process of vocal differentiation in the infant has been described by several researchers, notably Lewis (1951) and Wolff (1969), but only in relation to internal states such as hunger, pain and pleasure. Instances of differential vocalization in response to objects and people have been mentioned in the literature, but no systematic studies of the phenomenon have been made. The intent of the present study is to examine the certain aspects of vocal differentiation in the infant's response to objects in his/her environment. For the purposes of this thesis, the term 'vocal differentiation' is defined to be the developmental process by which the infant comes to represent different states or events by different types of utterances; 'differential vocalization', on the other hand, is defined to be an act which occurs when the infant's vocal output differs significantly from one situation to another.

The goal of this thesis is to determine if the infant modifies his/her vocal output in any way, in response to an object. The context of subject vocalizing alone (S) will be used as a baseline or control condition in order to determine if there are significant differences in the subject plus object condition (SO). If differential vocalization occurs, then the next step is to examine its change over time, which may be due to the influence of developmental factors.

In the examination of the infant's response to objects, it will also be determined whether or not the infant's vocal response varies from object to object, and, if this is the case, whether such differentiation can be demonstrated over time.

The contrasts of the different situational contexts will be carried out by comparing intonation contours that occur in the different contexts. The duration and within-utterance range of fundamental frequency will also be taken into account in the comparisons. An attempt to assess any developmental changes that may be occurring with respect to the variables mentioned above will be made using chronological age, in addition to mental and motor scores (as measured by the Bayley Scales of Infant Development), as covariates.

CHAPTER 2

Method

2.1. Experimental design

The present investigation is based on a larger study of the development of speech sound production in the infant and the ontogenesis of the sound-meaning correlation. In the larger study, nineteen infants (twelve males and seven females) served as subjects. All were normal, 'first-born', full-term infants who were referred to E by local physicians. One of the infants had an older, adopted sibling.

In the main study, E visited each infant in its home, beginning at the age of five weeks and proceeding on a biweekly basis until the infant reached approximately one year of age. At each visit, a fifteen-minute tape recording was made of the infant's vocalizations. In order to provide a measure of each infant's developmental status, the Bayley Scales of Infant Development (1969) were administered every three months, beginning at the age of three months. Each infant's home environment was evaluated at four-month intervals using the Heimler Scale of Social Functioning (Rev. II, 1967); the first in this series of tests was administered around the time of the child's birth. In addition, the parents kept records on their child's health status and development.

The vocalization data included the infant's spontaneous utterances, as well as interactive sequences with adults or objects. In the analysis, every utterance was categorized according to the situation in which it occurred; i.e., infant alone; infant vocalizing to mother, father, adult female, adult male; and infant vocalizing in the context of an object. Utterances were sampled from each of these categories and subjected to both perceptual and instrumental analyses.

Two of the situational categories mentioned above are examined in the present study: infant alone (S), and infant vocalizing in the context of various objects (SO). The context of infant alone served, for comparative purposes, as a pseudo-baseline condition. The utterances produced in the context of objects were contrasted with each other and with those utterances produced in the infant alone condition. The contrasts were carried out using a computerized multivariate analysis program, in which the variables of fundamental frequency of beginning- (BEGIN), middle- (MP), and end-points (END), duration (DUR), within-utterance range (RANGE) and contour were examined simultaneously. The effect of each variable could be determined, as well as the combined effects of the different variables. Contrasts were examined for each subject both within and across age levels.

In order to resolve some of the analytic problems encountered with small sample size the SO-data was recoded into four major categories, the characteristics of which would appear to correspond with the sensory modalities by which the objects would be primarily, or at least most likely, apprehended:

Visual (mobiles, tape recorder, microphone, pictures, reflections, etc.), Auditory + Visual (music box, radio, etc.), Tactile + Visual (stuffed toys, blankets, blocks, etc.), and Auditory + Tactile + Visual (rattles, bells, 'squeaky' toys, etc.). A technique known as Multiple Classification Analysis (MCA; cf. Andrews _et al_, 1967) was used to determine whether there was any difference among the object groups themselves, or between the _S_ and various _SO_ groups, across all variables.

The MCA program was also used to examine developmental trends with respect to the variables. Each variable was considered with respect to three separate measures of development: chronological age, Bayley Mental Score, and Bayley Motor Score. Intersubject differences were also examined via MCA. In addition, the distributions of the various contexts and contours were determined, as well as the development of the intonation contours over time.

The vocalizations of eighteen subjects were examined in this study. Subject 108-M from the larger study was rejected because it was thought that the classification of his utterances with respect to context was unreliable; in addition, this subject was unavailable for an interim 6-month period and therefore his data are longitudinally incomplete. He constantly kicked at a rattle which was suspended over his crib. The tapes of these sessions amount to rattle noise interspersed with vocalizations. According to the criteria established for the classification of utterances with respect to context, all of the utterances from these tapes should be classed as infant in the context of an object (SO). In fact, many of the utterances were classed as vocalizations in the context of a rattle even when there were other toys present in the crib. There were also a number of utterances in the SO category which should have been classed in the S category had the rattle noise not occurred.

Two of the eighteen subjects in this study: 114-M and 201-M, exhibited no utterances in the SO category. Of the sixteen subjects who did have utterances in the SO category, the number of utterances varied, as did the number of different objects. Therefore, some subjects may have only vocalized in the context of two different objects, while other subjects had as many as eleven different objects in the SO category.

2.2. Subjects

2.21. Sex and age range

The subjects for this study were nineteen infants, reduced to eighteen -- eleven males and seven females -- by the exclusion of 108-M for reasons discussed earlier. The vocalizations of ten subjects (101-F through 111-M), four females and six males, were analyzed between 5 weeks and 52 weeks. The remainder of the subjects (112-M through 201-M) were studied from 5 weeks to between 24 and 26 weeks. Of the eighteen subjects, two exhibited no vocalizations to objects, as mentioned earlier. The data of these two infants will therefore be examined only with respect to the subject alone (S) condition.

2.22. Medical history

The mothers of the infants were referred to E by local physicians on the basis of uneventful pregnancy, and no family history of gross physical or psychological disorders. All but three of the mothers had had no previous pregnancies. One infant had an older adopted sibling.

The infants were all judged to be normal, healthy babies at birth. The average Apgar score was 8 (range 6 to 10). The Apgar score is a rating system used to determine the immediate post-partum status of the infant. At one minute after birth, the following signs are rated on a scale of 0 (unfavorable) to 2 (favorable): heart rate, respiratory effort, muscle tone, reflex irritability and color. The maximum score obtainable is 10. Generally, a score between 8 and 10 indicates a healthy post-partum status. Ongoing medical and parental reports throughout the study indicated that the majority of the children remained normal and healthy. Exceptions were 107-M, 114-M and 115-F who had ongoing medical problems, and 101-F, 103-M, 104-F, 111-M, 112-M, 113-M and 201-M who had transitory health problems such as measles, flu and bronchiolitis.

2.23. Home environment and biographical information on the families

2.231. Language, education, occupation and income

The parents of the children in this study were native speakers of English and were representative of the local population in terms of education, occupation and accomodation (see Table IV), as well as income, religion and interests.

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Insert Table IV about here.

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The average income (1970) of the families was $11,500. This figure was calculated on the basis of sixteen families since three of the families had incomes which were not typical of the overall sample. The incomes of these families were: $2,600, $27,000 and $65,000. During the course of the study, two fathers changed jobs, and two of the fathers who had been students obtained full-time jobs. Table IV indicates each mother's occupation before the birth of the child. Only seven of the mothers returned to work after the birth of their child. Of these, one (117-M's mother) returned immediately, while the remaining six (from the families of 101-F, 102-F, 103-M, 106-F, 112-M and 116-F) did not return to work until their babies were six months of age or older. The mother of 106-F was the only one of these six mothers who worked full-time; the others worked only sporadically or part-time at the most.

2.232. <u>Heimler Scale results</u>

As mentioned earlier, the Heimler Scale of Social Functioning (Rev. II) was administered at intervals throughout the study. This scale gives an index of an individual's subjective view of

TABLE IV

PARENTAL BIOGRAPHICAL INFORMATION

SUBJECT ID	PARENT	AGE	EDUCATION (yrs) sec/voc/univ	OCCUPATION	ACCOMMODATION
101-F	Mother	25	3/2/0	practical nurse	1 B.R. apt.
	Father	33	3.5/4/0	tool and diemaker	
102-F	Mother	23	5/1/0	departmental store manager	3 room basement suite
	Father	24	6/0/1	insurance inspector	
103-M	Mother	27	4/0/0	secretary	house
	Father	29	5/1.5/0	warehouseman	
104-F	Mother	24	4/0/1	secretary	2 B.R. apt.
	Father	24	4/0/7	student	
105-M	Mother	28	2/1/0	secretary	1 B.R. apt. (12) condominium (24) house
	Father	27	4/3/0	fireman	
106-F	Mother	28	4/0/3	teacher	3 B.R. house
	Father	30	4/1/4	sales specialist	
107-M	Mother	24	4/2/0	secretary	suite (28) house
	Father	23	3.5/0/0	bandsaw operator	
108-M	Mother	25	4/1/0	nursing assistant	2 B.R. apt.
	Father	25	4/0/3	chartered accountant	
109-M	Mother	23	4/0/3	sales clerk	2 B.R. apt.
	Father	24	4/0/5	buyer	

TABLE IV (continued)

SUBJECT ID	PARENT	AGE	EDUCATION (yrs) sec/voc/univ	OCCUPATION	ACCOMMODATION
110-M	Mother	26	5/0/1	teacher	house (24) house
	Father	26	4/0/4	forester	
111-M	Mother	32	4/5/0	nurse	condominium
	Father	34	4/2/0	carpenter	
112-M	Mother	28	4/3*/0	secretary	house
	Father	29	5/5*/0	engineer	
113-M	Mother	21	4/0/1	housewife	apartment
	Father	29	5/0/3	student	
114-M	Mother	28	4/3/1	nurse	house
	Father	31	4/1/0	foreman	
115-F	Mother	22	4/0/3	teacher	house
	Father	23	4/0/4	Junior Administrator	
116-F	Mother	20	4/0/0	file clerk	apt. (11) house
	Father	21	4/0/0	machine operator	
117-M	Mother	32	4/0/7	lawyer	apt. (44) apt.
	Father	46	4/0/8	doctor	
118-F	Mother	27	2/0/0	clerk	house
	Father	31	2/3/0	office machine engineer	
201-M	Mother	28	4/0/0	housewife	house
	Father	35	4/0/3	insurance (clerical)	

All information regarding age and occupation was collected at the beginning of the study, before the birth of the baby.
( ) refers to moves made during the course of the study; the number in parentheses indicates the approximate age of the baby in weeks at the time of the move. * = part-time schooling.

the satisfactions and frustrations within his/her life. It indicates how positively the situations of work, finances, marriage, family life, and friendships are viewed. It also reveals the degree to which activity is inhibited by fatigue or depression; what escape routes, if any, are relied on (drugs, acting-out behaviour, etc.); and how effective the person feels himself/herself to be within his/her environment. In our study, all scores (with 4 individual exceptions) were high as expected from essentially stable middle-class families.

The data on each parent usually consisted of 4 Heimler schedules administered at intervals of approximately 4 months. The first was most usually done pre-natally, and on rare occasions shortly after the birth of the baby.

Two trends appeared in the data. The majority of the fathers demonstrated more positive perceptions of their lives at the end of the first year than at the initial interview (either pre- or post-natal). The majority of the mothers, on the other hand, showed higher positives at the first interview and lower scores at the end of the first year.

Full-year scores for fathers that could be characterized as rising in positive outlook or maintaining a high initial level occurred in 9 cases. In 3 cases there was a steady decrease of positive assessment of life situation. There were fluctuations within the remaining series of scores. Six of these showed the trend of low first score and high final report, two remained level, and one showed a drop in perceived positives during the course of the year.

None of the mothers maintained an overall level score for the series of schedules. Six showed consistent decline in scores, while only two increased consistently. The remaining 11 mothers exhibited fluctuating scores for the series; 7 of these ended with lower scores than on the first schedule.

There were only four schedules in the entire body of data which evinced a 'crisis' situation (these represent 2 fathers and 2 mothers); continuing contact with the four families demonstrated the passing nature of the difficulties in all but one case. One mother was very depressed for several months due to a combination of anaemia, probably post-partum depression, and a very tenuous financial situation. She showed marked improvement by the end of the first year. None of the crises were severe enough to warrant professional intervention other than the routine services of the family physician.

2.233. Household organization

The majority of the households in the study were organized along conventional lines. The husband was responsible for supporting the family financially, while the wife attended to household tasks and cared for the baby. The degree of involvement of the father in household activities varied with each family. Slightly more than half of the fathers took an active part in caring for the baby. With the exception of 117-M, whose mother worked, the children were rarely left with caretakers other than members of the extended family (e.g. grandparents).

Although 201-M was the only child who had a sibling, 107-M's five-year-old aunt stayed with that family from the time that the baby was about four months old until the end of the study. Pets kept in four households (107-M, 112-M, 115-F and 201-M) were occasionally present during the taping sessions.

The major orientation in most of the homes was toward family- and social-centered activities. Only the family of 107-M tended to be child-centered. In two families (111-M and 117-M), business activities played a dominant role. The fathers of 103-M and 104-F were both students, and thus much of those families' lives revolved around the fathers' schoolwork. The father of 104-F joined the work force about midway through the study, thus changing the orientation of that family.

2.234. Maternal care

The mothers were generally consistent in the way that they cared for their infants but there were exceptions. The mother of 101-F was anxious and would lose patience with the baby. This situation improved after the child was about five months old. The mother of 113-M had some problems in deciding how to handle her baby. Table V shows each mother's preferred mode of stimulation of the child (cf. Clarke-Stewart, 1973), as this may have some bearing on the child's involvement or lack of involvement with objects in its environment. This information is based on observations of the mother-child interaction over the entire study as well as maternal utterance counts. Where no strong preference for one mode was evident, the two most predominant methods of stimulation are noted.

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Insert Table V about here.

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Most of the infants were free to explore their environments. There was a general concern on behalf of the mothers that their children would not be involved in situations that might cause bodily injury, but only the mother of 113-M tended to be over-protective of her child. Only 106-F was physically restricted to her playpen in the living room, and later to the kitchen or recreation room. Portions of 107-M's home were blocked off.

Most of the children had an abundance of stimulating playthings, both purchased and homemade. The mothers varied in their abilities to use objects in the environment to advantage: some were very creative while others were not. They also varied in their understanding of their own child's functioning and their ability to determine what activities would be stimulating for the child.

TABLE V

MOTHERS' PREFERRED MODES

OF STIMULATION

SUBJECT ID	MODE
101-F	material
102-F	verbal
103-M	verbal/physical
104-F	verbal/material
105-M	material/verbal
106-F	material/verbal
107-M	verbal
108-M	physical/material
109-M	material
110-M	physical/material
111-M	physical/material
112-M	verbal
113-M	physical
114-M	verbal/material
115-F	verbal/material
116-F	material
117-M	verbal
118-F	physical/verbal
210-M	verbal/physical

2.3. Procedure

2.31. Data collection

2.311. Instrumentation

A Nagra IV-D portable tape recorder, AKG D202E directional microphone and Ampex 434 low-noise tape were used in the collection of data. The tape recorder was calibrated to give a flat response (± 2 dB) over a frequency range of 50-10,000 Hz. Every attempt was made to place the microphone approximately 36" from the infant's mouth throughout recording sessions.

2.312. Taping situation

The biweekly recordings were made in the infants' homes. Every effort was made to preserve the natural home setting. Any alterations made were only for the purpose of reducing noise which would interfere in the analysis. Where there was heavy traffic outside the infant's home, recording was carried out in the quietest room. Radios, TVs and noisy appliances were turned off.

In order to obtain as much vocalization data as possible, each mother was consulted as to the times during the day when her infant was most active. Every attempt was made to schedule recording sessions during these active periods. Efforts were made to carry out recording sessions when both parents were at home; however, as most childrens' active periods occurred when the father was out of the home, the mother was usually the only parent present during recordings. Although E and the tape recorder remained out of sight in many of the sessions, E did occasionally interact with the infants.

The goal of each taping session was to obtain a fifteen-minute recording of the infant's vocalizations under various conditions. The tape recorder was turned off if the infant engaged in inappropriate vocal behaviour (e.g., hiccoughing, coughing, fussing, or crying for long periods), or if the level of the ambient noise became too high (e.g., trucks nearby, planes overhead, construction noises, noisy neighbours). The fifteen-minute recording, then, did not always represent fifteen consecutive minutes. If the child was obviously too fussy or too sleepy for a good recording to be obtained, E would reschedule the taping session.

E kept records regarding the time and location of the tape sessions, people, objects and animals (if any) present, the baby's mood at the time of recording, and the different interactions that took place.

2.32. Spectrographic analysis

2.321. Instrumentation

The tapes were reproduced on an Ampex 440B tape recorder which was calibrated to give playback response characteristics essentially identical to the Nagra IV-D tape recorder. Spectrographic analysis was carried out on a Kay Sonagraph, Model 7029A, with a frequency range of 80-8,000 Hz.

2.322. Selection and classification of utterances

In the early phases of data analysis, all audible, harmonic portions of non-crying utterances were analyzed in which there was no overlap of another person's voice and/or background noise. Since the production of spectrograms is a time-consuming process and since there was a large amount of data to be analyzed, a sampling procedure was introduced. Under this method, a maximum of fifteen and a minimum of five utterances were analyzed per tape for each context.

Every utterance was classified according to the context in which it occurred. These contexts were determined from comments on the tape and from E's record of the recording situation. They were defined as follows:

(1) Child alone - S: child vocalizing with no apparent referent

(2) Child with object - SO: child vocalizing while fixated visually on, or touching an object; if the object was a noisemaker, an utterance emitted within 3 seconds of the noisemaker was classed as SO. Utterances were analyzed for a maximum of 3 objects per session: SO1, SO2 and SO3.

(3) Child with adult - SA: subcategorized into child with mother - SM, child with father - SF, child with adult female - SAF, child with adult male - SAM. In order for an utterance to be classed in this category the child had to vocalize within 3 seconds of the adult's vocalization.

Although criticism of the definitions in (3) is not unwarranted, it was thought that a broader definition such as child in the presence of an adult would produce more erroneous classifications of utterances, since one adult was usually present during taping. Also, differential responses, if such occurred would be obscured by such a classification. In the initial phase of the investigation, the maximum interval between vocalizations of adult and child was 5 seconds. As the child's attention can shift even within this time interval, a shorter interval of 3 seconds was adopted.

2.323. Reliability of context for the objects

The reliability of the object context presented a problem with certain subjects. A few of the mothers gave good commentaries on the activities of their children with the objects in the environment; other mothers gave few comments. In the absence of directive comments on the tapes, the classification of utterances as SO was often subjective. This may have resulted in some utterances being classed as SO when they should have been classed otherwise. In the same manner, some utterances which should have been classed as SO may have been included under some other context. However, it seems unlikely that the data are skewed in any given direction.

2.324. Production of spectrograms

Narrow-band spectrograms (45-Hz bandwidth filter) were produced for each utterance. A 500-Hz calibration tone was included on each spectrogram. The record, reproduce and mark levels were adjusted for each spectrogram. In this manner, background noise and signal distortion could be minimized. The gain control was adjusted such that the peak reading of the VU meter was between

0 and -2 dB. Spectrograms of the reference tone were made at 3-hour intervals to ensure that the machine was functioning consistently.

2.33. Measurement of spectrograms

2.331. Measurement of fundamental frequency

Fundamental frequency was measured at either three or four points in each utterance: beginning-point (BEGIN), first middle-point (FMP), second middle-point (SMP) and end-point (END). BEGIN and END were defined, respectively as the onset and disappearance of at least the third harmonic. MP was defined as a change in sign of the slope of the fundamental frequency (F_o) contour. When two or more changes occurred, the two changes that were considered the most characteristic were chosen for measurement. If there was no fluctuation in the F_o contour, the MP value was taken as the average of the BEGIN and END values.

In the measurement of the acoustical properties of adult utterances, the calculation of F_o is usually based on the measured value of the tenth harmonic. Measurement error at this level is usually minimal. In infant utterances, measurement of F_o based on the tenth harmonic is often not possible since this harmonic is not present in most cases. In order to minimize measurement error, the highest visible harmonic (generally the fifth) was chosen for measurement in this study. The distance between the baseline and the chosen harmonic was measured with calipers. This distance was then read against a template (based on a calibration tone of 500 Hz) in order to determine the value of the measured harmonic. The value obtained was then divided by the number of the harmonic in order to obtain the fundamental frequency. The standard error using this method was found to be ±30 Hz.

2.332. Calculation of within-utterance range

The value of within-utterance range was equal to the difference between the maximum and minimum values of F_o for each utterance. This variable is denoted as RANGE throughout the results and discussion sections.

2.333. Measurement of duration

The duration (denoted as DUR) of an utterance was equal to the distance between the BEGIN and END. It was determined by laying a clear plastic template over the spectrogram. On the template, 1.23 cm = 100 msec. Accuracy using this method was within 50 msec, except when the utterance required more than one spectrogram (i.e., when the utterance was longer than 2.4 sec). Measurement accuracy was not as good for these longer utterances.

2.34. Specification of the objects and object categories

Appendix A contains a list of all the objects that occurred in the analysis of each subject. Since subdividing each object category according to intonation contour resulted in many groups having a very small sample size, a classificatory scheme was devised for the objects whereby the sample size could be made large enough for statistical analysis. As mentioned earlier, the _SO_-data were recoded into four major categories: Visual (_SV_), Auditory + Visual (_SAV_), Tactile + Visual (_STV_), and Auditory + Tactile + Visual (SATV). The reclassification of each object is noted in Appendix A.

2.35. Classification of the contours

A computer program was used to determine the intonation contour of each utterance. If the fundamental frequency did not fluctuate more than ±5 Hz throughout the utterance, then that utterance was classed as level (_L_). An increase of more than 5 Hz from one measured point to the succeeding point was classed as a rise, while a decrease of more than 5 Hz from one point to the succeeding point was classified as a fall. Thus the following contours could be generated: rise (_R_), fall (_F_), rise-fall (_RF_), fall-rise (_FR_), rise-fall-rise (_RFR_), and fall-rise-fall (denoted as _FRF_).

At each age level, all utterances were grouped (within each context) according to the intonation contour that they exhibited. Mean values and standard deviations of the variables BEGIN, FMP, SMP, END, RANGE and DUR were calculated for each contour type. Since the contours _R_, _F_, _L_, _RF_ and _FR_ involve the measurement of one middle-point (with a few exceptions which are included in the two middle-point category), the utterances having these contours were grouped and new means and standard deviations of the variables were calculated for each context. These averages constitute the 1MP category. Similarly, the _RFR_ and _FRF_ contours, which require a minimum of two middle-points for their classification, were grouped and new means and standard deviations were calculated. Occasionally R, F, FR and RF contours appear under the two middle-point category because two middle-points were measured in these utterances. In addition to the summary statistics just described, overall mean values and standard deviations of each variable irrespective of intonation contour or number of middle-points, were also calculated for each context.

2.36. Hotelling's T^2 tests

The Hotelling's T^2 statistic can be used to test the assumption that two samples arise from the same population and have the same means on a given set of variables (Bjerring and Seagraves, 1972). One assumption made by this test is that there is homogeneity of covariances in the two populations. In addition to the T^2 statistic, a confidence interval $(1-\alpha) \times 100\%$ is calculated for the difference in population means for each pair of corresponding variables. Each confidence interval constitutes a univariate test for that variable. It must be remembered that the univariate tests do not take into account the covariances among the variables (Winer, 1971).

In this study, the Hotelling's T^2 statistic was used to determine, for a given subject at a given age level, whether there were significant differences between contexts -- for both similar and different types of utterances, and within contexts -- for different types of utterances. Contrasts were carried out on two levels: utterances classed according to the number of middle-points measured, and utterances classed according to intonation contour. A total of five or more utterances per context was required in order for a contrast to be carried out. Given a maximum of three objects per session, Figure 1 shows the maximum possible types of contrasts that could be performed (assuming a large enough sample) when utterances are classed according to the number of middle-points measured. Figure 2 outlines the possible contrasts involved in comparing both similar and different intonation contours.

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Insert Figures 1 and 2 about here.

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2.37. Multiple Classification Analysis

A computerized Multiple Classification Analysis (MCA) program (which is part of the OSIRIS III package at the University of British Columbia) was used to further analyze the data. Via this analytic technique a single variable can be related to several independent variables or 'predictors'. The underlying mathematics of the MCA assume that the data fit an additive model:

$$Y_{ijk} = \overline{Y} + a_i + b_j + c_k + \ldots$$

where $\overline{Y}$ is the grand mean of the dependent variable, and a_i, b_j, and c_k, etc. are numerical coefficients representing the main effects due to the independent variables (predictors) P_a, P_b, P_c, etc.

1 MP vs 1 MP	2 MP vs 2 MP
S x SO1	S' x SO1'
S x SO2	S' x SO2'
S x SO3	S' x SO3'
SO1 x SO2	SO1' x SO2'
SO1 x SO3	SO1' x SO3'
SO2 x SO3	SO2' x SO3'

1 MP vs 2 MP

S x S'	SO1 x S'	SO2 x S'	SO3 x S'
S x SO1'	SO1 x SO1'	SO2 x SO1'	SO3 x SO1'
S x SO2'	SO1 x SO2'	SO2 x SO2'	SO3 x SO2'
S x SO3'	SO1 x SO3'	SO2 x SO3'	SO3 x SO3'

Figure 1. Maximum possible contrasts occurring when utterances are examined according to number of middle-points.

RF x RF

FR x FR

R x R

F x F

L x L

RFR x RFR

FRF x FRF

The above contrasts could be performed for each of the following contexts:

S x SO1	SO1 x SO2
S x SO2	SO1 x SO3
S x SO3	SO2 x SO3

Contrasts of different intonation contours could be performed across contexts (as described above) and within contexts:

S x S

SO1 x SO1

SO2 x SO2

SO3 x SO3

The following contrasts are possible:

RF x FR	FR x F	R x FRF
RF x R	FR x L	F x L
RF x F	FR x RFR	F x RFR
RF x L	FR x FRF	F x FRF
RF x RFR	R x F	L x RFR
RF x FRF	R x L	L x FRF
FR x R	R x RFR	RFR x FRF

Figure 2. Contour contrasts.

The output of the MCA program shows the effects of each predictor both before and after the effects of the other variables have been taken into consideration. We can thus observe the trends of the actual data, as well as the goodness-of-fit of the predicted data to the actual data. Where the fit of the predicted curve is good, the additive model can be said to apply to the data. Where the fit of the predicted curve to the actual data is poor, we can conclude that either the additive model does not apply, or that the variance is not totally explained by the predictors under consideration. In the latter case, the addition of other factors might improve the fit of the curve if indeed the data fit an additive model. Another factor which could contribute to the poor fit of any predicted curve could be the categories of data being analyzed. If the data have not been grouped appropriately then the predicted curve probably will not show an optimal fit. Other features of the MCA program include the advantage of using either interval, ordinal or nominal scales of the data. Equal numbers of observations in each category are not required. One restriction is that there should be many more cases than degrees of freedom in the predictive model -- where df = (the sum of the number of categories for each of the predictors) - (total number of predictors). A disadvantage of the MCA program is that it does not take interactions among the dependent variables into account (Andrews et al., 1967).

For the present study the independent variables used in the MCA were age, context and subject. Chronological age, Bayley Mental score and Bayley Motor score were examined separately as age metrics. Due to restrictions in the MCA program involving the number of categories and the number of cases per category the data were grouped into a number of age intervals. These intervals were defined such that trends of the data observed in weekly or biweekly intervals would not be obscured. Chronological age was analyzed in ten age intervals of five weeks each. The first and tenth intervals were slightly greater, in order to accommodate cases at the extreme ends of the age scale. The following intervals were examined (all numbers refer to age in weeks): 0-10, 11-15, 16-20, 21-25, 26-30, 31-35, 36-40, 41-45, 46-50 and 51-60. The Bayley Mental scores were analyzed in eleven age intervals of ten points each as follows: 0-10, 11-20, 21-30, 31-40, 41-50, 51-60, 61-70, 71-80, 81-90, 91-100, and 101-110. The Bayley Motor scores were analyzed in eleven intervals of five points each as follows: 0-5, 6-10, 11-15, 16-20, 21-25, 26-30, 31-35, 36-40, 41-45, 46-50 and 51-55.

A total of seven contexts were examined -- S, SM, SOP, SV, SAV, STV and SATV. The SM and SOP contexts were included for purposes of the larger study and their results will be examined where appropriate. Preliminary analysis indicated that grouping the SF, SAM, and SAF contexts into a new category called S plus other person (SOP) would not obscure relationships between these contexts. The data from 108-M were included since separate MCA runs made both omitting and including this subject were found to show little difference in terms of the grand means.

The dependent variables employed in the analysis were DUR, RANGE, mean F_o, and two indices R/D and mean F_o x D x R. The variable mean F_o was used rather than analyzing BEGIN, FMP, SMP and END separately since preliminary analysis showed little difference among the four variables of F_o. For utterances having one measured middle-point the F_o was taken as (BEGIN + FMP + END)/3. The mean F_o for utterances having two measured middle-points was calculated as (BEGIN + FMP + SMP + END) / 4. R/D and mean F_o x D x R were index values created from the dependent variables. Using chronological age, context and subject as predictors the variables RANGE, DUR and mean F_o were analyzed for all subjects, and then for males only and females only. The Bayley age metrics were employed as predictors along with context and subject for all subjects only. The indices of R/D and mean F_o x D x R were analyzed for all subjects using chronological age, context and subject as predictors. The results for each analysis were graphed showing both the actual and predicted data curves.

2.38. Multivariate Nominal Scale Analysis

The Multivariate Nominal Scale Analysis (MNA) is the nominal scale version of the MCA program. Unlike the MCA, this program does not work on the principle of an additive model. The MNA program was employed in order to obtain frequency distributions of the intonation contours and the various contexts according to chronological age (in ten age levels as previously described), subject and sex. A distribution of the intonation contours in each context was also generated.

2.39. Development of the intonation contours with age

A program known as FMEANS (a one-way analysis of variance program which is also a part of the OSIRIS III package) was used to compute the means and standard deviations of the variables BEGIN, FMP, SMP, END, DUR and RANGE in three gross age categories (0-21 weeks, 22-38 weeks, and 39-60 weeks) in order to show the general changes that occurred within each contour over time. The means were calculated irrespective of context.

CHAPTER 3

Results

3.0. Introduction

This section includes the results of the following statistical analyses: Hotelling's T^2 contrasts (3.1), Multiple Classification Analysis (3.2 and 3.3), FMEANS (3.4), and Multivariate Nominal Scale Analysis (3.5).

3.1. Hotelling's T^2 contrasts

The results reported here represent only a portion of the possible contrasts that could have been carried out had there not been a constraint on sample size of the data with respect to the computer programs available. In order for a Hotelling's contrast to be carried out, each context under comparison must contain at least five utterances. An additional constraint on the data is that if the solution to the equation :

$$(n_1 + n_2 - 2) - p + 1$$

where n_1 = number of utterances for context (1)
n_2 = number of utterances for context (2)
p = number of variates

is less than 8, the F-probability cannot be computed.

A total of 666 Hotelling's contrasts were calculated. Of these, 432 (or 64.9%) were significant beyond the 5% level. The incidence of significant tests depended on the type of contrast being performed, as will be seen below. In addition to the T^2 value, F-value and F-probability, $(1-\alpha) \times 100\%$ (where $\alpha = 0.05$) confidence intervals were computed for each pair of corresponding variables; this constituted a univariate test for each variable under examination.

3.11. Contrasts of utterances with a single middle-point

A total of 95 Hotelling's tests were performed to determine whether the combined data for those intonation contours in which only one middle-point was measured differed for the subject alone and subject plus object conditions, or for utterances produced in the context of different objects. Only 19 (or 20% of the total) contrasts were significant at the five percent level or bettwe, indicating that there was little difference between the contexts when the contours were grouped in this manner (cf. Table VI). Only one univariate test (FMP of S x RATTLE for 104-F at 9 weeks was significant.

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Insert Table VI about here.

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3.12. Contrasts of utterances with two middle-points

Since the majority of the intonation contours produced by the infants involved the measurement of only one middle-point, only nine contrasts could be performed for those utterances in which two middle-points were measured. One of these contrasts was significant (see Table VI), and none of the univariate tests

TABLE VI

SIGNIFICANT CONTRASTS FOR UTTERANCES HAVING
THE SAME NUMBER OF MIDDLE-POINTS

ID	AGE (wks)	CONTRAST (1MP x 1MP)	df	T^2	F	uni-var.
102-F	54	S(1MP) x KEYS(1MP)	12,7	21.54	3.400*	
	54	S(1MP) x SLIPPER(1MP)	12,6	23.01	3.580*	
104-F	9	S(1MP) x RATTLE(1MP)	91,64	20.00	3.897**	FMP
	16	S(1MP) x MOBILE(1MP)	15,15	16.76	2.905*	
	16	MOBILE(1MP) x MIKE(1MP)	15,29	30.65	5.573***	
	20	S(1MP) x GREEFROG(1MP)	52,28	13.84	2.629*	
	24	S(1MP) x EATINCUP(1MP)	8,21	17.00	2.932*	
	24	HAIRDOLL(1MP) x EATINCUP(1MP)	21,21	32.77	5.930***	
	26	S(1MP) x EATINCUP(1MP)	19,21	19.46	3.503*	
105-M	53	DUCK(1MP) x TAPERECR(1MP)	8,9	22.10	3.380*	
106-F	50	S(1MP) x TOYMOUSE(1MP)	11,10	23.38	3.785*	
107-M	23	S(1MP) x SQUDUCK(1MP)	6,7	27.31	3.781*	
109-M	32	S(1MP) x TOYBOATS(1MP)	8,7	24.86	3.645*	
	41	S(1MP) x MIKE(1MP)	9,15	19.05	3.176*	
	44	S(1MP) x JUMPROPE(1MP)	15,9	18.37	3.062*	
111-M	14	S(1MP) x BLUBUNNY(1MP)	7,10	23.88	3.652*	
	18	RAGDOLL(1MP) x ELEPHANT(1MP)	9,11	20.25	3.239*	
	28	S(1MP) x BLUBUNNY(1MP)	7,8	35.84	5.257*	
	40	S(1MP) x BOWL(1MP)	9,8	25.49	3.899*	
ID	AGE	CONTRAST (2MP x 2MP)	df	T^2	F	
104-F	24	HAIRDOLL(2MP) x EATINCUP(2MP)	18,15	29.13	4.120**	

* p < .05
** p < .01
*** p < .001

were significant. Again, the results indicated that there was little or no difference between contexts based on this classification of the utterances.

3.13. Contrasts involving the same intonation contours

3.131. Intonation contours having one measured middle-point

Table VII presents the results of 57 Hotelling's tests involving pairwise comparisons of similar intonation contours which occurred in different contexts. Nine of these tests (or 15%) were significant at the five percent level or better, indicating that the subjects generally did not vocally differentiate between the S and SO states; only two univariate tests were significant. It can be seen that the majority of the contrasts involved RF contours. The RF contour was the most frequently occurring contour for all subjects and accounted for over forty percent of the utterances. The sample size of the other intonation contours in this category (FR, R, F and L) was not usually large enough for Hotelling's contrasts to be consistently carried out.

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Insert Table VII about here.

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3.132. Intonation contours having two measured middle-points

Due to problems in sample size, only three contrasts (all involving 104-F) for RFR and FRF contours could be performed

TABLE VII

CONTRASTS INVOLVING THE SAME INTONATION CONTOURS

ID	AGE (wks)	CONTRAST	df	T^2	F	uni-var.
102-F	41	S(RF) x SNOOPY(RF)	9,7	11.72	1.758	
	50	S(RF) x CANDLE(RF)	9,5	3.303	.4719	
	54	S(RF) x KEYS(RF)	11,6	16.90	2.585	
	54	S(RF) x SLIPPER(RF)	11,6	20.64	3.156*	
	54	KEYS(RF) x SLIPPER(RF)	6,6	1.149	.1532	
103-M	22	S(RF) x BELLS(RF)	18,7	4.355	.7316	
104-F	7	S(RF) x PINKTEDD(RF)	10,5	3.532	.5180	
	7	S(F) x PINKTEDD(F)	7,11	13.37	2.079	
	9	S(FR) x RATTLE(FR)	16,14	30.13	5.222**	FMP/ END
	9	S(R) x RATTLE(R)	16,13	6.537	1.127	
	9	S(F) x RATTLE(F)	28,17	3.645	.6642	
	14	SNOOPY(RF) x CLOWN(RF)	7,20	1.270	.2164	
	14	SNOOPY(F) x CLOWN(F)	10,32	2.294	.4150	
	16	S(RF) x MIKE(RF)	9,20	7.325	1.263	
	20	S(RF) x GREEFROG(RF)	20,17	19.75	3.523*	
	20	S(RFR) x GREEFROG(RFR)	9,5	14.50	1.554	
	20	S(FRF) x GREEFROG(FRF)	8,14	3.822	.4922	
	24	S(RF) x HAIRDOLL(RF)	4,16	3.210	.5136	
	24	S(RF) x EATINCUP(RF)	4,17	11.49	1.861	
	24	HAIRDOLL(RF) x EATINCUP(RF)	16,17	28.01	4.923**	
	24	HAIRDOLL(RFR) x EATINCUP(RFR)	10,10	14.37	.1668	
	26	S(RF) x EATINCUP(RF)	11,20	8.763	1.526	
105-M	23	S(RF) x BOOKS(RF)	19,4	1.674	.2766	
106-F	18	S(RF) x LION(RF)	18,6	8.862	1.477	
	24	S(RF) x PUPPY(RF)	7,6	6.185	.9436	
	28	S(RF) x YELORATT(RF)	6,9	4.042	.6457	

TABLE VII (continued)

ID	AGE (wks)	CONTRAST	df	T^2	F	uni-var.
106-F	50	S(RF) x BLOCKS(RF)	10,4	16.41	2.345	
	50	S(RF) x TOYMOUSE(RF)	10,4	15.72	2.246	
	54	S(RF) x BLANKET(RF)	8,4	10.54	1.405	
109-M	13	S(RF) x MOTHRING(RF)	11,4	3.782	.5547	
	35	S(RF) x BALL(RF)	14,4	5.476	.8518	
	41	S(RF) x MIKE(RF)	8,8	14.64	2.196	
	44	S(RF) x JUMPROPE(RF)	13,5	10.92	1.699	
110-M	41	S(RF) x MIKE(RF)	8,5	2.243	.3105	
111-M	12	MOBILE(RF) x TEDDY(RF)	6,8	12.72	1.818	
	14	S(RF) x RAGDOLL(RF)	7,9	12.89	1.934	
	14	S(RF) x TEDDY(RF)	7,6	18.86	2.611	
	14	S(RF) x BLUBUNNY(RF)	7,10	23.88	3.652*	
	14	RAGDOLL(RF) x TEDDY(RF)	9,6	3.105	.4554	
	14	RAGDOLL(RF) x BLUBUNNY(RF)	9,10	5.006	.7904	
	14	TEDDY(RF) x BLUBUNNY(RF)	6,10	.2569	.3854 E-01	
	15	S(RF) x RAGDOLL(RF)	6,9	12.75	1.870	
	15	S(RF) x BLUBUNNY(RF)	6,10	13.16	1.975	
	15	RAGDOLL(RF) x BLUBUNNY(RF)	9,10	12.58	1.987	
	18	S(RF) x RAGDOLL(RF)	8,9	8.029	1.228	
	18	S(RF) x BLUBUNNY(RF)	8,11	12.48	1.971	
	18	S(RF) x ELEPHANT(RF)	8,11	9.280	1.465	
	18	RAGDOLL(RF) x BLUBUNNY(RF)	9,11	4.952	.7924	
	18	RAGDOLL(RF) x ELEPHANT(RF)	9,11	20.25	3.239*	
	18	BLUBUNNY(RF) x ELEPHANT(RF)	11,11	4.659	.7624	
	24	S(RF) x RADIO(RF)	7,6	8.560	1.185	
	28	S(RF) x BLUBUNNY(RF)	5,8	32.22	4.462*	
	28	S(RF) x PLUTODOG(RF)	5,12	11.27	1.724	
	28	BLUBUNNY(RF) x PLUTODOG(RF)	8,12	3.493	.5588	
	32	S(RF) x MOBILE(RF)	6,6	8.322	1.110	

TABLE VII (continued)

ID	AGE (wks)	CONTRAST	df	T^2	F	uni-var.
111-M	40	S(RF) x BOWL(RF)	7,6	30.86	4.273*	
115-F	24	S(RF) x POOH(RF)	7,10	3.912	.5983	
116-F	22	S(RF) x RABBIT(RF)	8,6	37.38	5.339*	
118-F	19	S(RF) x GUNK(RF)	7,10	12.65	1.935	

* $p < .05$

** $p < .01$

(see Table VII). None of these contrasts was significant, nore were there any significant univariate tests.

3.14. One middle-point vs two middle-point contrasts

Of the 164 Hotelling's contrasts performed in this category, 82 (or approximately 50%) were significant at the five percent level or better. There were only 33 significant univariate tests out of a possible 820 which were performed. Two-thirds of these significant univariates involved the variable DUR. An additional eight involved the variable RANGE. In all instances, when a univariate test was significant for RANGE or DUR, the mean value of the variable concerned was higher for the two middle-point utterances than for the one middle-point utterances under comparison. It was previously reported by Handford (1972) that the duration of utterances having two measured middle-points was significantly longer than that of utterances having one measured middle-point. The within-utterance range for two middle-point utterances was also found to be greater than that of one middle-point utterances. The present data confirm Handford's findings.

Since half of the contrasts for one vs two measured middle-points were significant, any amalgamation of data from these two categories (as in Handford, 1972) should be seriously questioned. Our results indicate that these two types of utterances are different, especially with respect to range and duration. Grouping these two types of utterances together obscures not only their differences but also any developmental changes that may be occurring.

3.15. Contrasts of different intonation contours

The argument for analyzing the data separately according to number of middle-points measured or intonation contour is further supported by the results of Hotelling's T^2 contrasts for different intonation contours. A total of 347 contrasts of different intonation contours, occurring in either the same context or different contexts, were performed; of these, 320 (or 92.2%) were significant at the five percent level or better; many were significant beyond the one percent level. These results would seem to suggest that grouping the utterances according to intonation contour is a more reasonable way to examine the data than grouping irrespective of contour. The results of the contrasts of similar intonation contours indicate that the contours themselves are relatively uniform; otherwise one would have observed more significant contrasts in this category. One proviso must be made, however, with regard to those few instances in which two middle-points were measured for <u>RF</u>, <u>FR</u>, <u>R</u> and <u>F</u> contours. These utterances are generally longer than their one middle-point counterparts, and therefore a grouping of these two types of utterances would be suspect.

A total of 136 univariate tests were significant at the five percent level. Well over half (83) of the tests were significant for the variables BEGIN, FMP and END, and 47 of these significant tests were attributable to differences in FMP.

In the majority of these significant contrasts, F_o increased in one contour and decreased in the other (e.g., as in RF x FR or RF and FRF which accounted for 30/47 significant contrasts of FMP). Contrasts of one vs two middle-point contours accounted for 10/16 significant univariate tests for the variable RANGE and 31/37 significant univariate tests for the variable DUR.

3.16. Examination of cases having small sample sizes

Where the sample size was too small for the Hotelling's T^2 statistic and associated probabilities to be computed, the data were otherwise inspected to determine whether the mean values of the variables differed significantly. Only similar intonation contours were compared since these contrasts were of prime interest in this study. Given the rather large standard deviations, there was generally no difference between either the means for the S and SO conditions or between different SO conditions, at the same age level. Those substantial differences that were observed were usually associated with sample sizes of one or two utterances; consequently, it is difficult to assess whether they were actually indicative of differential vocalization. It would seem more likely that these differences are artifacts of small sample size.

3.2. Comparison of the age metrics: chronological age, Bayley Mental score and Bayley Motor score

Figure 3 shows the results of analyzing the changes of mean F_o, DUR and RANGE over time using three different age metrics: chronological age, Bayley Mental score and Bayley Motor score.

It is evident that changing the metric only slightly alters the configuration of the graph.

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Insert Figure 3 about here.

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A peak in mean F_o (370 Hz) is observed at 28 weeks chronological age, and at scores of 65 on the Bayley Mental scale and 28 on the Bayley Motor scale. The Bayley Mental score is equivalent to a chronological age of 24 weeks, while the Bayley Motor score has an age equivalent of 26 weeks. Since the age values used are midpoints of predefined intervals, the peaks of the three graphs are tantamount to equivalent.

Peak values in DUR are found to occur at 23 weeks (760 msec), 38 weeks (865 msec) and 48 weeks (755 msec) chronological age. Using Bayley Mental score as an age metric, DUR peaks at scores of 65 (760 msec) and 85 (830 msec). The Mental scores correspond to chronological ages of 24 and 39 weeks respectively. Peaks on the Bayley Motor score graph occur at 18 (695 msec), 28 (755 msec) and 38 (820 msec). The motor scores correspond to chronological ages of 19, 26 and 39 weeks respectively. Since the three age classes span slightly different intervals, their maximum values will not necessarily coincide, but it is evident that the values do not differ to a great extent. For example, at approximately 38 weeks values of 865 msec, 830 msec and 820 msec are observed

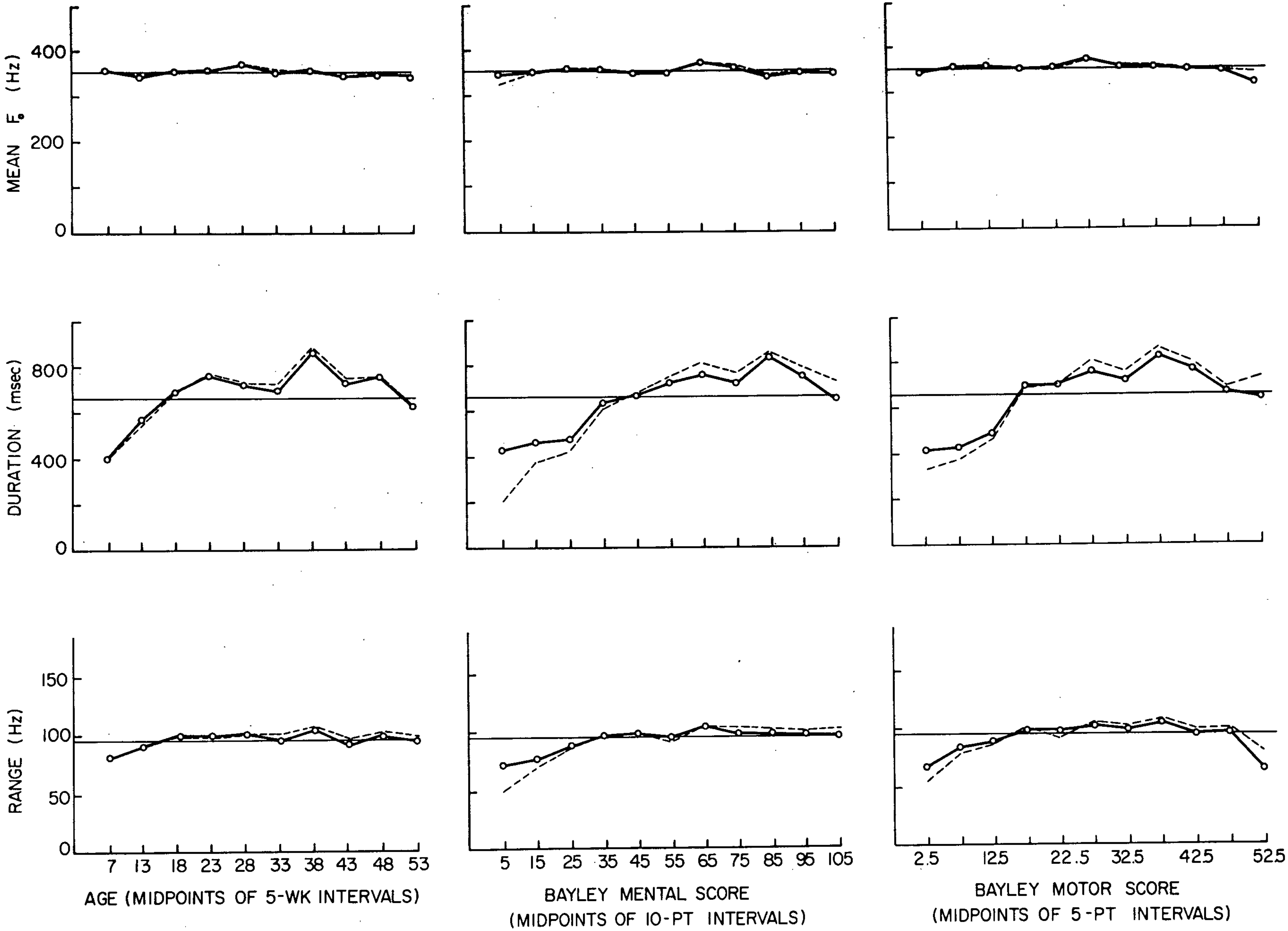

FIGURE 3. All Subjects (N = 19): Means of F_0, duration, and within-utterance range with respect to chronological age and the mental and motor scores based on the Bayley Scales of Infant Development. Solid lines represent the averaged data; dashed lines are predicted curves based on the MCA additive model; horizontal lines correspond to the overall means.

for chronological age, Bayley Mental score and Bayley Motor score respectively.

RANGE is observed to peak at 28 (102 Hz), 38 (106 Hz) and 48 weeks (100 Hz) chronological age. Using the Bayley Mental score, peak values occur at 35-45 (98 Hz) and 65 (196 Hz). The first interval corresponds to a chronological age of 13-17 weeks while the second score is equivalent to 24 weeks. Maximum values of RANGE are observed at Motor scores of 18 (99 Hz), 28 (103 Hz) and 38 (105 Hz) The age equivalents of these peaks are 19, 26 and 39 weeks.

The best fits of the MCA predicted curves (see dashed lines, Figure 3) are observed when chronological age is used as the age metric. The predicted curves for mean F_o have the best fit of all the Bayley score curves. Predicted curves for RANGE and DUR vs Bayley scores do not fit the measured data as well. This is especially true for the extreme low and high Bayley scores. The poor fit for the low Bayley scores may be attributable to the relatively poor reliability of the results of psychological tests in very young infants. It must also be noted that the averages of the variables in both end classes of the Bayley score graphs do not necessarily represent equal numbers of subjects, and therefore the predicted curves deviate somewhat at these points.

The use of the Bayley scores as measures of development does not appear to provide any additional information to that furnished by chronological age, nor does it improve predictive power. For these reasons, chronological age is used as the age metric in the remainder of this study. No attempt has been made to examine the actual Bayley test items in relation to the results but it is possible that certain of the observations, especially those regarding the peaking behaviour of the variables, coincide with the successful completion of certain items on the Bayley Scales. A factor analytic study would be needed to elicit such trends.

3.3. Results of Multiple Classification Analysis

3.31. Age and sex trends of the dependent variables and two related indices

As can be seen in Figure 4, the average F_o centers around 355 Hz for all subjects and does not vary appreciably with age, except for a slight peak between 26 and 30 weeks. The peaking behaviour is still observed when the data are subdivided according to the sex of the subject (Figures 5 and 6) except a broader peak (21-30 weeks) is observed in the case of the females. The mean F_o for the female subjects (370 Hz) is consistently 25 ± 20 Hz higher than that of the males (345 Hz). The mean F_o of the females rises from an initial value of 365 Hz to a peak value of 380 Hz, and then decreases to 370 Hz by the end of the first year of life. The males' mean F_o rises from 350 Hz at birth to a peak value of 360 Hz and then drops to 325 Hz by about one year of age.

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Insert Figures 4, 5 and 6 about here.

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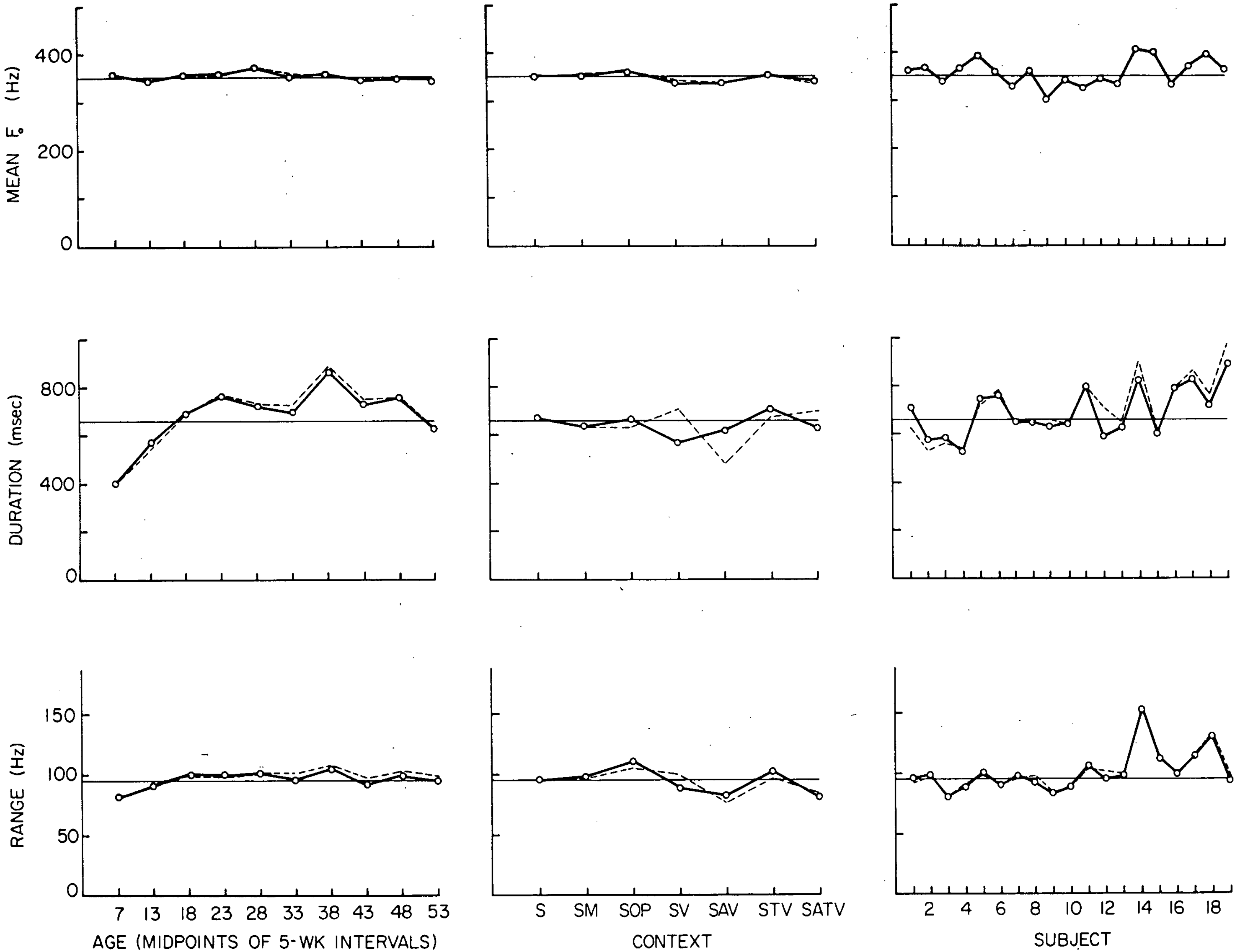

FIGURE 4. All Subjects (N = 19): Means of F_o, duration, and within-utterance range (11,368 vocalizations). Solid lines represent the averaged data; dashed lines are predicted curves based on the MCA additive model; horizontal lines correspond to the overall means.

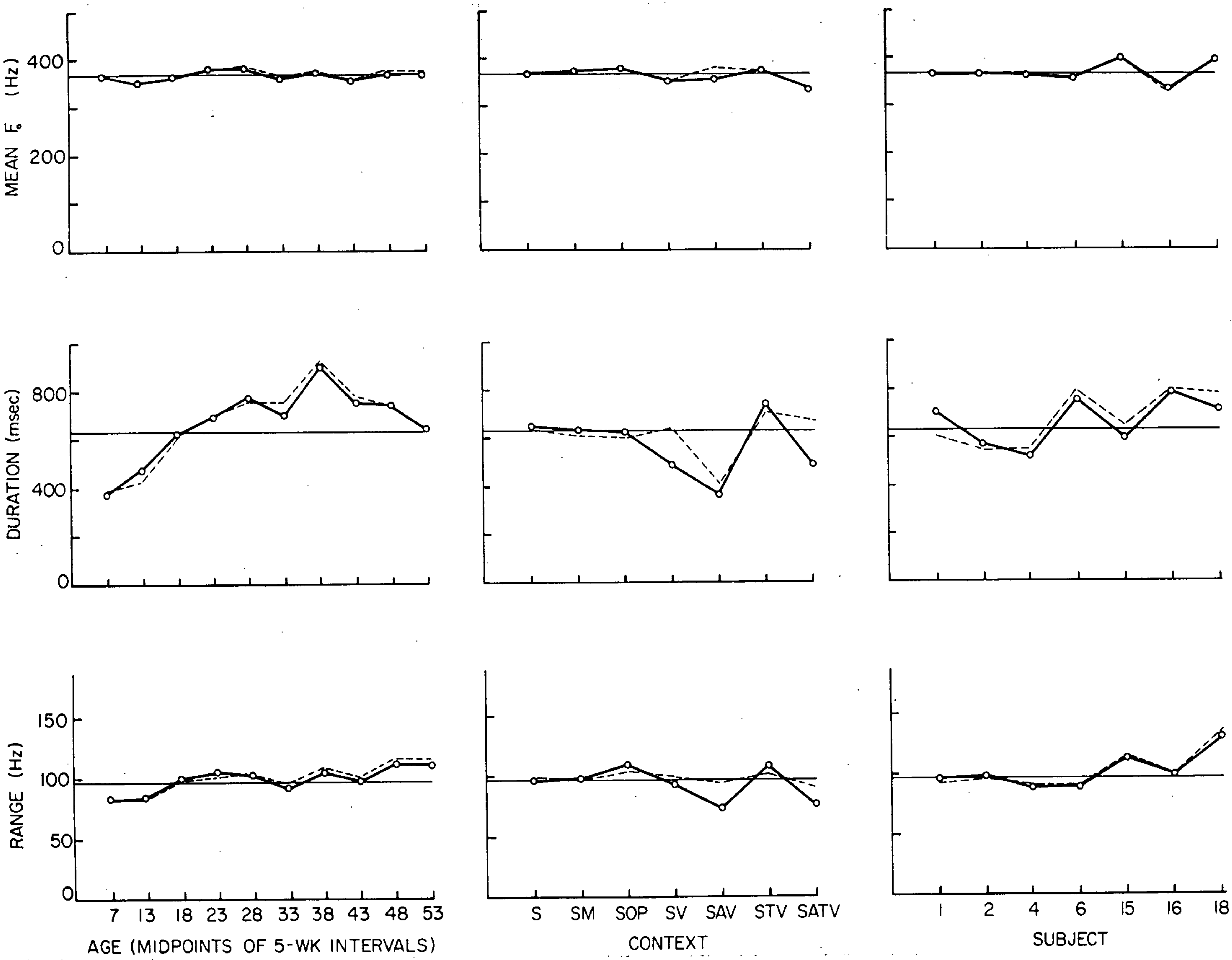

FIGURE 5. Females (N = 7): Means of F_0, duration, and within-utterance range (4,540 vocalizations). Solid lines represent the averaged data; dashed lines are predicted curves based on the MCA additive model; horizontal lines correspond to the overall means.

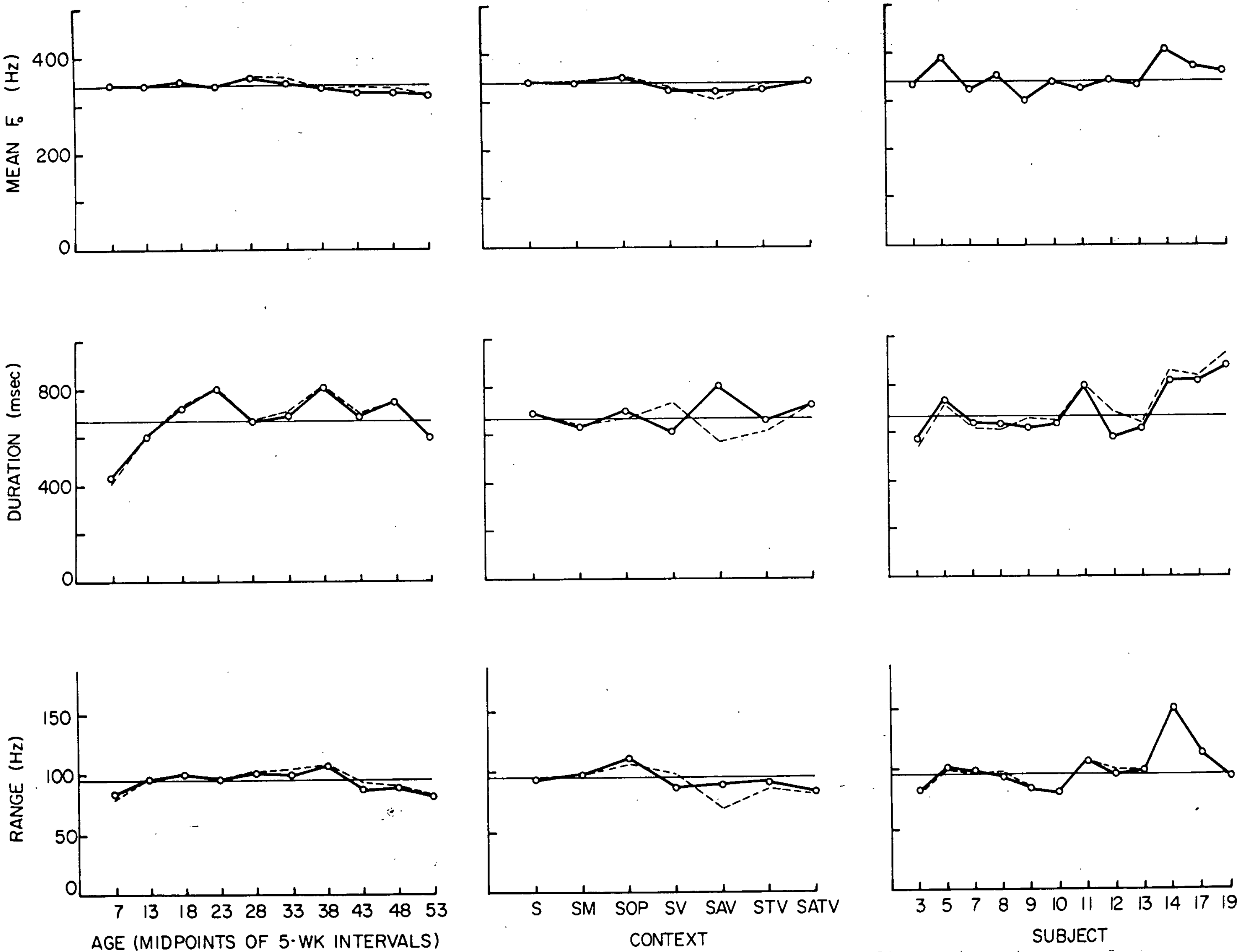

FIGURE 6. Males (N = 12): Means of F_o, duration, and within-utterance range (6,828 vocalizations). Solid lines represent the averaged data; dashed lines are predicted curves based on the MCA additive model; horizontal lines correspond to the overall means.

All graphs of DUR *vs* AGE show an increase in DUR with age (Figures 4, 5 and 6). The average DUR of an utterance is 660 msec for all subjects; when sex is considered, the averages are 635 msec for females and 675 msec for males. The males' utterances are longer in duration from birth to 25 weeks, whereas the duration of the females' utterances has the higher value from 26 weeks to about one year (with one exception at 46-50 weeks where males' and females' utterances are essentially equal in length). The average difference in length between males' and females' utterances is never larger than 130 msec which, in view of the standard deviations observed for DUR (averaging 500 msec), may not be large enough to infer a sex difference in the sample.

The average DUR of the females' utterances increases from 375 msec at birth to a peak value of 775 msec between 26 and 30 weeks; a second peak value of 900 msec is observed between 36 and 40 weeks. The DUR then decreases to 645 msec by approximately one year of age. In the case of the males, DUR increases from 430 msec at birth to a peak value of 805 msec at 26-30 weeks. A second peak value (815 msec) is observed at 36-40 weeks, and a third peak (755 msec) occurs at 46-50 weeks. The male infants' average utterance is about 605 msec by one year of age. The graph of DUR *vs* AGE for all subjects (Figure 4) exhibits three peaks at the same age levels as were observed for the males. Since there were more male subjects and thus more male utterances, the graph for all subjects is likely weighted in favor of the male subjects.

The within-utterance range of the females' utterances (Figure 5) exhibits a gradual increase (with some fluctuation) from 80 Hz at birth to 110 Hz by one year of age. The males, on the other hand, exhibit an increase in RANGE from 85 Hz at birth to 105 Hz at 36-40 weeks, and then a decrease to 80 Hz by one year (see Figure 6). Since the terminal portions of the graphs for males and females are changing in opposite directions, the graph of RANGE vs AGE for all subjects (Figure 4) exhibits a rise initially, followed by a relatively level terminal portion.

The graph showing the change in the ratio of RANGE to DUR (R/D) with age (Figure 7) is bowl-shaped, beginning at a high value (0.26) at 0-10 weeks, decreasing to a minimum at 36-40 weeks (0.16) and then increasing in its terminal portion. The shape of the graph indicates that RANGE and DUR are relatively independent variables. The change of the second index mean Fo x D x R (x 10^{-7}) with age is also graphed in Figure 7. This index value increases with age, peaking at 21-25 weeks (3.45), 36-40 weeks (4.06) and 46-50 weeks (3.04). This graph rather dramatically shows the peaking behaviour observed with the individual variables. (See Appendix B for the actual values of the variables on which Figures 4, 5, 6 and 7 are based.)

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Insert Figure 7 about here.

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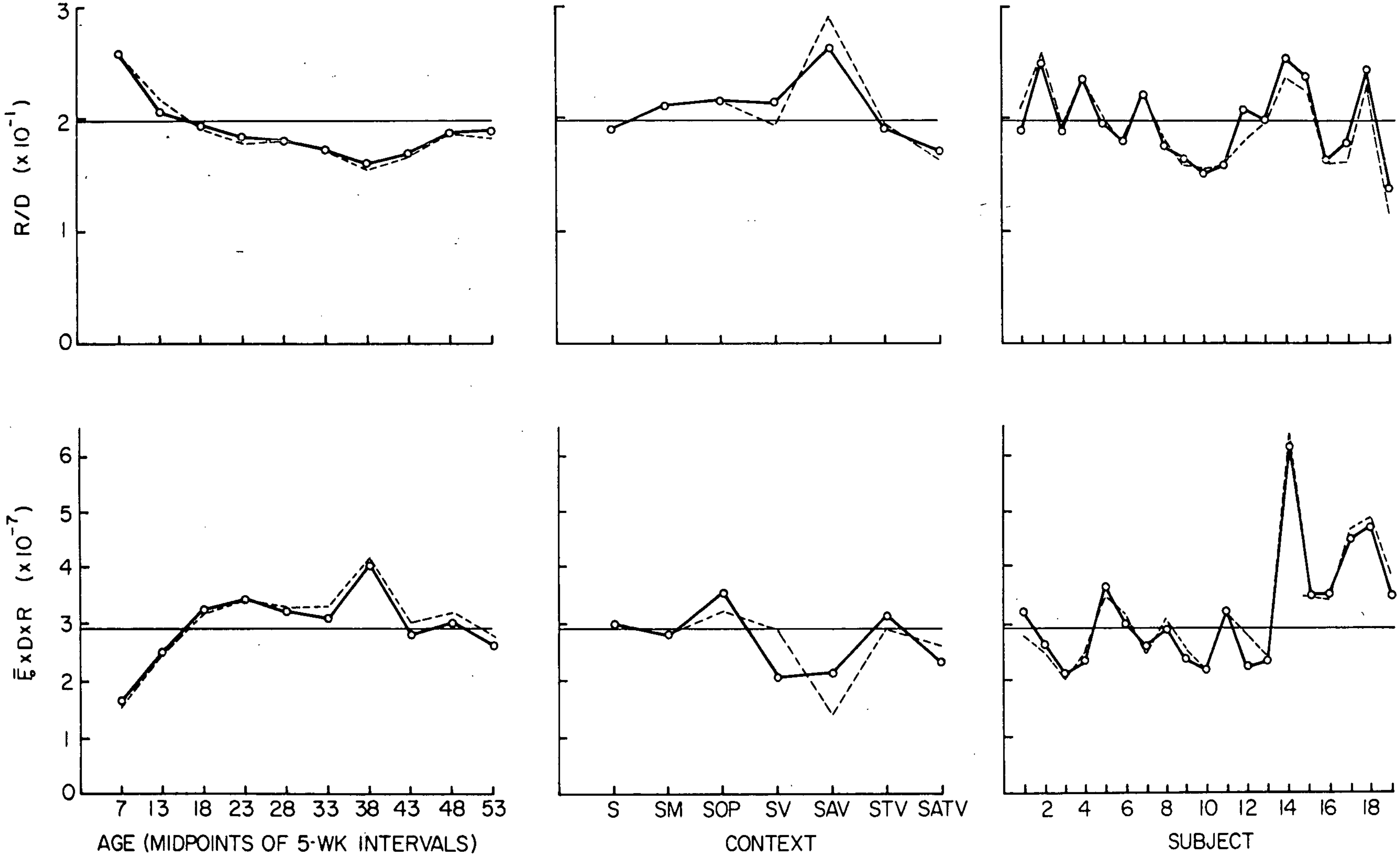

FIGURE 7. All Subjects (N = 19): Means of Range to Duration and of mean F_0 x Duration x Range. Solid lines represent the averaged data; dashed lines are predicted curves based on the MCA additive model; horizontal lines correspond to the overall means.

3.32. The use of CONTEXT as a predictor

Mean values of the three variables: mean F_o, DUR and RANGE, in addition to the two indices: R/D and mean F_o x D x R, were calculated for each of the contexts (see Figures 4, 5, 6 and 7). In this manner it could be determined whether the child was altering his/her vocal output in a particular manner depending on the context of the utterance.

The graphs of mean F_o vs CONTEXT are seen to be essentially unremarkable, with all values lying close to the grand mean. The predicted curves fit the actual data with the exception of a slight discrepancy in the SAV context for males and females. This would indicate that the additive model can be applied to the data but in the case of the SAV context it does not explain all of the variance. This context actually played a minimal role in this study because it contained few objects and very few utterances. It is possible that the objects could have been placed in a more appropriate category or categories.

The mean F_o for the SV and SAV categories is, on the average, 20 Hz lower than the grand mean. The SATV category is noted to be 30 Hz below the mean for the females' utterances. These values are within the range of measurement error for spectrographic analysis (Lindblom, 1962). They are also associated with relatively low sample sizes.

Generally, the S, SM and SOP contexts lie close to the grand mean for DUR, while the SO contexts tend to deviate somewhat. All values are well within one standard deviation of the mean.

The STV category is usually closer to the grand mean than the other categories. This category also had the largest number of observations and therefore the deviations of the remaining SO contexts from the mean may be a reflection of low sample size. The mean DUR for the SV context is consistently lower than the grand mean for all contexts for males, females and all subjects. Such consistencies are not noted with the other two object contexts: the values of the SAV and SATV contexts are consistently higher than the grand mean for males and lower than the grand mean for females.

The S, SM and (for the most part) STV contexts are close to the grand mean in all graphs of RANGE vs CONTEXT. The average RANGE of the SOP category is consistently higher than the grand mean. The mean values of the SV, SAV and SATV contexts all lie below the grand mean of RANGE for the females, with the SAV and SATV contexts showing the largest deviations from the grand mean. In the case of the males, the SO categories all exhibit a slightly lower mean RANGE than the grand mean. For both males and females the deviations observed are well within one standard deviation (75 Hz) of the mean.

The graphs of R/D and mean F_o x D x R vs CONTEXT (see Figure 7) are essentially mirror images of each other. One would expect this behaviour knowing the mathematical nature of these two indices. The S, SM and STV categories are generally close to the grand mean while the SOP and remaining SO categories usually show a deviation from the grand mean.

The MCA predicted curves for DUR, RANGE, R/D and mean F_o x D x R vs CONTEXT generally show a good fit for the S, SM and SOP contexts and a poor fit for the SO contexts. It seems that the additive model may not apply for CONTEXT as a predictor. It is also possible that the data may have been inappropriately classified in terms of the four object contexts chosen; likewise, an additive model may not be appropriate for predicting data classed according to context. The latter seems rather unlikely given the relatively good fit of the model to the S, SM and SOP contexts. One requirement of the MCA (or any other statistical procedure for that matter) is that there must be enough cases in each category to provide stable estimates of the means. The SAV category contains only 32 observations and therefore the likelihood of obtaining reasonable estimates of the means for this category is remote. The STV category contained the largest number of observations for all subjects and for the females; this context was generally closer to the grand mean for all the variables than were the other object categories. We do not know the exact number of cases needed in order to give a stable picture of what is occurring in each of the categories. This would require repeating the MCA and experimenting with different numbers of observations; it could give some insight into what is occurring with respect to the object contexts.

3.33. Intersubject variability

The MCA was performed using SUBJECT as a predictor for the variables mean F_o, RANGE, DUR and the indices R/D and mean F_o x D x R. The predicted curves fit the actual data in most cases, indicating that the additive model applied for this predictor.

From Figure 4 it can be observed that the mean F_o of about one-half of the subjects was close to the grand mean. The remainder of the subjects showed a larger deviation from the grand mean with 109-M having the lowest mean F_o and 114-M having the highest F_o. In the case of the females, those subjects deviating from the grand mean (115-F, 116-F and 118-F) were only analyzed up to six months of age. Since mean F_o does not seem to change appreciably with age the differences are likely attributable to small sample size. In the case of the males, deviations from the grand mean cannot be explained wholly by low sample size since two of the subjects (105-M and 109-M) involved relatively large numbers of utterances. The variability in the males' F_o is likely due to individual physical or environmental differences.

On visual inspection, the graph of DUR vs SUBJECT (Figure 4) exhibits a considerable amount of intersubject variability which is not entirely due to small sample size. Despite the variability, the values for all subjects were within 150 msec of the grand mean. Given the large standard deviations observed for DUR (540 msec for females, and 475 msec for males), the data appear uniform. Subject 104-F exhibited the shortest average DUR, while 201-M exhibited the longest.

The graph of RANGE _vs_ SUBJECT evinces rather less variability than that for DUR just described. Those females deviating from the grand mean (115-F and 118-F) were only analyzed up to six months. The exceptional cases for the males, which again cannot be totally ascribed to low sample size, include 103-M who exhibited the lowest average RANGE for all subjects, and 114-M who exhibited the highest average RANGE for all subjects.

The graphs of R/D and mean F_o x D x R (Figure 7) also exhibit considerable intersubject variability. In the graph of R/D those subjects who exhibited values somewhat lower than the mean tended to be males, while those subjects having large excursions above the mean were females. No such sex trend was observed in the mean F_o x D x R _vs_ SUBJECT graph. Since both indices are based on the dependent variables described earlier, those subjects who tended to be 'outliers' were often the same subjects whose index values varied condiserably from the means for R/D and mean F_o x D x R.

3.4 Intonation contour configurations

The configurations of the various intonation contours in three different age categories are shown in Figure 8. Since mean F_o was found to remain stable across contexts, the means for each variable were calculated irrespective of context. In general, the changes of BEGIN, FMP, SMP, END and RANGE with time are minimal. Occasional large fluctuations of DUR with age are noted but these reach significane (at the 1% level) only for the RF, F and RFR contours. All contours do, however, show an increase in DUR with age.

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Insert Figure 8 about here.

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The L utterances are typically the shortest utterances, having an average DUR of about 300 msec. By operational definition mean F_o does not fluctuate and therefore RANGE is zero (± 5 Hz cf. 2.35). The R and F utterances average approximately 425 msec in length and have an average RANGE of about 68 Hz. In terms of numerical values of mean F_o the two contours are mirror images: BEGIN of the R and END of the F are approximately equal, as are END of the R and BEGIN of the F. The RF and FR utterances have an average DUR of about 680 msec and an average RANGE of aobut 100 Hz. RFR and FRF have the longest DUR (985 msec) and the largest RANGE (118 Hz) of all of the contours.

3.5. Results of Multivariate Nominal Scale Analysis

3.51. Intonation contour distributions

3.511. Distribution of contour by age

Figure 9 shows the distribution of the intonation contours by age in ten intervals of five weeks each. It can be seen that only the distribution of RF contours changes appreciably with age, and that this change is occurring in a positive direction

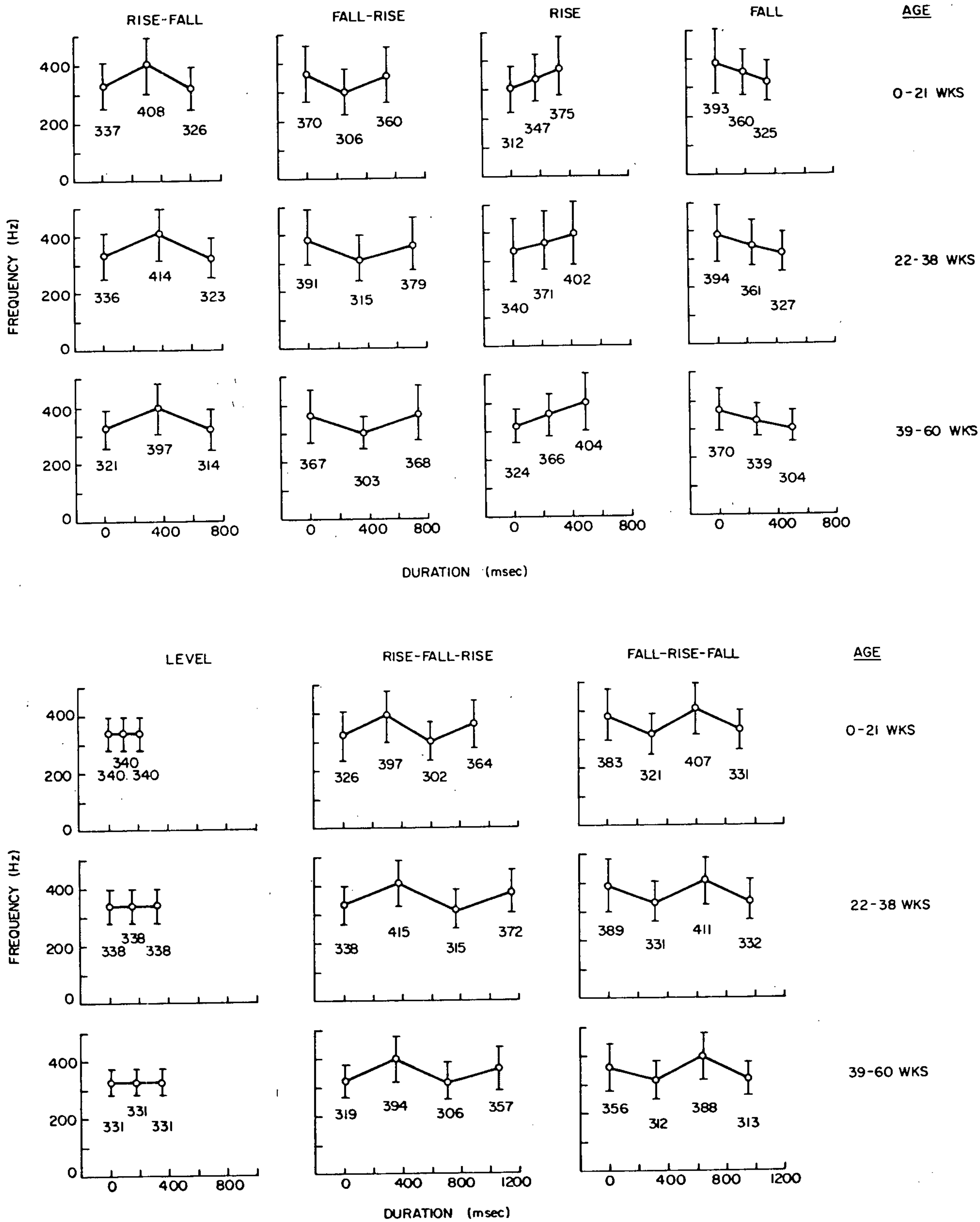

FIGURE 8. Contours and their development status in three age categories for all subjects.

(40% at 5 weeks to 55% at one year). On the average, RF contours account for approximately 43% of the data, followed by the F and FRF contours which each account for about 13% of the data; RFR, R, FR and L account for 11%, 10%, 7% and 2.5% respectively.

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Insert Figure 9 about here.

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The distribution of the RFR contour observably peaks at 21-25 weeks and 36-40 weeks, while the distribution of the FRF contour peaks at 16-20 weeks, 26-30 weeks, and 46-50 weeks. The variable DUR and the mean F_o x D x R index were observed to peak at 26-30 weeks, 36-40 weeks and 46-50 weeks. Part of this peaking behaviour may then be a result of the child's production of a larger proportion of the RFR and FRF contours which characteristically exhibit longer durations than the other intonation contours.

3.512. Distribution of contour by subject and by sex

It is evident is Figure 10 that the distributions of the different intonation contours are relatively uniform across subjects. The RF contour always accounts for the largest proportion of the utterances, while the L contour occurs the least often. The subjects who were analyzed only up to six months tend to show a larger proportion of the RFR and FRF contours. This trend may be due to the larger proportion of 2MP contours observed at six months. It could also be an artifact of small sample size. The

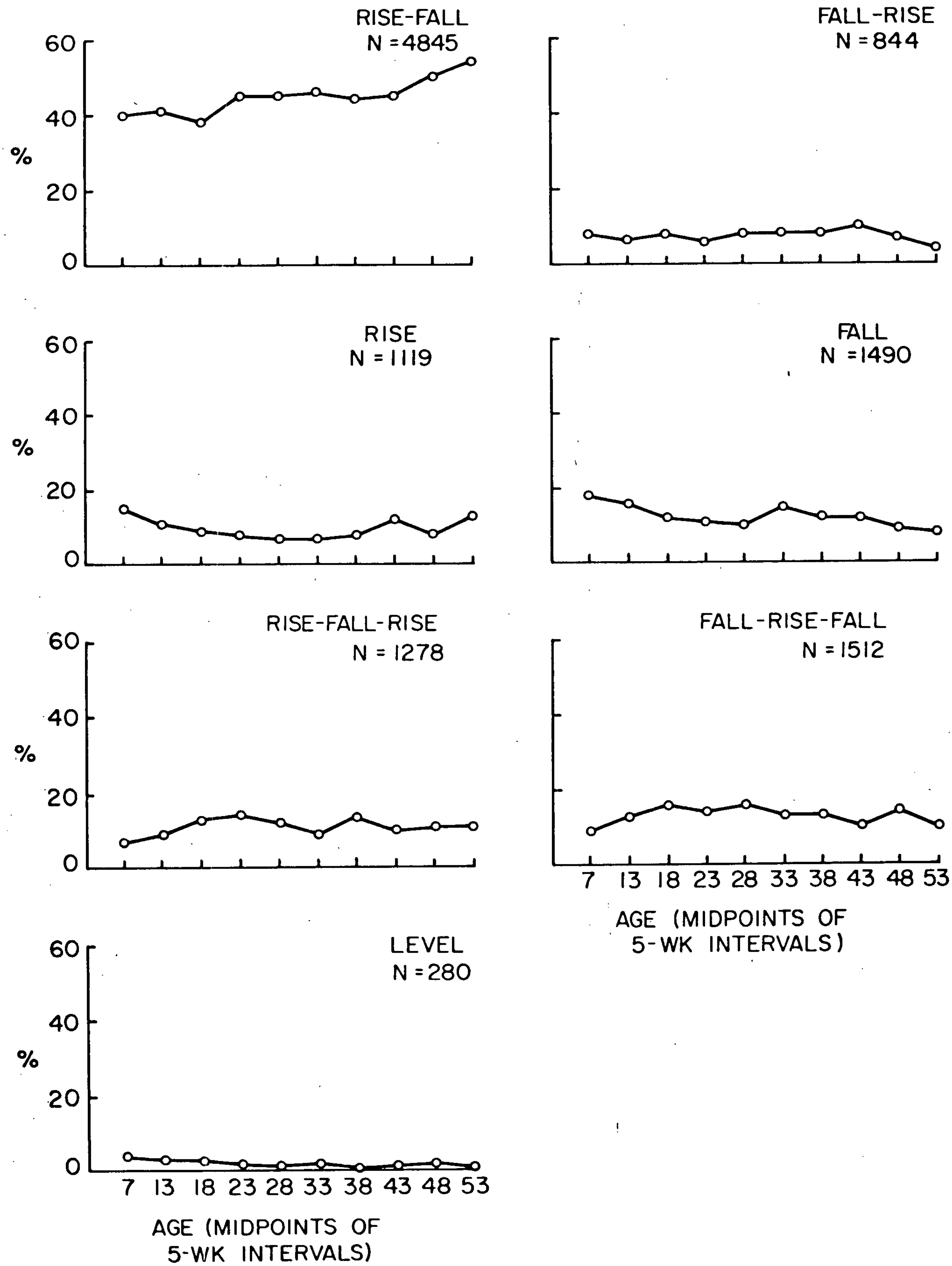

FIGURE 9. Developmental trend of frequency of each contour for all subjects.

data for 108-M are included, from which it will be noted that the shape of the distribution of contours for this subject deviates from that of the majority of the subjects.

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Insert Figure 10 about here.

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When the data are grouped according to the sex of the subject (Figure 11), the distributions of contour for males and females are found to be the same: The shape of the two distributions is essentially similar to that observed for the individual subjects, and for all subjects.

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Insert Figure 11 about here.

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3.52. Context distributions

3.521. Distribution of context by age

Figure 12 shows the distributions of the various contexts over the first year of life. The S context, although fluctuating quite dramatically, exhibits an overall increase with age, with peaks in frequency at 16-25 weeks and 36-40 weeks. Of interest, the SM category shows a complementary decrease with age, but shows an increase near the end of the first year. While the distribution in the SOP category appears moderately random in

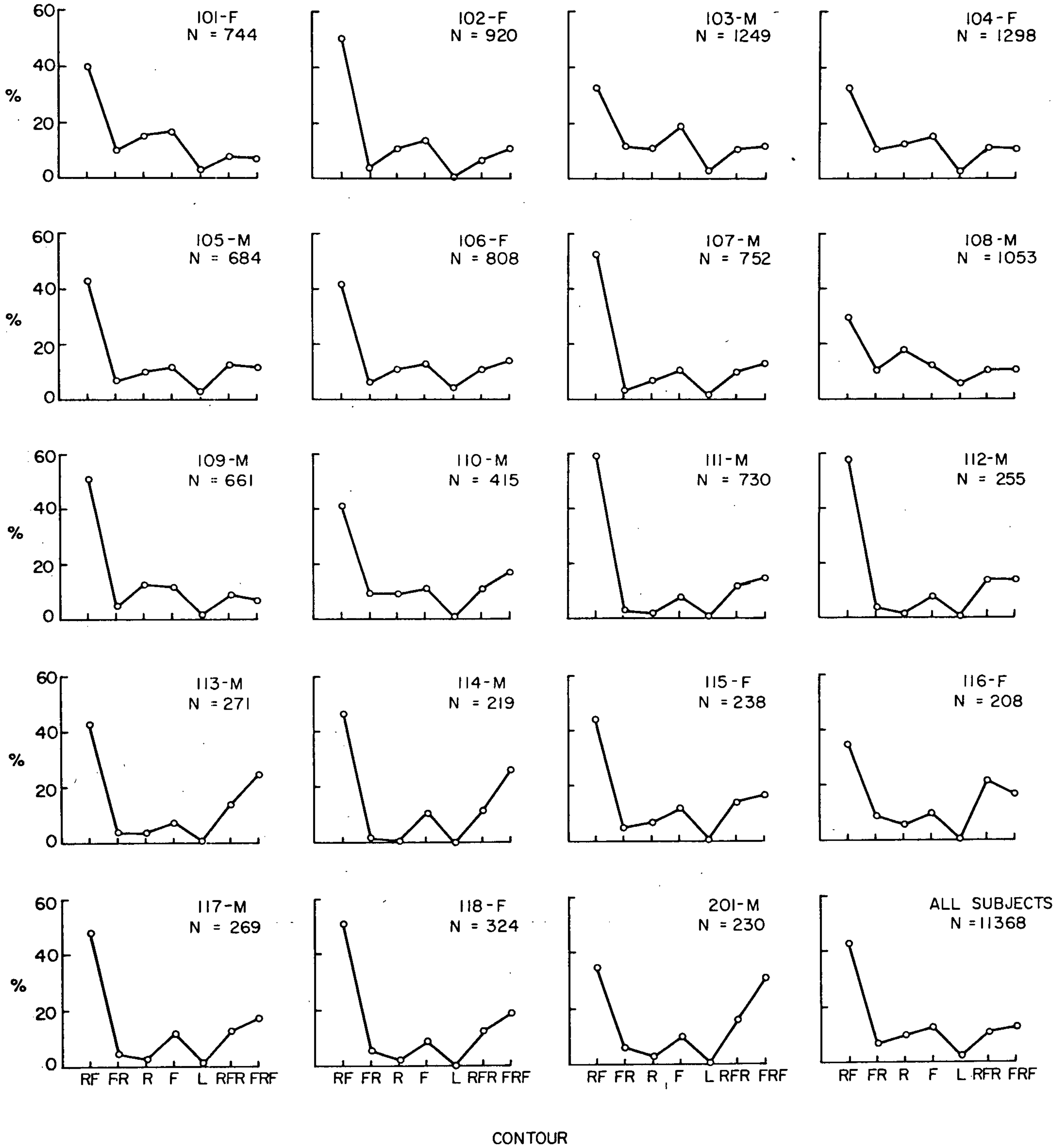

FIGURE 10. Percentage distribution of contour frequency for each subject and for all subjects.

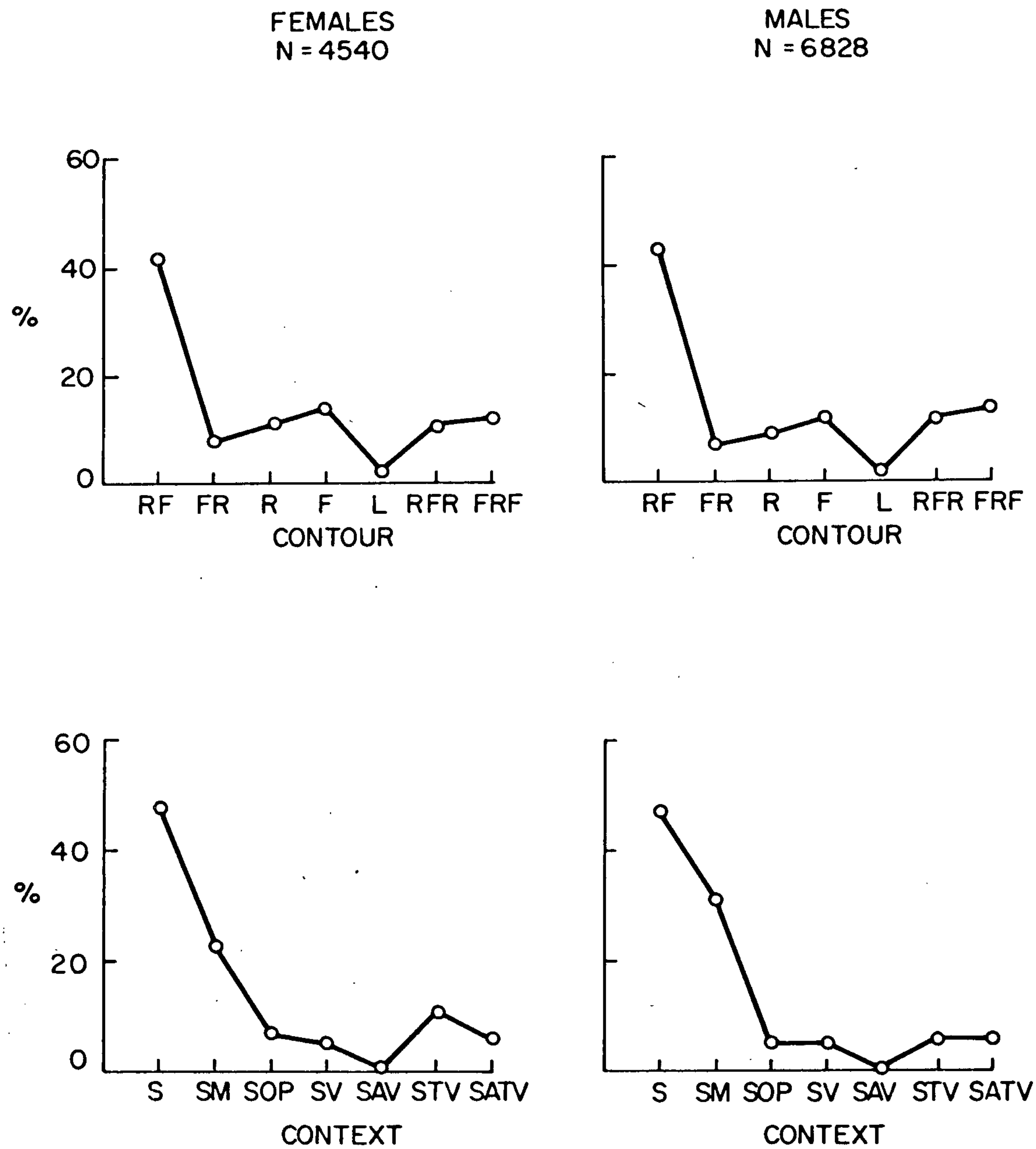

FIGURE 11. Percentage distribution of vocalizations by contour and context for females and males.

nature, a few interesting trends are apparent in the object categories.

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Insert Figure 12 about here.

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The SV category is shown to occur more frequently at 11-15 weeks and 41-45 weeks. Between these two peaks the graph remains at a relatively low level, indicating few utterances in the SV context at other age levels. During the first months of life the SV category consisted largely of utterances produced in the context of crib mobiles which many of the children possessed. Since the initial taping sessions were often carried out with the child in its crib, those children who had crib mobiles tended to vocally express great interest in these toys and therefore the majority of the utterances produced were categorized as SO. It can also be noted that the SATV category exhibited a larger percentage of utterances at the younger age levels. This would be due to the large numbers of utterances produced in the context of crib toys such as rattles, squeakers, and noisemaker mobiles (cf. Appendix I) which were not only visually but auditorily interesting.

As the infants became older and more active, they were less likely to be restricted to their cribs and more likely to be playing with items such as stuffed toys, blocks and stacking rings. This accounts for the higher percentage of STV utterances

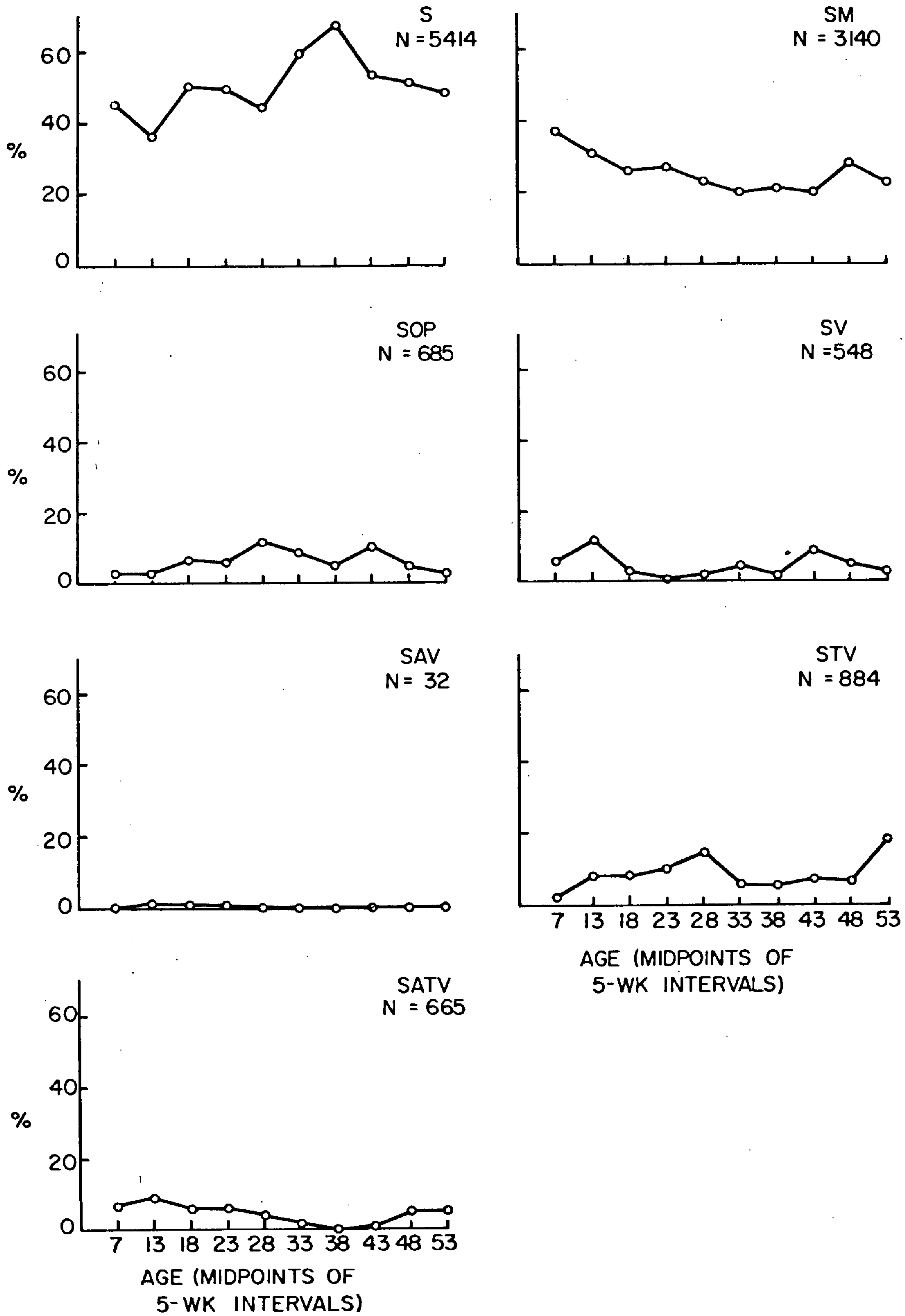

FIGURE 12. Developmental trend of frequency of each context for all subjects.

at the age levels between 26 and 40 weeks, where the SV, SATV and SAV categories show a low frequency of occurrence.

The relatively high incidence of the SV category at 41-45 weeks is likely a reflection of the child's interest in learning about his/her environment. Many of these later sessions included sequences of the child gesturing or somehow expressing interest in a distant object, and the mother naming or describing that object. For at least one subject (102-F) this activity became a game. The objects referred to were included in the SV category because they were not auditory and the child generally did not touch them. Also included in this category were utterances produced in the context of the microphone, an object which proved highly intriguing to many of the children. Utterances produced by the child in response to seeing his/her reflection in glass or a mirror were also classified as SV.

3.522. Distribution of context by sex

The distributions of context according to sex (Figure 11) are virtually identical in all but the SM and STV categories. The males exhibit a much higher percentage of utterances in the SM category than do the females, while the females exhibit a slightly higher percentage of utterances in the STV category than the males. It appears that the females' lower percentage of utterances in the SM context is reflected by a higher percentage in the STV category, while the reverse is true for the males.

3.53. Distribution of contour by context

Subdividing the data according to context results in distributions of the intonation contours that are similar in shape to those of SEX *vs* CONTOUR and SUBJECT *vs* CONTOUR. A few slight differences among the contexts are noted and these differences become slightly more visible when graphs of percent distribution *vs* CONTEXT are produced for the seven contours (see Figure 13).

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Insert Figure 13 about here.

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While the frequencies remain much the same across contexts, detailed inspection of the distributions reveals differences sufficient to warrant a classification on the basis of contour expectancy. Although statistical evaluation finds that only the contour distributions of the *SAV*, *STV* and *SATV* categories differ significantly from the mean, examination of relatively substantial deviations from the mean (as an index of distributional anomaly) indicates that each context may be described by a unique constellation of contours, in terms of their greatest deviations (both positive and/or negative). Any predictive power achieved should not be overrated, however, since some of it may be due to analytic artifacts (such as contextual categorization procedures).

In the following list, and in order of magnitude, reference is made exclusively to contours whose frequency is substantially above (positive) or below (negative) the mean for a given context.

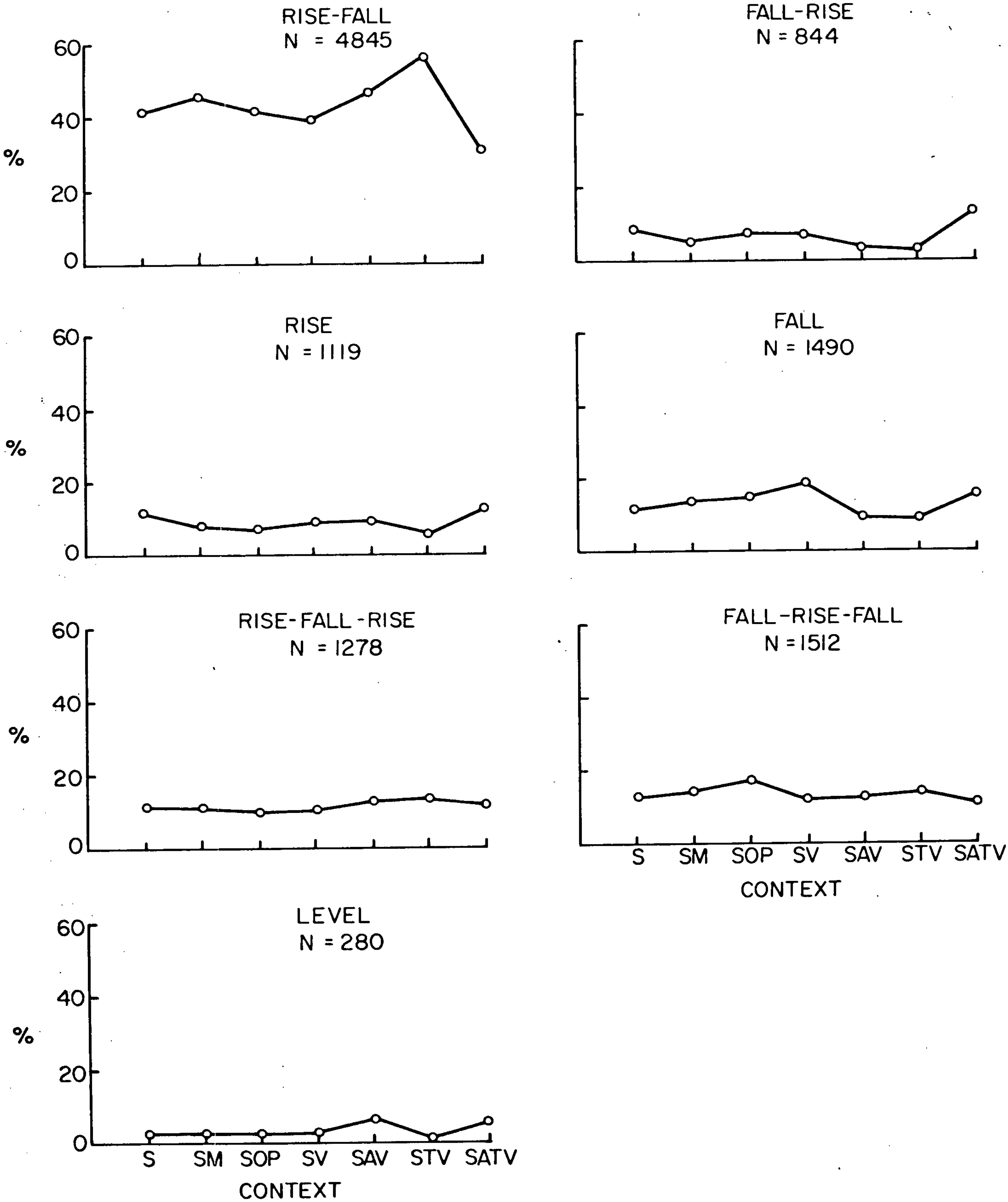

FIGURE 13. Percentage distribution of contours by context for all subjects.

CONTEXT	CONTOUR	
	Positive	Negative
S	FR, R	RF
SM	RF	FR, R
SOP	FRF, F	R, RFR
SV	F	RF
SAV	RF, L	FR, F
STV	RF	FR, R, F
SATV	FR, R, F, L	RF, FRF

It is interesting to note that the distributions of contour in the S and SM contexts are complementary when examined on such an index. By the same token, S and SATV exhibit virtually the same patterning, albeit with more variation in the latter, with (relatively speaking) most vocalizations rising in their terminal portion. In all other cases, falling contours predominate on the positive end of the scale. Further reseach involving a more uniform sample of utterances is needed in order to determine whether an index, such as the one described, can be used to describe various contexts of vocalization more viably.

CHAPTER 4

Discussion

4.1. Review of the present results in relation to theory and previous research

As noted in the literature review, very little research has been carried out on infant non-cry vocalizations. Consequently, it is difficult, but not impossible, to assess our results in the light of past research.

We found that the mean F_o remains fairly stable over the first year, averaging about 355 Hz. A recent study of infant crying vocalizations (Prescott, 1975) failed to show any consistent developmental change in F_o from birth to nine months; F_o values of 385 Hz (0-10 days) and 415 Hz (6-9 months) were cited. These values are higher than those reported in the present study because of the disparate nature of the utterances involved. Sheppard and Lane (1968) found that the F_o of their two subjects decreased initially (up to 21 days) and then increased (by 45 days), whereupon it stabilized until 5 months of age when the study was terminated. Both cry and non-cry utterances were examined in that study, with the consequence that the values of F_o cited are 50-100 Hz higher than those found in the present study. Sheppard and Lane's results also take into account the first few weeks of life, a period which was not examined here.

In the Sheppard and Lane study, the single male subject's F_o was consistently about 25-35 Hz higher than the female's F_o.

The reverse was found to be true in the present study: the mean F_o of the females was observed to be 25 ± 20 Hz higher than that of the males. This disparity may well be due to Sheppard and Lane's small subject sample; intersubject variability in our sample shows individual trends of similar proportions. However, in view of what is known of the anatomy and physiology of the infant's vocal tract, one would not expect to observe sex differences at such an early age. One would expect to see a slight drop in F_o over the first year, due to the lengthening of the vocal folds. Such a decrease was not immediately apparent in the data. An increase in length of the vocal folds may be counterbalanced by other effects, such as increased muscle control over laryngeal activity. It is equally possible that certain psychological variables are operating that result in the observed sex differences and perhaps obscure the changes that one might expect to occur as a result of physiological changes in the larynx. Moss (1967) found that mothers of females were more likely to imitate their infants than were mothers of males; the most likely (albeit unspecified) parameter in this regard would be F_o-mimicry. This intimates that mothers of female infants may employ a slightly higher-pitched voice when speaking to their infants which the infant would, in turn, imitate. Lewis and Freedle (1973) noted that mothers responded to infant-initiated vocalizations more often with male infants than with female infants (except by means of vocal interaction). Infant vocalization in response to maternal behaviour was more likely for females than males. If these observations are accurate, then it would appear that more vocal interaction takes place between female infants and their mothers than between male infants and their mothers. This could account for the precocity of the speech and language development of female children which has often been cited in the literature. The project under which the present research was carried out is currently undertaking an intensive investigation of this purported phenomenon.

A drop in the females' mean F_o of 15 Hz can be observed at 41-45 weeks. This drop may be related to physiological changes, but it is immediately followed by a mean increase of 15 Hz. For the males in our study, the F_o remains relatively stable until 30 weeks, when it begins to decrease; an overall drop of 35 Hz is observed by the end of the first year. This decrease may be mostly attributable to physiological changes, but it may have a psychological component inasmuch as the male infant may be lowering his pitch because of imitation of, or identification with the father, towards the end of the first year. Such behaviour has been observed with a 10-month-old male infant (Lieberman, 1967).

In the present study, DUR was found to increase from approximately 400 msec to 700 msec over the first year. Since the first age interval encompassed measurements from 4-10 weeks, the beginning estimate of DUR may be slightly high. Graphs of DUR vs AGE for each subject revealed that DUR was initially about 250 msec, and therefore increased about 450-500 msec from birth to one year. Our results at the earlier age levels are similar to those obtained for the duration of non-cry vocalizations by Murai (400 msec) and Ringwall, Reese and Markel (350 msec).

Nakazima (1962) reported a more exaggerated duration (600-800 msec) for one-month-old subjects. In the Sheppard and Lane (1968) study, the arithmetic mean of duration was about 550 msec, which is comparable to the results reported here, except that Sheppard and Lane included cries in their study. They also reported geometric mean durations, but this was not calculated in the present investigation, since no viable meaning can be ascribed to such a calculation.

Prescott (1975) measured the durations of cries; the values cited in that study are much higher than those obtained here and were noted to increase with age. Significant differences in that study were found between age levels (0-10 days, and 6-9 months), and between subjects at the earlier age levels only; variability was greater at the earlier age level. Our results indicate that the variability (qua standard deviation) in duration increased as the duration increased.

In the present study, within-utterance range was found to increase with age. It was noted that while the RANGE for females increased consistently with age, that for males increased until about 40 weeks and then decreased. Studies such as those of Prescott (1975) and Sheppard and Lane (1968) have examined within-utterance variability, but do not define their terms. Prescott (1975) noted that within-utterance F_o variability was consistently greater at the advanced age level (6-9 months) for four of the subjects, than it was from birth to 10 days. Sheppard and Lane (1968) computed coefficients of variation in fundamental frequency, both between and within utterances, and found no change with age.

Prescott (1975) also tested but did not bear out the hypothesis that within-utterance F_o variability covaried with duration. RANGE and DUR were thought to covary in the present study, but graphs of RANGE _vs_ DUR, and R/D _vs_ AGE (cf. 3.31) did not evince any consistent relationships between the two variables.

As mentioned earlier, _RF_ contours accounted for about 43% of the data. Considered together, the three contours which fall in their terminal portions, _RF_, _F_ and _FRF_, account for about 70% of the data. These results lend credence to Lieberman's (1967) hypothesis concerning the fall of F_o at the end of an utterance.

The overall percentage distributions of the contours agree, to a certain extent, with those of Wasz-Höckert et al. (1968) for pleasure cries. The percentage distributions of the _F_, _R_ and _FR_ contours are very similar. A larger difference is noted for _RF_ which accounted for 31% of the Wasz-Höckert data; _RFR_ and _FRF_ contours were not described in that study. The main discrepancy occurs in the distribution of _L_ contours which accounted for 2.5% of the present study, as opposed to 46% in the Wasz-Höckert study. The difference lies in the operational definition of _L_ used in the two studies. For the purposes of the present study, a level utterance exhibited little or no change in F_o, whereas in the Wasz-Höckert study a much larger deviation in F_o

was required. The use of the L contour in the present study implies that considerable control is being exercised over the vocal apparatus; since muscular control is not fully developed in the infant, one would not expect to see many L utterances.

It is more difficult to compare the present results with those of Tonkova-Yampol'skaya (1969). Her study involved a qualitative description of the intonation contours which was more concerned with the 'meaning' attached to the contour. One similarity is evident between the R of this study and the infant intonation of expressive calm cooing in Tonkova-Yampol'skaya's investigation which would be described as R in terms of our study. The incidence of this pattern is found to increase at nine months in both studies.

The peaking behaviour of the graphs, which is commonly observed at 4-6, 9, and (to a lesser degree) 11 months, is reminiscent of Bever's (1961) findings upon reanalysis of Irwin and Chen's data concerning phonemic development in infants. While Bever interpreted the peaks as discontinuities (as per the maturational approach), it would appear that this is not necessarily the case. If concomitant peaks are occurring when both segmental and suprasegmental phenomena are considered, it would seem that this would demonstrate a continuity in the system which has otherwise been ignored. As suggested by Bever (1961) and Tonkova-Yampol'skaya (1969), this peaking behaviour may be correlated with the advent of cortical control and organization of vocal output.

Moreover, descent and growth of the larynx, as well as the concomitant readjustment of the supralaryngeal vocal tract and its growth may be of import here (cf. Wind, 1970; Kirchner, 1970). It was noted earlier that the adult female ratio of vocal fold length to the diameter of the lumen of the trachea (viz. 1 : 1.5) is reached by nine months of age. This coincides with the most commonly observed nine-month peak. It is also around this time that more precise imitation of both segmental and suprasegmental phenomena are noted and 'role-playing' or imitation of adult models occurs (Lewis, 1951; Lieberman, 1967; Piaget and Inhelder, 1966).

In general, the distributions of CONTEXT vs AGE reflected the subjects' interests in their surroundings, and to some extent, artifacts in our sampling procedures. The distributions of CONTEXT vs SEX did not indicate any clear-cut preferences for certain types of objects by one sex or the other. It was not found, for example, that males were more visually oriented and females were more auditorily oriented, as has been suggested in the literature. There was a higher percentage of STV utterances for females than males which balanced the lack of utterances in the SM category. The higher percentage of SM utterances for the males is a more curious finding, in view of the results of Moss (1967) and Lewis and Freedle (1973). Perhaps if the mothers of females vocalize more often to their infants, the females have less of a chance to vocalize in turn; or if the females do vocalize, there could be some overlap with the mother's utterance which would mean that the child's utterances could not be analyzed spectrographically. Alternatively, the finding may be correlated with Lewis and Freedle's (1973) observation that the female infants tended to be more restricted than the males in terms of muscular activity. Perhaps this restriction extends to vocal activity as well.

The results of the Hotelling's T^2 tests indicate that differential vocalization is not occurring with respect to the variables examined. The MCA results also indicate little difference between contexts. The slight differences that are observable are generally not consistent from one context to the next. It is possible that other variables not examined -- such as amplitude, harmonic structure, or temporal factors such as the time at which a change (i.e. middle-point) occurs in an utterance -- may be of importance in differentiating environmental events. In addition, a more specific situational analysis regarding the antecedent and subsequent events with respect to infant vocalization would elicit some valuable information. It is not known, for example, what reinforces an act of differential vocalization, if and when such an act does occur. Again, research into this problem is currently in progress within the framework of the more comprehensive project of which this study is a part.

An inspection of the sequences of utterances in the data reveals that on occasion, infants repeat similar intonation patterns in successive utterances; such behaviour is also known to occur at the segmental level. It is not known at this time whether this type of activity takes place in some situations more than in others. There is some evidence in the results of

CONTOUR vs CONTEXT to suggest that the infants may utilize contour volitionally (rather than the individual parameters of F_0, DUR and RANGE) to indicate the situation of vocalization. If this is the case, then non-significant results from a statistical test such as the Hotelling's T^2 would be expected, as found.

4.2. Limitations of the present investigation

4.21. Sample size

A major problem encountered in this experiment was that of sample size. The SO categories tended to have fewer utterances than the S and the incidentally examined SM and SOP categories. The accuracy of our results depends on the stability of the mean values calculated. Furthermore, the MCA predicted model is of no use when there are only a few observations in each cell. Consequently, a large number of utterances are needed, or failing that, each available utterance must be typical of a particular category. Analysis of the utterances according to intonation contour was often impossible because most statistical procedures require at least five utterances per category, and this condition was often not satisified by our corpus of data.

4.22. Classification of utterances according to context

Some difficulties were encountered in the initial, rather *ad hoc* classification of the infants' utterances in terms of the contexts in which they occurred. Without a video tape and an ongoing description of the events occurring during the recording sessions, we cannot be certain of the precise events that resulted in a given infant's vocalization. Despite such problems, we believe that the classification scheme used was consistent enough that certain behaviours, if they occurred, could be examined systematically.

Due to the problems with sample size, it was necessary to group the objects into gross categories. In selecting the categories and assigning objects to these categories we have necessarily imposed an adult judgement as to which attributes of the objects the infants would find most salient. We cannot be certain that the four designated object categories were necessarily correct or appropriate in terms of the infant's interests/ motivations. Categories such as STV consist of a potpouri of objects which should probably have been subcategorized, were it not for constraints on the analytic procedures employed.

Ideally, a uniform sample of objects should have been used for all subjects. In this manner more valuable intersubject comparisons could have been made. This was not of major import in the collection of the data and therefore remains a desideratum for future study.

4.23. Measurement

Due to the laborious and time-consuming work involved in spectrographic analysis and measurement, we were forced to limit our measurements of fundamental frequency (and necessarily intonation contour) to a maximum of four points per utterance. Measurements at more points would have given a more accurate picture of the contour; however such an undertaking awaits more sophisticated instrumentation for use with recordings obtained in a natural (i.e., non-laboratory) setting.

4.3. Implications for theory and future research

The findings of this study answer a few of the questions concerning prosodic development and prosodic contrastivity in the first year of life, but as expected, raise even more questions. Developmental observations of the different acoustic parameters (F_o, RANGE, DUR and CONTOUR) indicate their complex interdependent nature. A satisfactory explanation of the behaviour of these parameters in physiological terms is not possible, given the lack of information concerning the development of respiratory function and the action of the laryngeal muscles in young infants. There is still no adequate description of the infant's psychological development during the first year, nor is enough known of the infant's perception of his/her vocal output and how this relates to speech development. Moreover, how these parameters are cortically controlled remains a mystery.

Earlier, remarks were made concerning the peaking behaviour observed in this study and the coincident peaks observed when segmental behaviour has been studied. This seems to indicate the relative inseparability of segmental and suprasegmental phenomena in early life. Since suprasegmental development is known to be continuous with later speech development, babbling and experimentation at the segmental level must also be recognized as being of import and in continuity with later speech development.

The present study also shows the importance of using contextual information in any study of speech and language development. Future research should be designed to obtain more information along these lines. The insight thus achieved could be used in devising models of speech and language development which could aid in a further understanding of the complex processes involved.

4.4. Summary

Intonation patterns of non-cry vocalizations of infants occurring in two basic situations (i.e., infant alone and infant in the context of various objects) were analyzed spectrographically for fundamental frequency, within-utterance range, duration and contour. Each variable was examined longitudinally and in different contexts.

A number of age trends were evident. Duration and within-utterance range increased with age, whereas fundamental frequency remained relatively stable over the first year. Females exhibited a higher F_o than the males at all age levels examined. Peak values of the variables were commonly observed at 4-6, 9, and (to a lesser degree) 11 months. The RF intonation contour increased in frequency of occurrence during the first year, while the other contours examined demonstrated little change.

Contrasts of utterances occurring in different categories revealed essentially no difference between contexts for the variables studied. Examination of the distributions of the different intonation contours for each context indicated that the infants could be manipulating contour differentially in a given context.

In sum, the findings of this study document a very real, albeit circumscribed, capacity of the part of the infant for vocally differentiating environmental events, one of the basic components in the development of communicative competence. In general it is held that there exists sufficient evidence to refute the parochial view that linguistic acquisition can only be relevantly discussed when the child's segmental phonetic output begins to resemble that of the adult standard; in other words, we support the hypothesis of continuity from babbling to speech. It is hoped that this research will help to fill the gap of "ignorance about the fundamental development of prosodic contrastivity in children" (Crystal, 1973b, p. 33) and, more importantly, will ultimately provide a fund of information on infant vocalization whose essence will find its proper niche in the overall characterization of the development of communicative function.

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APPENDIX A

The following is a list of the objects analyzed for each subject, the age (in weeks) of the subject at which the object occurred, and the total number of utterances analyzed for the object. The mnemonics were devised for use in the computer, and appear in the body of the thesis. Where the mnemonic is not self-explanatory a description of the object is given. The reclassification of each object according to input mode -- Visual (V), Tactile + Visual (TV), Auditory + Visual (AV) and Auditory + Tactile + Visual (ATV) -- is listed in the column under description. Where multiple entries appear under LOCATION and N, read the first entry in each column, then the second entry in each column, and so on.

SUBJECT ID	MNEMONIC	LOCATION (in weeks)	N	DESCRIPTION	
101-F	MOBILE	14	14	V	
	TESSIE	16	7	TV	stuffed turtle
	SWAN	18	1	TV	
	TOYRINGS	47	1	TV	stacking rings
	TAMBOURI	27	4	ATV	tambourine
	BLANKET	18	5	TV	
	BIB	22	20	TV	
	MIRROR	47	1	V	
102-F	MOBILE	7	77	V	
	TOY	21	1	TV	
	BLUEBEAR	27	5	TV	stuffed bear
	SNOOPY	41	15	TV	stuffed dog
	DOG	47	7	TV	
	BLOCKS	54	6	TV	
	BALL	47	9	TV	
	RATTLE	24,25	1,1	ATV	
	CLINKS	18	1	ATV	unidentified

SUBJECT ID	MNEMONIC	LOCATION (in weeks)	N	DESCRIPTION
102-F	MOBBELLS	19	2	ATV mobile with bells
	MIKE	21	1	V microphone
	PAPERS	41	10	V newspapers
	PHOTO	45	6	V family photograph
	BOOKS	47,50	7,6	V
	CANDLE	50	8	V
	KEYS	54	9	ATV
	SLIPPER	54	7	TV
103-M	MOBILE	15	213	V
	BALL	28	5	TV
	RATTLE	28	3	ATV
	BELLS	22	17	ATV
104-F	MOBILE	16	16	V
	PINKTEDD	7	29	ATV musical teddy bear
	SNOOPY	14,16,20	34,3,6	TV stuffed dog
	GREEFROG	20	50	TV stuffed frog
	HAIRDOLL	24	41	TV hairy doll
	GRAYDOG	26	10	TV stuffed dog
	GROUNHOG	26	15	TV groundhog
	RATTLE	9	65	ATV
	CLOWN	14	103	ATV jingling clown
	PULLTOY	52	6	ATV
	EATINCUP	24,26	38,25	TV baby's mug
	MIKE	16	50	V microphone
105-M	BOOKS	23	6	V
	DUCK	53	9	TV toy duck
	TAPERECR	53	10	V tape recorder
	MIRROR	33	6	V
	BOTTLE	7,16	25,3	TV
106-F	PUPPY	24	13	TV toy dog
	BLOCKS	50	6	TV
	POPBEADS	54	7	TV plastic beads
	RINGTOSS	54	8	TV toy rings
	RATTMOBI	20	3	ATV rattle mobile
	RATTBELL	15	3	ATV rattle
	MUSICBOX	14	14	AV
	LION	15,18	1,7	ATV squeaky toy
	YELORATT	28	16	ATV rattle
	TOYMOUSE	50	15	ATV squeaky toy
	RATTLE	50	7	ATV
	POTS	44	8	TV kitchen pots
	BLANKET	54	9	TV

SUBJECT ID	MNEMONIC	LOCATION (in weeks)	N	DESCRIPTION
107-M	BLOCKS	53	12	TV
	TOY	32	10	TV unidentified
	TOYRINGS	35	5	TV stacking rings
	RATTLES	10	4	ATV
	BELLS	13,24	3,7	ATV
	SQUDUCK	23,24	15,3	ATV squeaky duck
109-M	TOYBOATS	32	9	TV
	BALL	35	8	TV
	JUMPROPE	44	12	TV
	TOYSUNID	18	4	ATV unidentified
	TELEPHON	32	6	ATV toy phone
	HAMMER	35	7	ATV squeaky toy
	WHISTLE	41	6	ATV
	MIKE	41	18	V microphone
	CHAIR	7	13	V
	MOTHRING	13	8	TV mother's ring
	SHOE	24	5	TV
	JUDYHAIR	30	5	TV E's hair
110-M	BLOCKS	38	15	TV
	BALLOON	48	5	TV
	MIKE	38,41	11,13	V microphone
	REFLECT	30	18	V reflection of child
111-M	MOBILE	12,32	12,10	V
	RAGDOLL	14,15,18,21/	15,15,16,7	TV stuffed toy
	TEDDY	12,14	16,13	TV stuffed toy
	BLUBUNNY	14,15,18,28/	16,15,16,10	TV stuffed toy
	ELEPHANT	18,21	15,7	TV stuffed toy
	PLUTODOG	28	15	TV
	RATTPIN	21	9	ATV rattle
	RATTLE3	23	8	ATV rattle
	MIKE	35	5	V microphone
	RADIO	24	7	AV
	WALPAPER	32	5	V wallpaper
	BOWL	40	12	TV
112-M	TEDDBEAR	11	9	TV stuffed toy
	BALL	20	15	TV
113-M	GREBUNNY	13	8	TV green bunny toy
	PANDBEAR	26	6	TV panda bear
	RATTLE	24	5	ATV
	KEYS	26	12	ATV
	HAT	26	5	TV

SUBJECT ID	MNEMONIC	LOCATION (in weeks)	N	DESCRIPTION	
115-F	POOH	22,24	5,15	TV	teddy bear
	TAPERECR	20	6	V	
	NECKLACE	19	6	TV	
116-F	MOBILE	22	7	V	
	TEDDBEAR	18,22,26	15,12,7	TV	teddy bear
	RABBIT	22	8	TV	toy rabbit
117-M	STUFFDOG	16	5	TV	stuffed dog
	TEDDY	20	12	TV	teddy bear
	MUSICBOXI	16	11	AV	musicbox
118-F	TEDDBEAR	15	15	TV	teddy bear
	GUNK	19,23,24	15,9,9	TV	stuffed toy
	DOLLY	23	8	TV	doll
	STUFFDOG	24,26	9,10	TV	stuffed dog
	RATTLE	8	5	ATV	
108-M	RATTLE	11,13,15, 18,21	43,13,19, 139,64	ATV	

APPENDIX B

AVERAGED DATA FOR

MULTIPLE CLASSIFICATION ANALYSIS

FUNDAMENTAL FREQUENCY (MEAN / S.D. IN HZ)

AGE (WKS)	FEMALES	MALES	COMBINED
0 - 10	365 / 65	350 / 80	355 / 75
11 - 15	350 / 55	345 / 80	345 / 75
16 - 20	365 / 80	355 / 80	360 / 80
21 - 25	380 / 65	340 / 65	355 / 65
26 - 30	380 / 65	360 / 110	370 / 90
31 - 35	360 / 65	350 / 80	350 / 75
36 - 40	370 / 70	340 / 45	360 / 60
41 - 45	355 / 60	330 / 70	340 / 70
46 - 50	370 / 70	330 / 55	350 / 65
51 - 60	370 / 60	325 / 60	345 / 65
CONTEXT			
S	365 / 65	350 / 85	355 / 80
S M	375 / 70	345 / 70	355 / 70
S OP	380 / 70	355 / 90	370 / 85
S V	350 / 55	330 / 40	340 / 50
S AV	355 / 90	325 / 65	340 / 80
S TV	375 / 65	330 / 50	355 / 65
S ATV	335 / 60	345 / 80	340 / 75
TOTAL	370 / 70	345 / 80	355 / 75

DURATION (MEAN / S.D. IN MSEC)

AGE (WKS)	FEMALES	MALES	COMBINED
0 - 10	375 / 310	430 / 330	405 / 320
11 - 15	480 / 380	610 / 425	575 / 415
16 - 20	630 / 535	725 / 480	695 / 505
21 - 25	695 / 620	805 / 560	760 / 590
26 - 30	775 / 540	670 / 410	725 / 480
31 - 35	705 / 505	690 / 470	700 / 485
36 - 40	900 / 685	815 / 510	865 / 620
41 - 45	760 / 520	695 / 465	725 / 490
46 - 50	750 / 570	755 / 515	755 / 545
51 - 60	645 / 450	605 / 375	625 / 415
CONTEXT			
S	645 / 535	695 / 490	675 / 510
S M	630 / 530	640 / 475	635 / 495
S OP	620 / 470	705 / 490	665 / 485
S V	485 / 435	615 / 420	565 / 430
S AV	365 / 405	810 / 325	615 / 420
S TV	740 / 660	660 / 380	705 / 560
S ATV	485 / 435	730 / 520	625 / 500
TOTAL	635 / 540	675 / 475	660 / 500

WITHIN-UTTERANCE RANGE (MEAN / S.D. IN Hz)

AGE (WKS)	FEMALES	MALES	COMBINED
0 - 10	80 / 75	85 / 70	85 / 75
11 - 15	85 / 65	95 / 85	95 / 80
16 - 20	100 / 80	100 / 80	100 / 80
21 - 25	105 / 70	95 / 70	100 / 70
26 - 30	105 / 70	100 / 85	100 / 80
31 - 35	90 / 70	100 / 80	95 / 75
36 - 40	105 / 80	105 / 60	105 / 70
41 - 45	100 / 75	85 / 60	95 / 65
46 - 50	110 / 85	90 / 55	100 / 70
51 - 60	110 / 85	80 / 60	95 / 75
CONTEXT			
S	95 / 75	95 / 80	95 / 80
S M	100 / 75	100 / 70	100 / 75
S OP	110 / 75	110 / 100	110 / 90
S V	95 / 65	85 / 55	90 / 60
S AV	75 / 60	90 / 85	80 / 75
S TV	110 / 75	90 / 50	100 / 65
S ATV	75 / 75	80 / 65	80 / 70
TOTAL	95 / 75	95 / 75	95 / 75

MEAN / S.D. :	FUNDAMENTAL FREQUENCY (Hz)	RANGE (Hz)	DURATION (MSEC)
SUBJECT			
101-F	365 / 80	95 / 80	705 / 570
102-F	370 / 65	100 / 75	570 / 500
103-M	340 / 65	85 / 65	580 / 435
104-F	365 / 65	90 / 75	525 / 480
105-M	395 / 105	100 / 90	740 / 520
106-F	360 / 60	90 / 65	755 / 590
107-M	330 / 50	100 / 60	645 / 500
108-M	360 / 90	95 / 90	645 / 415
109-M	305 / 75	85 / 80	630 / 480
110-M	345 / 50	80 / 55	640 / 445
111-M	325 / 65	110 / 65	795 / 450
112-M	345 / 55	95 / 55	590 / 415
113-M	335 / 50	100 / 55	630 / 410
114-M	410 / 95	150 / 115	825 / 520
115-F	405 / 75	115 / 90	595 / 470
116-F	340 / 45	100 / 65	790 / 600
117-M	370 / 70	115 / 95	825 / 615
118-F	400 / 60	130 / 70	715 / 545
201-M	365 / 40	95 / 55	890 / 555
TOTAL (WEIGHTED)	355 / 75	95 / 75	660 / 500

	RANGE ÷ DURATION ($\times 10^{-1}$)	$\bar{F}_0$ x RANGE x DURATION ($\times 10^{-7}$)
AGE (WKS)		
0 - 10	2.60	1.64
11 - 15	2.07	2.51
16 - 20	1.94	3.28
21 - 25	1.83	3.45
26 - 30	1.82	3.24
31 - 35	1.73	3.11
36 - 40	1.61	4.06
41 - 45	1.69	2.83
46 - 50	1.87	3.04
51 - 60	1.89	2.64
CONTEXT		
S	1.89	3.02
S M	2.13	2.84
S OP	2.16	3.56
S V	2.14	2.06
S AV	2.62	2.15
S TV	1.90	3.17
S ATV	1.73	2.34
TOTAL (WEIGHTED)	1.98	2.93

	RANGE ÷ DURATION ($\times 10^{-1}$)		$\bar{F}_0$ x RANGE x DURATION ($\times 10^{-7}$)	
SUBJECT	FEMALES	MALES	FEMALES	MALES
101-F	1.90		3.25	
102-F	2.50		2.67	
103-M		1.89		2.15
104-F	2.33		2.36	
105-M		1.96		3.69
106-F	1.81		3.04	
107-M		2.22		2.61
108-M		1.76		2.94
109-M		1.66		2.40
110-M		1.52		2.20
111-M		1.59		3.26
112-M		2.09		2.25
113-M		1.99		2.36
114-M		2.54		6.12
115-F	2.35		3.54	
116-F	1.63		3.51	
117-M		1.78		4.50
118-F	2.45		4.74	
201-M		1.36		3.52
TOTAL	2.14	1.86	3.30	3.17
COMBINED (UNWEIGHTED)	1.96		3.22	
COMBINED (WEIGHTED)	1.98		2.93	

APPENDIX C

DISTRIBUTIONAL DATA DERIVED FROM MULTIVARIATE NOMINAL SCALE ANALYSIS

DISTRIBUTION (%) OF CONTOURS BY AGE, CONTEXT, AND SEX

CONTOUR:	N	R - F	F - R	RISE	FALL	LEVEL	R-F-R	F-R-F
AGE (WKS)								
0 - 10	1518	40.0	7.9	14.6	17.9	3.9	7.1	8.6
11 - 15	2046	41.1	6.5	10.9	16.1	3.4	9.1	13.0
16 - 20	2498	38.3	8.3	9.2	12.2	2.6	13.4	16.1
21 - 25	2047	45.0	6.4	7.9	10.9	1.7	13.9	14.2
26 - 30	815	45.0	8.0	7.2	10.4	1.5	12.1	15.7
31 - 35	584	45.7	8.2	7.0	14.6	2.4	9.1	13.0
36 - 40	554	44.0	8.3	8.3	11.6	1.1	13.5	13.2
41 - 45	531	45.4	9.6	11.7	11.7	1.5	9.8	10.4
46 - 50	450	49.6	7.1	8.0	8.7	1.8	11.3	13.6
51 - 60	325	54.2	3.7	12.6	7.7	1.2	10.8	9.8
CONTEXT								
S	5414	41.0	8.8	11.6	12.2	2.4	11.3	12.7
S M	3140	45.2	5.3	7.9	13.8	2.4	11.1	14.3
S OP	685	41.6	7.4	7.2	15.2	2.3	9.8	16.5
S V	548	39.6	7.1	9.7	19.0	2.6	10.4	11.7
S AV	32	46.9	3.1	9.4	9.4	6.3	12.5	12.5
S TV	884	54.6	2.8	5.8	9.3	0.9	12.9	13.7
S ATV	665	30.8	13.1	12.9	15.6	5.3	11.4	10.8
SEX								
FEMALE	4540	41.5	7.8	11.2	14.3	2.5	10.6	12.1
MALE	6828	43.4	7.2	8.9	12.3	2.4	11.7	14.1
TOTAL	11368	42.6	7.4	9.8	13.1	2.5	11.2	13.3

DISTRIBUTION (%) OF CONTOURS BY SUBJECT

CONTOUR:	N	R - F	F - R	RISE	FALL	LEVEL	R-F-R	F-R-F
SUBJECT								
101-F	744	39.7	9.7	15.5	17.1	3.0	7.7	7.5
102-F	920	51.5	4.3	10.7	14.2	1.4	7.1	10.8
103-M	1249	32.7	12.2	10.6	18.6	2.8	11.4	11.7
104-F	1298	33.4	11.3	13.3	16.4	3.2	11.5	10.9
105-M	684	43.4	6.9	9.6	12.1	2.6	13.2	12.1
106-F	808	41.8	5.7	10.6	12.7	4.0	11.0	14.1
107-M	792	53.3	3.5	6.9	11.2	2.4	9.7	12.9
108-M	1053	30.3	11.1	17.7	12.5	5.6	11.4	11.4
109-M	661	50.7	5.1	12.9	12.3	2.4	9.4	7.3
110-M	415	41.4	8.9	8.9	11.1	1.2	11.1	17.3
111-M	730	59.3	3.3	1.6	7.7	0.5	12.2	15.3
112-M	255	57.3	3.9	2.4	7.8	1.2	13.7	13.7
113-M	271	43.2	4.1	4.4	8.1	1.1	14.0	25.1
114-M	219	47.0	1.8	0.9	11.4	---	12.3	26.5
115-F	238	44.5	4.6	7.1	11.8	0.4	14.3	17.2
116-F	208	35.1	9.1	6.3	9.6	1.4	21.6	16.8
117-M	269	48.0	5.2	3.3	11.9	1.5	12.6	17.5
118-F	324	50.6	5.6	2.5	8.6	---	13.3	19.4
201-M	230	34.8	5.7	3.0	9.6	0.4	15.7	30.9
TOTAL	11368	42.6	7.4	9.8	13.1	2.5	11.2	13.3

DISTRIBUTION (%) OF CONTEXTS BY AGE AND SEX

CONTEXT:	N	S	S M	S OP	S V	S AV	S TV	S ATV
AGE (WKS)								
0 - 10	1518	45.1	37.3	3.2	5.9	---	1.6	6.8
11 - 15	2046	36.3	30.9	3.4	11.6	0.7	8.0	9.0
16 - 20	2498	49.8	26.3	6.7	2.9	0.4	7.6	6.2
21 - 25	2047	48.9	27.3	6.4	0.7	0.3	10.1	6.4
26 - 30	815	43.9	22.7	12.4	2.2	---	14.5	4.3
31 - 35	584	58.9	20.0	8.9	4.5	---	5.5	2.2
36 - 40	554	67.3	21.1	4.7	2.0	---	4.9	---
41 - 45	531	52.9	20.0	10.5	8.9	---	6.6	1.1
46 - 50	450	50.9	27.8	5.3	4.9	---	6.2	4.9
51 - 60	325	48.3	23.1	3.1	3.1	---	17.8	4.6
SEX								
FEMALE	4540	48.3	22.8	6.9	4.6	0.3	11.0	6.1
MALE	6828	47.2	30.9	5.4	5.0	0.3	5.6	5.7
TOTAL	11368	47.6	27.6	6.0	4.8	0.3	7.8	5.8

DISTRIBUTION (%) OF CONTEXTS BY SUBJECT

CONTEXT: SUBJECT	N	S	S M	S OP	S V	S AV	S TV	S ATV
101-F	744	66.9	16.5	9.4	2.0	---	4.6	0.5
102-F	920	53.0	22.2	5.3	12.5	---	5.4	1.5
103-M	1249	49.2	26.1	5.8	17.0	---	0.4	1.6
104-F	1298	44.5	12.4	5.2	5.1	---	17.1	15.6
105-M	684	64.2	18.3	8.9	3.2	---	5.4	---
106-F	808	48.8	35.8	1.0	---	1.7	6.3	6.4
107-M	792	33.8	49.2	9.5	---	---	3.4	4.0
108-M	1053	62.6	10.3	0.7	---	---	---	26.4
109-M	661	38.3	37.5	8.9	4.7	---	7.1	3.5
110-M	415	61.7	23.4	---	10.1	---	4.8	---
111-M	730	32.6	27.9	6.0	4.4	1.0	25.8	2.3
112-M	255	35.7	54.9	---	---	---	9.4	---
113-M	271	49.4	32.5	4.8	---	---	7.0	6.3
114-M	219	35.2	52.5	12.3	---	---	---	---
115-F	238	24.4	43.7	18.5	2.5	---	10.9	---
116-F	208	35.1	24.0	17.3	3.4	---	20.2	---
117-M	269	35.7	49.1	4.8	---	4.1	6.3	---
118-F	324	31.8	31.5	12.0	---	---	23.1	1.5
201-M	230	42.2	57.8	---	---	---	---	---
TOTAL	11368	47.6	27.6	6.0	4.8	0.3	7.8	5.8

DISTRIBUTION (%) OF CONTOURS BY AGE (3 CLASSES)

CONTOUR:	N	R - F	F - R	RISE	FALL	LEVEL	R-F-R	F-R-F
AGE (WKS)								
0 - 21	6489	39.5	7.8	11.2	14.9	3.1	10.5	13.1
22 - 38	3375	46.5	6.7	7.1	11.0	1.6	12.7	14.5
39 - 60	1504	47.2	7.7	10.2	10.3	1.4	11.4	11.8

DISTRIBUTION (%) OF CONTEXTS BY AGE (3 CLASSES)

CONTEXT:	N	S	S M	S OP	S V	S AV	S TV	S ATV
AGE (WKS)								
0 - 21	6489	45.0	29.6	4.8	6.2	0.4	6.1	8.0
22 - 38	3375	50.5	25.7	7.9	2.0	0.2	10.6	3.1
39 - 60	1504	52.5	23.4	7.1	5.3	0.0	8.8	2.9

APPENDIX D

MISCELLANEOUS DATA

DISTRIBUTION OF VOCALIZATIONS BY SUBJECT

SUBJECT	DATA EPOCH (IN WEEKS)	NO. OF SESSIONS	OBSERVATIONS NUMBER	OBSERVATIONS PERCENTAGE
101-F	5 - 51	22	744	6.5
102-F	5 - 54	22	920	8.1
103-M	7 - 55	20	1249	10.9
104-F	5 - 52	20	1298	11.4
105-M	5 - 53	20	684	6.0
106-F	5 - 54	19	808	7.1
107-M	5 - 53	23	804	7.0
108-M	5 - 21	8	1053	9.2
109-M	6 - 55	18	661	5.8
110-M	5 - 55	18	415	3.6
111-M	7 - 55	19	730	6.4
112-M	5 - 24	10	281	2.5
113-M	7 - 26	11	271	2.4
114-M	6 - 25	9	219	1.9
115-F	5 - 24	9	238	2.1
116-F	8 - 26	7	208	1.8
117-M	5 - 24	9	269	2.4
118-F	4 - 26	10	324	2.8
201-M	5 - 24	9	237	2.1
TOTAL:		283	11,413	100.0

N.B.-- THE UTTERANCES OF THE 10 SUBJECTS (FEMALE: N = 4; MALE: N = 6) FOLLOWED OVER THE COURSE OF ONE YEAR CONSTITUTE 68% (N = 7761) OF THE TOTAL SAMPLE/OBSERVATIONS.

DISTRIBUTION OF VOCALIZATIONS BY SUBJECT AND CONTEXT

SUBJECT	S	S F	S M	S AN	S AM	S AF	S V	S AV	S TV	S ATV	S OP	S O	TOTAL
101-F	498	10^{4}	123	--	22^{3}	38^{9}	15	--	34	4	70	53	744
102-F	488	21^{2}	204	--	1^{1}	27^{4}	115	--	50	14	49	179	920
103-M	614	16^{2}	326	--	--	56^{8}	212	--	5	20	72	237	1249
104-F	578	18^{2}	161	--	19^{1}	31^{6}	66	--	222	203	68	491	1298
105-M	439	32^{6}	125	--	13^{2}	16^{4}	22	--	37	--	61	59	684
106-F	394	--	289	--	1^{1}	7^{2}	--	14	51	52	8	117	808
107-M	268	73^{4}	390	12^{1}	--	2^{1}	--	--	27	32	75	59	804
108-M	659	--	109	--	--	7^{1}	--	--	--	278	7	278	1053
109-M	253	--	248	--	--	59^{5}	31	--	47	23	59	101	661
110-M	256	--	97	--	--	--	42	--	20	--	--	62	415
111-M	238	--	204	--	--	44^{4}	32	7	188	17	44	244	730
112-M	91	--	140	26^{2}	--	--	--	--	24	--	--	24	281
113-M	134	--	88	--	--	13^{1}	--	--	19	17	13	36	271
114-M	77	15^{1}	115	--	--	12^{1}	--	--	--	--	27	--	219
115-F	58	14^{1}	104	--	--	30^{2}	6	--	26	--	44	32	238
116-F	73	13^{1}	50	--	--	23^{2}	7	--	42	--	36	49	208
117-M	96	--	132	--	--	13^{2}	--	11	17	--	13	28	269
118-F	103	29^{2}	102	--	--	10^{1}	--	--	75	5	39	80	324
201-M	97	--	133	7^{1}	--	--	--	--	--	--	--	--	237
TOTAL:	5414	241	3140	45	56	388	548	32	884	665	685	2129	11413

NOTE: (1) CONTEXT S OP = S F + S AM + S AF, GIVEN THE SMALL NUMBER OF OBSERVATIONS IN THESE CATEGORIES. CONTEXT S AN HAS BEEN EXCLUDED FOR THE SAME REASON. CONTEXT S O IS THE AGGREGATE OF ALL FOUR OBJECT CATEGORIES.

(2) SUPERCRIPTS ($^{1\ 2\ 3\ \cdots}$) INDICATE THE TOTAL NUMBER OF SESSIONS COMPRISED IN THE NUMBER OF OBSERVATIONS CITED.

DISTRIBUTION OF OBSERVATIONS BY CONTOUR

CONTOUR	FEMALE (N=7; 37%)		MALE (N=12; 63%)		COMBINED (N=19; 100%)	
	N	%	N	%	N	%
Rise-Fall	1883	41.5	2994	43.6	4877	47.4
Fall-Rise	353	7.8	491	7.1	844	7.4
Rise	509	11.2	612	8.9	1121	9.8
Fall	650	14.3	841	12.2	1491	13.1
Level	113	2.5	167	2.4	280	2.5
R - F - R	482	10.6	801	11.7	1283	11.2
F - R - F	550	12.1	967	14.1	1517	13.3
TOTAL:	4540	100.0	6873	100.0	11413	100.0
	(39.8%)		(60.2%)		(100%)	

DISTRIBUTION OF OBSERVATIONS BY CONTEXT

CONTEXT	FEMALE (N=7; 37%)		MALE (N=12; 63%)		COMBINED (N=19; 100%)	
	N	%	N	%	N	%
S	2192	48.3	3222	46.9	5414	47.4
S F	105	2.3	136	2.0	241	2.1
S M	1033	22.8	2107	30.7	3140	27.5
S AN	0	0.0	45	0.7	45	0.4
S AM	43	0.9	13	0.2	56	0.5
S AF	166	3.7	222	3.2	388	3.4
S V	209	4.6	339	4.9	548	4.8
S AV	14	0.3	18	0.3	32	0.3
S TV	500	11.0	384	5.6	884	7.7
S ATV	278	6.1	387	5.6	665	5.8
TOTAL:	4540	100.0	6873	100.0	11413	100.0
	(39.8%)		(60.2%)		(100%)	

LEGEND:

S = SUBJECT ALONE

S F = SUBJECT IN CONTEXT OF FATHER

S M = SUBJECT IN CONTEXT OF MOTHER

S AN = SUBJECT IN CONTEXT OF LIVE ANIMAL

S AM = SUBJECT IN CONTEXT OF ADULT MALE (OTHER THAN FATHER)

S AF = SUBJECT IN CONTEXT OF ADULT FEMALE (OTHER THAN MOTHER)

S V = SUBJECT IN CONTEXT OF OBJECT (CATEGORY: VISUAL)

S AV = SUBJECT IN CONTEXT OF OBJECT (CATEGORY: AUDITORY + VISUAL)

S TV = SUBJECT IN CONTEXT OF OBJECT (CATEGORY: TACTILE + VISUAL)

S ATV = SUBJECT IN CONTEXT OF OBJECT (CATEGORY: A + T + V)