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Relationship Between Neonatal Sucking Behaviour
And The Acquisition of Infant Vocalizations

by

Sally E. Plaunt

Thesis presented to the Faculty of
Graduate Studies of Carleton University
in partial fulfillment of the requirements
for the degree of Master of Arts

Ottawa, September 1981

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Abstract

Two measures of non-nutritive sucking, the amplitude and the pattern were examined in 13 healthy neonates to determine whether high amplitude scores and consistent sucking patterns were strong predictors of the date of onset of stop vocalizations. Sucking measures were recorded on the fourth day of life, and vocalizations were taped once a week, in the home, from 6-12 weeks of age. Multiple regression analyses showed that the two sucking measures contributed little in predicting date of onset of stop vocalizations. Non parametric correlations revealed significant relationships between the onset and frequency of different sounds, but no relationship between sucking and vocalization scores. Analyses of variance revealed no significant effects of maternal medication nor sex differences in the sucking measures. A significant effect was noted in the frequency of the stop vocalization "g" in that it occurred more than the vocalizations "b" and "d". This study provides further normative data on the sucking behaviour of neonates, plus the type and amount of vocalizations occurring between 6 and 12 weeks in the infant.

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Introduction

There is a high incidence of speech disorders in primary grade elementary school children. Between 7.7 and 9.5% of them receive therapy and this number is sufficiently high to warrant the implementation of an earlier intervention programme than presently exists (Myklebust 1954). Children born with physical facial anomalies such as cleft palate are soon identified at birth, but other children at high risk for speech development may not be detected until three to four years of age. The purpose of this thesis was to determine whether a specific response occurring as early as the fourth day of life, could be used to determine those children at high risk for the development of speech sounds.

The neonatal response examined was the amplitude and consistency of pattern of non-nutritive sucking (NNS) in the four day old neonate. There were two reasons for using sucking as a possible predictor of later speech problems. First, the physiological mechanisms involved in sucking and the production of certain vocalizations, such as "p", "b", "t", "d", "k", "g", are similar (Keene and Willis 1950; Kaplan 1960; Sessle and Kenny 1973); and secondly, a consistent sucking pattern at four days may reflect the adequacy of the nervous system in carrying out the fine co-ordinated muscle movements of those organs later used in speech, such as the lips, tongue and palate (Peiper 1963; Wolff 1968).

If the sucking pattern is a reflection of the adequacy of the nervous system, it would be expected that a neonate with a consistent pattern, who thus demonstrated co-ordinated movements of the articulators, would vocalize earlier than one with an inconsistent pattern.

Therefore those vocalizations involving similar physiological mechanisms as the sucking act, were examined from six weeks to three months of age to determine their date of onset.

The following literature review first examines the physiological mechanisms involved in sucking and the production of certain vocalizations. Various aspects of sucking are considered including the different patterns of sucking in the human neonate; central mechanisms underlying NNS, and methods of measuring sucking behaviour.

This is followed by a discussion on the importance of early vocalizations for later development of speech sounds; the different features of early vocalizations that have been examined in previous studies; and different methods of measuring vocalizations. Finally studies pertinent to the present experimental design are considered.

This review suggests a relationship does exist between sucking and early vocalizations, but reveals a lack of systematic research and the need for empirical studies to examine such a relationship.

Chapter I

Review of the Literature

Physiological Mechanisms Involved in Sucking and the Production of Stop Vocalizations

Both sucking and the production of stop vocalizations require a build up of pressure within the mouth. The physiology involved in creating this pressure is first examined, and the similarities between sucking and stop vocalizations are shown.

Co-ordinated activities of the lips, tongue, palate and mandible are necessary for the neonate to suck. Touching the lips with the nipple results in opening of the mouth and subsequent enclosure of the nipple (Bosma 1975). The tongue fills the oral cavity and physiologically it has been likened to a piston, which is driven forward and backwards by the extrinsic tongue muscles (Fletcher 1973).

At the start of sucking, the nipple is grasped and held against the hard palate by the tip and adjacent blade of the tongue. The tongue and lower lip enclose the nipple from below, while the upper lip and incissor gingival ridge enclose it from above (Bosma 1972). This creates a seal at the anterior opening of the mouth. A posterior seal is created by the approximation of tongue and soft palate, which occurs as a result of the tongue filling the oral cavity, plus the lowered position of the soft palate (Keene and Willis 1950; Kaplan 1960). It is these two points of closure, plus a lowering of the floor of the oral cavity, which creates a vacuum in the mouth. Fluids are then drawn into the mouth by means of negative oral pressure, as the neonate sucks. The floor of the mouth is subsequently raised in preparation for swallowing (Keene and Willis 1950).

Negative intra-oral pressure is also necessary for the production of the stop vocalizations "p", "b", "t", "d", "k", "g". In the adult a stop sound is made by first completely blocking (hence the word "stop") the airstream in the mouth, and subsequently releasing it at a specific place of articulation. For the production of "p" and "b", the anterior seal is at the lips; for "t" and "d" the tip of the tongue is raised against the alveolar ridge; and for "k" and "g", the back of the tongue is brought into contact with the junction between the hard and soft palate. The posterior seal for all six sounds is achieved by raising the soft palate against the pharyngeal wall. This closure effectively seals the oral from the nasal cavity, and occurs during the production of all non-nasal sounds (Lieberman 1977).

The anterior seals for these sounds are the same in the neonate, but the posterior seal differs owing to the close anatomical position of the tongue and soft palate, and the physiological differences in the movement of the soft palate (see Figure 1). In the neonate the palatal muscles lower the soft palate to ensure the maintenance of a nasal airway for unobstructed breathing. Thus sounds resembling stop vocalizations are made by the neonate using the posterior seal of the palate and tongue, rather than the palate and the pharynx, as in the adult. Intra-oral pressure is therefore built up for both sucking and stop vocalizations in the neonate, by specific muscles creating anterior and posterior seals in the mouth (Kent 1980; Netsell 1980).

Lip Muscles. The physiological mechanisms involved in sucking and stop vocalizations require co-ordination of the oro-facial musculature. The lip muscles used in sucking are the buccinator and

FIGURE 1

Vocal Tract of the Neonate and Adult

- Li = lips
- HP = hard palate
- T = tongue
- SP = soft palate
- M = mandible
- E = epiglottis
- La = larynx

orbicularis oris. The buccinator forms the lateral wall of the mouth and lies deep to other facial musculature. Its fibres go forward to the corners of the mouth where they decussate, the lower fibres going to the upper lip and the upper fibres to the lower lip. These fibres dovetail into the muscle fibres of the orbicularis oris and encircle the lips. The buccinator narrows the mouth opening while the orbicularis oris protrudes the lips, thus allowing the infant to grasp the nipple. This latter muscle is particularly important during the production of "p" and "b", when it acts as a sphincter to close the oral cavity (Abbs and Eilenberg 1976).

Sudden reduction in lip tension by the orbicularis oris is followed by the expulsion of air resulting in the bilabial sounds "p" and "b". At this point it should be noted that the difference between "p" and "b" is dependent on the activity of the vocal tract. If the vocal cords are vibrating "b" will result. If not, the unvoiced "p" will be heard. This difference in voicing also occurs between "t" and "d"; and "k" and "g" with "t" and "k" as the voiceless sounds. This voiced/voiceless distinction need only be noted, and is not of significance for the present study. The buccinator and orbicularis oris are innervated principally by the motor division of the facial nerve, but also by the motor section of the trigeminal nerve (Kenny and Platt 1977).

Tongue and Palate Muscles. The tongue musculature is comprised of both extrinsic and intrinsic muscles. The function of the extrinsics is to change the position of the tongue within the mouth, while the intrinsic muscles tend to change the shape of the tongue at a particular position in the mouth (Keene and Willis 1950). In

the neonate however, it is the extrinsics which perform most of the tongue movements, as the intrinsic muscles have to rely on the continuous action of the extrinsics to become functionally mature. Changes in the shape of the oral cavity at approximately four months of age, also aid in the development of the intrinsic muscles (Kent 1980).

The extrinsic muscles used in sucking are the genio-glossus, hyoglossus, palatoglossus and styloglossus. The genioglossus is the strongest of the extrinsic muscles and forms most of the substance of the tongue. Its mid and lower fibres protrude the tongue when the neonate is seeking the nipple. The upper fibres draw the tongue tip down and back while the middle fibres depress the middle area of the tongue. The hyoglossus muscle, which extends from the hyoid bone to the side of the tongue, draws the tongue down and back (Kaplan 1960).

Thus the upper and middle fibres of the genioglossus and the hyoglossus muscles work together to depress the tongue. This results in the enclosing of the nipple, by the tongue below, and in providing a concave surface for the collection of fluids as they are drawn into the neonate's mouth.

The two muscles responsible for providing a seal at the posterior section of the mouth during sucking are the palatoglossus and the styloglossus. The palatoglossus extends between the soft palate and each side of the tongue and on contraction depresses the soft palate. This depression is aided by the contraction of the tensor palati muscle which depresses the arched soft palate, as does also the levator palati muscle. In the neonate the levator functions as

a tensor instead of its adult role as an elevator of the palate (Bosma and Fletcher 1962; Kent 1980). The palatoglossus also raises the posterior part of the tongue so that it is in contact with the lowered soft palate. It is aided by the styloglossus muscle which stretches from the styloid process to the apex of the tongue, and on contraction, retracts and elevates the tongue. This lowering of the soft palate and raising of the back of the tongue enables the neonate to breathe while sucking.

During the production of stop vocalizations the tongue is pulled back and shortened by the upper fibres of the genioglossus and the hyoglossus muscles. Concurrently, the middle fibres of the genioglossus depress the middle area of the tongue during the production of "t", "d", "k", and "g". The elevation of the tongue tip necessary for the production of "t" and "d" in adults cannot be achieved in the neonate, owing to the immature function of the intrinsic muscles. Instead, the entire frontal portion of the tongue is raised against the hard palate to produce sounds approximating "t" and "d". This is achieved by the middle and lower fibres of the genioglossus and styloglossus muscle.

The action of the palatoglossus muscle is important for the production of "k" and "g", as it raises the posterior portion of the tongue bringing it into contact with the junction of the hard and soft palate. Release at this point of contact results in expulsion of air from the back of the mouth and the sound "k" or "g".

The posterior seal in the mouth for the six stop vocalizations in neonates is achieved by the contraction of the levator palati and uvula muscles, which tense the soft palate. Contact with the post-

erior pharyngeal wall is achieved by the close proximity of the wall with the soft palate in the neonate, and by contraction of the palato-pharyngeal sphincter. This action results in the raising of a ridge on the pharyngeal wall, thus providing contact with the tensed soft palate:

Nerve innervation to all the tongue muscles except the palatoglossus, is supplied by the hyoglossal nerve (Cranial nerve XII). The palatoglossus and all other palatal muscles, with the exception of the tensor palati are supplied by the motor fibres of the vagus nerve (Cranial nerve X). The tensor palati is innervated by the motor division of the trigeminal nerve (Cranial nerve V), (Sheets 1973; Kenny and Platt 1977; Netter 1977).

Jaw Muscles. The muscles which open the jaw to allow the neonate to search for the nipple are the external pterygoid and the anterior belly of the digastric. The former is a triangular muscle which lies deep to the temporalis muscle, and on contraction it protrudes the lower jaw by pulling the mandible forward, downward and inward. The anterior belly of the digastric arises from the base of the mandible and passes downwards and backwards to its insertion into the hyoid bone. When the hyoid bone is stabilized by tensoring muscles, the anterior belly of the digastric opens the jaw (Liebermann 1977). The mandibular muscles which close the jaw during sucking are the masseter, the temporalis and the internal pterygoid. The temporalis also pulls the lower jaw backwards.

The mandibular muscles interact during the production of stop vocalizations to raise and lower the jaw. The jaw is raised prior to the release of the air stream, and is slightly lowered at the

moment of plosion. Nerve innervation to the mandibular muscles is by the motor branch of the trigeminal nerve.

Combined Muscle Activity. Although the action of individual muscles during sucking and the production of stop vocalizations has been described, it is the combined actions of the tongue, jaw and lip muscles which allow for the fine co-ordinated movements necessary for sucking and vocalizations. During sucking for example, "the tongue, lower lip, and mandible form a motor effector that moves in a circular course, expressing the nipple and effecting negative intra-oral pressure" (Bosma 1975). Similarly during the production of vocalizations, the palatal muscles co-ordinate with lip and tongue muscles to ensure that the air stream is first stopped, and then released, at the appropriate moment. In addition, size and shape of the oral cavity is dependent on the co-ordinated activities of jaw, tongue and palate and result in fine differences in production of vocalizations. (Liebermann 1977). (See Figure 2).

In summary, there are certain similarities between sucking and the formation of certain types of vocalizations which later become speech sounds. First, intra-oral pressure is necessary for both sucking and for the production of stop vocalizations. Secondly, the musculature used for both behaviours is similar, and consequently adequate functioning of the cranial nerves is necessary for both. It is these physiological similarities between sucking and stop vocalizations which provide the rationale for examining sucking as a predictor of early vocalizations.

FIGURE 2

Adult Vocal Tract

STRUCTURES

- 1 - abdominal muscles
- 2 - diaphragm
- 3 - ribcage
- 4 - larynx
- 5 - tongue/pharynx
- 6 - posterior tongue
- 7 - anterior tongue
- 8 - velopharynx
- 9 - jaw
- 10 - lips

AERODYNAMICS

- Ps - subglottal air pressure
- Po - intraoral air pressure
- Vg - glottal air flow
- Vo - oral air flow
- Vn - nasal air flow

Nutritive Versus Non-nutritive Sucking

There is evidence to suggest that humans have two distinct patterns of sucking, known as nutritive and non-nutritive (NS and NNS respectively), and that the temporal organizations of these two patterns are different. This is in contrast with other mammals who have only one temporal organization of sucking behaviour (Wolff 1972; Brown 1973; Sameroff 1973). It was important for the present study to determine which pattern provided a more reliable and stable indicator of neonatal sucking.

NS has been defined as "any repetitive mouthing on a nursing nipple associated with negative intra-oral pressure sufficient to deliver a potable liquid ... from that nipple" (Wolff 1968). In contrast, NNS is defined as "any repetitive mouthing activity on a blind nipple, other than biting ... which is organized in a relatively stable rhythm" (Wolff 1968, 1972). No explanation is given for excluding consideration of negative intra-oral pressure during NNS. Another study however, which has described and measured the negative intra-oral pressure occurring during NNS was conducted by Martin, Martin, Streisguth and Lund (1978). It appears that the earlier studies by Wolff omitted to examine the negative intra-oral pressure as his interest was in the rate and pattern of sucking rather than the amplitude. Thus the definition of NNS for this study, in addition to repetitive mouthing movements, also included the build up of negative intra-oral pressure.

There are several dimensions that differentiate NS and NNS including the rate, amplitude and pattern of sucking. NS consists of a continuous stream of sucks at the rate of approximately one suck

per second, whereas NNS is composed of a series of alternating bursts and rest periods at approximately twice the mean rate of NS (Kaye 1967; Wolff 1968). Thus a burst of NNS consists of 4-12 sucks separated by a rest period of 4-8 seconds (Wolff 1972). The difference in rate between the two sucking patterns is presumably due to the co-ordinated activities of respiration and swallowing which occur more frequently during NS. The rate of sucking in NS must decrease to allow the infant to swallow the nutrient received.

There appears to be an inverse relationship between the rate and amplitude of sucking. Thus the amplitude of each suck is higher during NS when the rate of sucks is lower, and is lower during NNS. A higher amplitude during NS is to be expected as the neonate has to suck more vigorously in order to extract the milk from the bottle or breast.

The rhythmic pattern of alternating bursts and pauses found in NNS has been found by several independent researchers (Wolff 1972; Brown 1973; Sameroff 1973), and is now an accepted phenomenon in the area of sucking research. The pattern is not so readily agreed upon. One suggestion is that NS is comprised of continuous sucks (Wolff 1972), although it has also been suggested that towards the end of a feeding there is a breakdown of continuous sucking into a pattern of bursts and pauses similar to NNS (Balint 1948; Sameroff 1973). It was found that the initial burst of NS could be maintained for as long as three minutes, but subsequently, the burst-pause pattern became evident (Sameroff 1973). It does appear that the bursts and pauses evident towards the end of NS do not show the same temporal organization as in NNS. The rise in peak interval time (PIT)

which is a characteristic feature towards the end of each burst of NNS, does not appear at the end of NS. It may be that the increase in time from the peak of one suck to the peak of the next, is possible evidence of a control mechanism, whereas the burst-pause pattern toward the end of NS reflects fatigue.

It has also been shown that the pattern of NNS is less sensitive to changes in the state of the neonate than NS (Wolff 1968; 1972; Sameroff 1973; Crook 1979) and that NNS is therefore a more reliable measure of neonatal sucking. Although specific parameters of NNS may be somewhat affected by a change in the baby's state, the overall temporal organization of the pattern remains unchanged. There is a slight increase, for example, in the amplitude of NNS as the neonate goes from deep to light sleep, and then to more awake state, but the overall pattern remains constant (Wolff 1972). In addition to being more reliable, the NNS pattern can be obtained during all states except that of crying, including sleep.

NS has been shown to be adversely affected i.e. reduced rate, by obstetric medications (Brazelton 1961; Kron, Stein and Goddard 1966), whereas NNS appears resistant to adverse pre and perinatal factors (Dreier and Wolff 1972; Crook 1979). The importance of obstetric medication is discussed in more depth in a later section.

The NN mode of sucking therefore, was a more appropriate measure for the present study for the following reasons: 1) the parameters involved in NS may also be examined during NNS; 2) the specific pattern of NNS is not affected by changes in the neonate's state, thus giving a reliable measure of sucking behaviour; 3) NNS is more readily obtainable than NS in that it can be elicited in all states

except crying; 4) NNS is more resistant to effects of obstetric medication; 5) NNS avoid the issue of reinforcement which must occur when milk, glucose or water are delivered during NS; 6) and finally, it was preferable to the majority of mothers in this study who requested that no nutrients be given their offspring between feeding schedules.

Central Mechanisms Underlying NNS

The manner in which co-ordinated activities of NNS are regulated by the nervous system is not clear. It has been suggested that a central pacemaker with excitatory and inhibitory properties initiates NNS. The pacemaker is thought to be controlled by a dampening mechanism which causes the pacemaker to recycle at gradually lowering frequencies until sucking finally ceases (Wolff 1967; 1968; Wolff and Simmonds 1967). The data which led to this conclusion showed that neonates, both full term and premature, sucked in a set fashion in the NN mode and that this pattern was characterized by an increase in the length of pause between sucks as a particular sucking burst continued (termed peak interval time or PIT). The argument against this being due to fatigue of the peripheral musculature came from two sources. First, the increase in PIT was apparent in bursts at the end of a half hour testing session as well as in those at the beginning; secondly, premature infants, whose sucking activity is susceptible to fatigue, showed the same pattern. This increase in PIT was also found when repetitive mouthing movements without a nipple were made by the neonate during restful sleep.

This idea of a central pacemaker is strengthened by the suggestion that other central pattern generators with innate oscillators

exist to drive other cranial and spinal motor nuclei. These central pattern generators are thought to be located in the various brainstem centres and are involved in the control of respiration, sucking, chewing and swallowing (Lund 1978; Netsell 1980).

From the data obtained in the above mentioned studies, it was suggested that the presence of the sucking pattern irrespective of the use of a nipple, indicated that feedback from the peripheral musculature was not a prerequisite for control of the central pacemaker and oscillator (Wolff and Simmonds 1967). As added evidence they reported that some children with oro-facial malformations such as cleft palate, who were able to suck, showed this same pattern non-nutritively. A neonate with a cleft palate however, who was able to suck would be one with a relatively small fistula as a cleft and thus the peripheral musculature would be sufficiently intact to provide feedback to the nervous system.

The disadvantage to the idea of a central pacemaker and oscillator independent of peripheral feedback is that more recent work suggests that feedback from the intra-oral structures, temporal mandibular joint and appropriate muscles is important, at least for mastication (Dubner, Sessle & Storey 1978; Sessle and Hannam 1976). As sucking is considered to be the more elementary pattern of mastication (Dubner et al 1978), feedback from the peripheral structures may also be important for sucking.

Two other issues not considered by Wolff and Simmonds, are whether the pacemaker and dampening mechanism involved in NNS occur at the brain stem level as has been suggested for NS (Peiper 1963; Sessle 1976); and whether the sensory feedback in NNS influences the

cortical and subcortical levels. The cortex has been implicated in receiving information from intra-oral receptors during mastication in the cat (Sessle 1976).

It would appear that the existence of a central pattern generator and oscillator is parsimonious with other theories of motor control of oral reflexive movements; and that peripheral feedback is probably important in controlling the function of the pacemaker. Whether such control exists at the brain stem level and/or is functionally important at the cortical level also, remains to be determined.

Measurement of the Sucking Response

The particular parameters for measuring the sucking response that were important for this study, were those of amplitude of suck, and the overall sucking pattern. The sucking amplitude is a measurement of the negative intra-oral pressure, while the sucking pattern measures the overall consistency of the sucking response.

In order to measure the amplitude of a suck, it is necessary to distinguish between sucking and mouthing. If no differentiation is made, a high amplitude response could be a reflection of both negative and intra-oral pressure and mouthing movements, and would therefore give an inaccurate measure of amplitude alone.

Sucking has been defined as "the emptying of the nipple by development of sub-atmospheric pressures within the oral cavity", while mouthing refers to the "squeezing out of the nipple contents by compression between the jaws or other mouth parts" (Kron & Litt 1971). This distinction was first made in the late nineteenth century (Cramer 1900) and is still debated in spite of modern methods of

technology which can more accurately describe the sucking response. In an attempt to differentiate between sucking and mouthing, researchers have developed different instrumentation to record the negative intra-oral pressure, i.e. the sub-atmospheric pressure, in isolation from mouthing movements (Kron et al 1963; 1971; Sameroff 1965; 1973).

The instrument devised by Kron et al. (1963) was to measure amplitude during NS. It utilizes a closed pressure system connected to an air-pressure transducer and then to a special nipple. Liquid is stored in a stoppered 50 ml. side-arm burette which is connected to a calibrated, flow-regulating capillary tube and then to a special nipple. The nipple cannot be emptied by mouthing movements and no nutrient flow occurs unless the neonate sucks at the nipple and develops negative intra-oral pressure. It was found that pressure recordings ranged up to 300 mmHg. with averages between 30 and 60 mmHg. per minute. These recordings were of healthy normal infants over a nine minute test period.

Although this instrument was originally designed to measure NS, it can be easily adapted for NNS by use of a switch to prevent the flow of nutrients into the nipple. The neonate sucks on the nipple and the pressure is then converted into an electrical signal and is recorded on the graphic recorder. It is calibrated into mmHg. by a sphygmomanometer. Pilot work presently under way using such an adapted form of the original instrument indicates that negative intra-oral pressure can be measured independently of mouthing movements for both N and NN sucking.

The instrument designed by Sameroff (1965) measures both the suction and expression components separately for both N and NNS. The

suction component is synonymous with the build up of negative intra-oral pressure, while the expression component is the manner in which the tongue "strips" the milk from the nipple by applying pressure to the nipple and moving the tongue back and forth. A special nipple was designed, based on the one devised by Kron et al, in which three tubes were connected to the nipple. The first measured the pressure inside the nipple and reflected the expression component of sucking; while the second extended through the nipple and measured the suction component. The third tube also passed through the nipple and milk was delivered through it. Thus milk could be delivered as either a consequence of the sucking or expression component.

It was found that while the suction and expression components usually paralleled each other for NNS, there was no evidence of any build up of negative intra-oral pressure in the expression component alone. Thus the technique devised by Sameroff is also capable of recording amplitude of sucking in isolation from other components.

These two instruments described also have the advantage of being able to obtain amplitude measures independent of "background pressure". Such pressure occurs when a back pressure develops as nutrient continues to be withdrawn from the bottle (Kaye 1966; Kron and Litt 1971). By using a nipple unattached to a bottle, such pressure is prevented from occurring, and thus allows for an accurate recording of negative intra-oral pressure.

The main advantage of the Kron and Litt design is its simplicity in that it records pressure by use of one tube attached to the nipple rather than three.

Amplitude. Studies examining NS have made extensive use of amplitude as a measure of the sucking response (Sameroff 1968; Kron, Stein and Goddard 1963; Kron, Ipsen and Goddard 1968). In contrast, studies involving NNS have examined such parameters as the frequency of sucks per second, the mean duration of bursts of sucking, and the mean duration of rest periods, but have ignored the use of amplitude as a measurement (Wolff 1967; 1968; Brown 1973). A later study by Wolff (1972) does note that the amplitude of NNS increases as the neonate changes from a sleeping to an awake state, and that within a burst of sucking, the amplitude is highest during the middle portion of a burst, but the implications of such a finding are not discussed except in relation to the rate of sucking.

One study which did examine the amplitude during NNS was carried out on 151 two day old infants born to mothers who either smoked during pregnancy, or took alcohol prior to and during pregnancy (Martin et al 1978). Two of four sucking measures were the average pressure for the whole trial, and the average pressure from the first response to the end of the trial. A sucking response was defined as a change of at least 10 mmHg. from baseline, and a trial consisted of ten responses on a nutritive nipple. Alternately, a trial was considered to have occurred if no response was made after 30 seconds. Both pressure measures were found to discriminate significantly between offspring of alcohol or smoking mothers and the control neonates of abstaining mothers, i.e. the sucking pressure and the whole trial average pressure decreased in the experimental group.

One major difficulty in attempting to compare studies of NNS is the use of different populations by different researchers. The

criterion for subject selection in the Martin et al study was based on the pregnancy habits of the mothers, whereas other studies have selected subjects on the basis of normal healthy neonates (Wolff 1966; 1967; Kaye 1972). Thus the amplitude measures can be expected to yield very different results. It is not always possible to even compare the different amplitude measures. The study by Kaye for instance, used the frequency of pressure responses as the dependent variable, whereas the study by Martin et al took the average pressure response in terms of mmHg.

The times at which the pressure recordings were taken differs between studies. The neonates were tested midway between feedings in the Martin et al study, but were tested "shortly before a meal" in the Wolff study (1967). The neonate is more likely to be aroused immediately prior to a feeding, and amplitude measures have been shown to increase in the aroused state (Wolff 1972). The neonate is also more likely to be hungry prior to a feed and therefore amplitude measures are likely to be maximized if obtained immediately before a feeding.

Variation in the length of trial between the different studies also makes comparisons difficult. The trial length in the Martin et al study was terminated either after 10 responses or after 30 seconds had elapsed. The earlier study by Wolff (1968) used a "burst of sucking" rather than a time interval to comprise one trial, although his later study (1972) used five minute samples of NNS, which were then analyzed in 30 second segments.

Sucking data obtained in the Fried and Knights study presently underway, suggests that while 30 seconds is a sufficient trial length for those neonates who exhibit sucking responses immediately they are

presented with a nipple, it is insufficient for those neonates who explore and mouth the nipple before starting to suck. Trial lengths of one minute, however, have been found to be adequate in obtaining sufficient amplitude measures for analysis, for the majority of neonates.

Thus the literature and current pilot work suggest that amplitude of sucking can be measured using one minute trials and recording the average pressure for the whole trial. As little difference was found between the scores when the average pressure for the whole trial, and the average pressure from the first suck to the end of the trial was examined, it was not considered necessary to evaluate both. The former method was considered preferable as it ensured an identical trial length for each neonate.

Pattern. The consistency of the sucking pattern rather than its individual parameters was of interest for the present study. This was based on the premise that a consistent sucking pattern is related to a mature nervous system (Wolff 1968; 1972). A study by Kron (1972) investigated both the different parameters of sucking and the organization of the overall sucking response in 50 premature infants. The consistency of rhythmicity of the neonate's sucking over a ten minute period was rated on a three point scale. A score of two was given to those neonates exhibiting a sustained rhythmic sucking throughout; a score of one to those whose rhythmicity varied from minute to minute; and a score of zero for completely disorganized sucking. The neonates were rated for each minutes and then the minute scores were averaged.

The NNS pattern has been found to be present minutes after birth, and although changes in pattern were noted during the first 72 hours,

no further differences were apparent by four days of age (Wolff 1968).

For this reason the fourth day of neonatal life was considered to be the earliest at which a reliable measure of pattern consistency could be obtained. In spite of this finding there is considerable variation in the age at which neonatal NNS is recorded in the existing studies.

The study by Martin et al recorded sucking on the second day, while another study recorded between two and four days (Kaye 1972). In yet a third study, recordings were taken initially between two and seven hours after birth, and were then repeated at 24 hour intervals between two and four days (Brown 1973). If, as is suggested by Wolff (1968), the pattern is not stable until four days of age, any discrepancies in NNS patterns may well be a function of age. It was noted however, that only ten neonates were used in the study by Wolff and that four of these had stable patterns as early as the first day of life. By the fourth day, all ten neonates showed a consistent pattern.

The current literature therefore on NNS amplitude and consistency of pattern is sparse. Those existing studies show differences in the criteria used for subject selection; ill-defined or different recording times of the sucking amplitude; and variations in the trial lengths examined. There is presently only one study which examines the overall consistency of the sucking pattern which is by use of a three point scale (Kron 1972). Other studies which mention the temporal organization of the pattern, have not attempted to measure this pattern (Wolff 1968; 1972). It does appear that the pattern may not be stable until four days of age.

Relationship Between Sucking and Vocalizations

The close relationship between sucking and vocalizations has been suggested by various authors (Ribble 1944; Lewis 1963; 1968; Wolff 1968; Olmsted 1971; Dellow 1976).

Sucking has been used to account for the early differences in vocalizations produced by the neonate (Lewis 1963; 1968). It was noted that neonates after a feeding tended to produce approximations of velar or back-type sounds such as /k/, /g/, /x/ and /r/. It was suggested that when the neonate is held in an almost horizontal position during feeding, the back of the tongue rests against the soft palate. Any attempts at phonation will result in a consonant, rather than a vowel, due to the constriction of air stream caused by the contact of the back of the tongue with the soft palate. It is also suggested that an increase in swallowing activity immediately after a feeding will increase the chances of velar sounds for the same reason.

In contrast, frontal type consonants are the result of approximation made by the lips and tongue blade during phonation. Such approximations occur during the anticipatory sucking movements made before feeding and result in sounds such as "p", "b", "m", "t", "d" and "n". These observations were made using a single case study only, but were compared with three other single case studies which showed similar findings. Any discrepancies were in the date of onset of these sounds.

The work of Olmsted (1971) looked at the development of speech and language between 15-24 months of age, but stressed the importance of the motor patterns used in sucking for speech development. A similar opinion was voiced by Ribble (1944) in her account of the

importance of early infantile experiences for later personality development. She concluded that

"a favourable sucking experience contributes to the development of several aspects of structure and behaviour. The evidence indicates that sucking experience is important ... for the age at which speech appears and for the facility of the speech function."

The relationship between sucking and speech has been suggested by Wolff (1968). The study indicated that minor disturbances of the central nervous system affect the sucking pattern, and follow up studies were advised to determine whether these disturbances were transitory, or whether voluntary rhythmic actions such as speech were also affected. The rhythmic nature of both speech and sucking has been stressed by Dellow who stated that "subtending speech there is an element which is rhythmic and it might be within our realm of postulation to consider this to be related to the sucking mechanism" (Dellow 1976).

The studies by Lewis imply a relationship between sucking and vocalizations, while those by Ribble, Wolff, Olmsted and Dellow indicate a possible relationship between sucking and speech. As yet, no systematic research has attempted to describe the nature of such relationships.

The Role of Vocalizations in the Acquisition of Speech Sounds

In order to show that sucking measures can be of prognostic value in identifying children at high risk for speech development, it is necessary to show not only that a relationship exists between sucking and early vocalizations, but that these early vocalizations are related

to later acquisition of speech. There are two viewpoints regarding this issue: the continuity approach which relates early vocalizations and speech sounds in the sound acquisition process; and the discontinuity approach which sees the two as separate systems.

Continuity versus Discontinuity. Sound acquisition is regarded as a continuous process by learning theorists who maintain that the principles of reinforcement apply in sound acquisition as in other forms of learning (Latif 1934; Skinner 1957; Mowrer 1958; Winitz 1968). One suggestion is that infants are able to produce all the possible speech sounds but their actual vocal response resembles sounds similar to adult sounds. This response occurs as these sounds are selectively reinforced by the adults in the environment (Latif 1934; Skinner 1957). A second suggestion is that the infant imitates only those sounds he hears. Any sound resembling an adult sound will be positively reinforced by the infant's caretakers (Mowrer 1958; Winitz 1968). Through selective reinforcement the infant gradually acquires the sounds of his language.

The idea of continuous acquisition of speech sounds was supported by the work of Lewis (1963) who recorded one infant's vocalizations over the period of the first eleven months. He compared his findings with the vocalization records of three other infants, and concluded that while there was a gradual increase in the infants' speech responses, there was no sudden change in the pattern of sounds used (Lewis 1963).

Linguists who have studied the early vocalizations of infants do not consider sound acquisition a continuous process (Bever 1970; Jakobson 1968; McNeill 1970). Although they agree that the young infant produces a random collection of sounds in the first six months

of life, they suggest a distinct change occurs before the end of the first year. Sounds which an infant made in the first half year now cannot be produced unless unintentionally. It is suggested that the sounds made in the earlier period show no particular order of development, while the sounds that emerge at approximately the end of the first year follow a universal order of development. It is from the latter sounds that language is thought to emerge (Jakobson 1968).

While linguists agree that there are two different sound systems, there is some discussion as to whether the change from one to the other is gradual or abrupt. Jakobson argues that the transition is gradual while Bever (1970) and McNeill (1970) consider it to be abrupt. They suggest there are two periods of discontinuity in the first year, one occurring at approximately four months, when the frequency of vowels and consonants drops markedly, and the other at approximately 11 months when the early babbling-type vocalizations collapse.

There are difficulties with both the continuous and discontinuous process of sound acquisition. The learning theorists will need to account for the disappearance of the early used sounds of babbling, such as "r" at the end of the first year. They will also need to explain why such a sound can be made spontaneously in babbling after the first year, but cannot be used with intent until much later.

A second problem with the learning theory approach is that of reinforcement. Any particular caretaker is more apt to reinforce indiscriminately rather than selectively, thus reducing the importance of the role of reinforcement in sound acquisition. In addition, there is a considerable range in social practices in the type and amount of vocalizations to infants, and yet the process of sound acquisition is

relatively uniform. If reinforcement can influence sound development, it should be possible for new sounds to be acquired by this technique. While there is evidence that reinforcement can influence the frequency of sounds uttered, there is no evidence to suggest that new sounds may be elicited by this method (Rheingold, Gerwartz and Ross 1959; Stark 1979).

Other research which suggests that reinforcement may have little influence in the process of early sound acquisition concerns the vocalizations of hearing children of both deaf and hearing parents. No differences in early vocalizations were found in children of either hearing or deaf parents (Lenneberg 1967). If reinforcement was important in sound acquisition, the children of deaf parents should have shown delayed or reduced vocalizations. In addition deaf children are known to go through the periods of early vocalizations up to approximately six months. This would not be expected if the acquisition of early sounds was contingent upon reinforcement (Fry 1966; Lenneberg 1967; Rees 1972).

The discontinuity approach also has its problems. The suggestion that early vocalizations lack the structure of a system does not apply when one considers both the emergence of types of sounds, and the development of suprasegmental features in the first year. Initially vowels occur and the consonant-like sounds (Lenneberg 1967; McNeill 1970; Lewis 1963). Indeed it is the linguists who stress that in the first year the vowels are front vowels, while the consonants produced are back or velar consonants. This certainly suggests a structured system. In addition, the structure of babbling is very specific. Initially CV sounds are made, such as "ba", and these are followed by

sounds of the CVCV type, "ba-ba" (Kaplan 1970). There is also evidence that suprasegmental features of early vocalizations, such as intonation, show a continuous and structured development during the first year, and thus cannot be regarded as totally discontinuous (Crystal 1973).

The most quoted sound to support the discontinuity viewpoint is "r". However, other sounds which occur early in vocalizations are "p", "b", "t", "d", "k" and "g", and of these, the first four are among the first sounds used in a child's speech.

It would appear that the discontinuity viewpoint has been incorrectly overstated, partly because differences between vocalizations and speech have been stressed rather than similarities. A study by Oller (1975) looked at the various ratios of occurrence of preferred and non-preferred type vocalizations in infants 6 to 8 months and 12 to 13 months of age. Both groups showed a preference for those phonetic elements also preferred by children who are speaking meaningfully. The conclusion reached was that there are similarities between early vocalizations and speech of a continuous nature.

The importance of the anatomical and physiological changes in the infant's vocal tract during the first year of life has been overlooked by both the learning theorists and those involved in the continuity/discontinuity debate. In the neonate, the tip of the epiglottis is at the level of the first cervical vertebra. This high position of the larynx results in almost constant epiglottic-velic contact and thus the use of nasalized sounds in the neonate. By six months however, the larynx descends and the epiglottis is then at the level of the third cervical vertebra, allowing for the production of oral and nasal sounds (Sasaki, et al, 1977; Kent 1979).

Differences in the vocalizations at these two ages can be detected by both auditory and spectrographic analysis.

In addition to the changes in position, shape and size of the vocal tract, are the changes brought about by increased neuromuscular control. The continuous nature of early vocalizations serves to build up the fine kinaesthetic control necessary for the production of speech sounds. At this early stage, it also provides proprioceptive feedback at a time when the auditory feedback loop may not yet be established. This could explain the early vocalization period that deaf children experience.

The development of the vocal tract can be used to explain the process of sound acquisition. The inability to produce certain sounds at one year, that we supposedly produced earlier, can be explained by differences in the position, shape and size of the vocal tract. Thus a sound which approximates an "r" in the first few months, may appear to be absent at one year, because of the changes that have occurred to the vocal tract. This is not a discontinuity or breakdown of a particular sound, but rather a gradual alteration of that sound due to the physiological changes occurring with maturation. Simultaneously the neuromuscular control of the articulators approximate those of the adult and the sounds become a closer approximation. This continuous development of infant vocalizations allows us to measure such sounds to assess early speech development.

Studies of Infant Vocalizations

Studies examining the neonatal cry have been conducted to determine whether the fundamental frequency (Fo) is different in normal and brain-

damaged neonates (Wasz-Hockert, Lind, Vuorenkoski, Partanen and Valanne 1968). Other researchers have looked at the Fo of non-distress vocalizations in normal healthy neonates (Delack 1976; Laufer and Horii 1977). Their findings suggest that the Fo remains relatively constant at approximately 335 Hz with a range of 250-450 Hz, with little increase in age for normal neonates. The Fo for brain-damaged neonates is considerably higher and ranges from 650-800 Hz. The within utterance range and variability in normal neonates did show changes with differences in age. There was a tendency for both to decrease up until eight weeks, and then increase gradually from 8-20 weeks (Laufer and Horii 1977). It would have been of interest to compare those parameters of non-distress vocalizations with a behavioural description of the sounds made.

Such a description was made in a study using two female infants from 1-8 weeks (Stark, Rose, McLagen 1975). By listening to many infant utterances recorded prior to, during and after feeding, and examining sound spectrograms, these authors arrived at a set of distinctive features, some of which were specific to infants. The four main categories were breath direction features; degree of constriction of the vowel-tract above the glottis, features of open, vowel-like sounds and features of closed, consonant-like sounds. Three types of vocalizations were analyzed with respect to these distinctive features; cry, discomfort and vegetative sounds. It was found that 33-66% of vegetative sounds were consonant like sounds, with the majority of these sounds consisting of stops and fricatives. This suggests that stops and fricative-type sounds are the earliest vocalizations to occur in the neonate, although replication of the

study using a larger number of neonates is necessary to verify this finding.

A further study used six different behavioural classifications of infant vocalizations, and sounds falling into each of the categories were later verified by auditory and acoustic analysis (Stark, Rose, Benson 1978). The assumption was that classification of infant sounds which was then followed by auditory and acoustic analysis would provide more information than any one method of analysis alone. The six behavioural classifications were cry, discomfort, comfort, laugh, vegetative and speech play sounds, and these were examined from 2-40 weeks in a cross-sectional design using two infants at each of the nine levels. Before eight weeks nearly all sounds made were of the cry, discomfort, or vegetative type, with vegetative sounds increasing in frequency up until the twelfth week. The earlier study found stop-like sounds were made during vegetative vocalizations, and it thus appears that eight to twelve weeks of age produces the highest frequency of stop-like vocalizations.

While the studies examining Fo of infant cries provide some information, a need exists to relate these findings to other behaviours including the development of speech. It may be that other types of infant vocalizations will provide more information regarding the development and use of speech sounds. The classification of infant vocalizations by Stark et al suggest this is the case and further research is necessary to validate their findings.

Methods of Recording Infant Vocalizations

There are two main methods of measuring infant vocalizations. The

first approach used phonetic transcription to transcribe infant sounds in an attempt to determine the developmental trends of sound acquisition (Irwin 1948; 1957; Stark et al 1978).

The second and more recent approach has been to use acoustic analysis by means of sound spectrographs (Sheppard and Lane 1968; Wasz-Hockert et al 1968; Delack 1976; Stark et al 1978).

The drawbacks to using a phonetic transcription to analyse infant vocalizations are three fold. First, such an analysis must be influenced by the distinctive features of adult sounds and thus other sound qualities may be ignored or considered irrelevant. Secondly, there is some question as to whether the acoustic properties of adult and infant sounds are similar. Spectrographic analysis has shown differences in the physical configuration of adult and infant sounds even when an adult is trying to imitate infant vocalizations (Lynip 1951; Crystal 1976). A third difficulty with phonetic transcription is that of reliability between examiners, as minor differences in sound may not be detected identically by two different examiners. It has been suggested however, that phonetic analysis is appropriate in spite of these difficulties, providing the researcher is aware of the possible discrepancies that may occur (Crystal 1973; Oller 1975).

There are also drawbacks to using spectrographic analysis to identify infant vocalizations. In order to obtain a two second sample of vocalizations "approximately 15 minutes are required to process, calibrate, crudely quantify and classify each spectrogram" (Sheppard and Lane 1968). The cost and time involved might be worth while if one could be assured of the validity of spectrographic descriptions of infant vocalizations. It has been argued however, that the difference

between infant and adult vocalizations noted on a spectrograph is not an adequate device for the study of infant vocalizations (Winitz 1968). Nevertheless, most recent studies have made use of spectrographic analysis.

The problems of reliability noted for phonetic transcription also apply to spectrographic analysis. Individual interpretation is as necessary for spectrograms as for phonetic transcriptions, except that the problem becomes one of visual reliability rather than auditory.

It thus appears there are drawbacks to both phonetic and spectrographic analysis and the decision to use either must depend on the type of vocalization under examination. When acoustic features such as F_0 , duration and intensity of a sound are studied, spectrographic analysis is more appropriate. When the interest is in the type of sound used in relation to developing speech, phonetic analysis should be used.

Other Parameters Relevant to the Present Study

Effects of Obstetric Sedation on Neonatal Sucking. Studies have shown that drugs given to mothers during labour and delivery can depress neonatal nutritive sucking behaviour for up to four days after delivery (Brazelton 1961; Kron, Stein and Goddard 1966; Kron, Ipsen and Goddard 1968; Dubignon, Campbell, Curtis and Partington 1969). In the study by Brazelton, alertness to feedings and effectiveness of feeding was affected in the offspring of mothers who received 150 mg. of barbiturates one to six hours prior to delivery. Conversely feeding measures were not affected by type or amount of anaesthetics given during delivery; and neither were they affected when 60 mg. or less of barbiturates were given. The difficulty with this study is that the

feeding measures were based on the subjective impressions of the mothers; and in addition the study did not control for duration or effects of labour, nor in the effects of maternal medication on the mother's handling of the baby.

A single dose of 200 mg. of Secobarbital Sodium given to mothers during labour depressed the sucking behaviour for up to four days (Kron et al 1966). Although sucking rate was primarily affected, sucking pressure was also decreased, particularly in the first two days of feeding. This resulted in a particularly large between-trials increment as the effects of the drug wore off. Those neonates whose mothers received no barbiturate or Demerol, suck without interruption during all the trials (up to 80 hours of age) suggesting that these latter offsprings showed a more consistent sucking pattern. The conclusion reached was that "obstetric medication has a significant depressant effect on newborn feeding behaviour" (Kron et al 1966).

In contrast NNS appears to be less affected by obstetric medication (Dubignon et al 1969; Ellison et al 1979). The former study found that sucking pressures were affected by maternal anaesthetics during N but not NNS, although the definition of sucking pressure appears to be different from that used by other authors (Wolff 1968; Sameroff 1965). In the study by Dubignon et al it is positive pressure exerted by the baby's tongue and gums that is measured rather than negative intra-oral pressure. This positive measure appears to be similar to the expression component of sucking as described by Sameroff (1963).

The study by Ellison investigating the sucking behaviour of 30 newborns revealed no differences in the NNS pressures of babies whose mothers received minimal or moderate medication or anaesthesia. Although

the specific amounts of medication were not recorded, the authors noted that the levels of all analgesics and anaesthetics were well below those reported in the earlier study of NS by Kron et al (1966). It is therefore difficult to determine whether differences between these studies were due to a real effect of N versus NNS, or instead were due to differences in dosage.

These studies reveal differences in results which may be due to the investigation of N versus NNS, or to the use of different sucking measures. Likewise differences in the amounts of medication given at varying times may also explain the inconclusive results as to the effects of maternal medication.

Sex of the Neonate. The literature on sex differences in the neonate with respect to sucking is conflicting. It appears that females may be more receptive to certain types of stimuli, particularly those involving the oral and cutaneous areas (Wolff 1966; Körner 1969; 1973; 1974). Spontaneous movements of the neonate also suggest a sex difference exists, with more reflex smiles and rhythmical mouthing movements being present in females during three different sleep states (Wolff 1966). It was suggested that this behaviour reflects a discharge of "neural energy" and that female tend to discharge this potential more frequently via the facial musculature than do males. As only five neonates were used in this study, the findings cannot be considered conclusive.

In contrast to the findings for rhythmical mouthing, no sex differences were apparent in the rate, amplitude or frequency of spontaneous sucking, sucking on a pacifier, or sucking for food (Dubignon et al 1969; Körner 1973). Similarly, no significant differences were found

in sucking amplitude between sexes in a correlational study conducted by Ellison et al (1979).

However, a difference in frequency of sucking was noted in the fourth day after birth by Hwang (1978) who found that females sucked more frequently than males. It was also found that males showed a more interrupted feeding pattern than females at four days, although there were no differences in sucking frequency or pattern at two days. In contrast, full term females showed a greater change of breathing rate and longer duration of breathing pauses during NNS than males, in a study by Dreier, Wolff, Cross and Cochran (1979).

The findings are inconclusive in that variables such as the state of the neonate, effects of circumcision, primi or multiparous offspring, or even differential treatment of the male and female neonate by the mother, were not controlled.

Bottle versus Breast Feeding. In a correlational study by Dubignon et al (1969), it was found that breast and bottle feeding do not result in different NNS performances in neonates. Sucking amplitude, however, was not one of the sucking measures used. In addition NNS was defined as changes in positive pressure exerted by the baby's tongue and gums which is different from the build-up of negative intra-oral pressure as described by Sameroff (1965) and Martin et al (1978).

Crook (1979) suggests that differences in the rhythm and sucking pauses are to be expected between bottle and breast feedings. The latter type of feeding may well show more variability in these measures owing to amount of available milk, the regularity of its flow from the breast, and changes in milk viscosity and texture. But whether the amplitude of sucking is different between bottle and breast fed babies,

is not clear.

As 90% of the mothers in the larger study from which this present sample was drawn breast fed their babies and as no previous studies suggest that sucking amplitude of NNS is different using either feeding method it was decided to investigate sucking amplitude and pattern in breast fed neonates only.

Position of the Neonate in the Family. A correlational study by Ellison (1979) suggests a positive relationship between amplitude of suck and multiparous offspring, in that these offspring exerted higher sucking amplitudes at five minutes of age, than offspring of primiparous mothers. As sucking measures were not carried out after the first day of life it is not known whether such a correlation would have persisted at four days. As no other correlations between parity and sucking amplitude were noted even during the first day, it is unlikely they would be present at four days.

It has been suggested that a relationship exists between the amount of time spent by mothers talking to primiparous offspring and the length of time the neonate nursed at the breast (Thoman, Leiderman and Olson 1972). These neonates spent less time at the breast and when at the nipple, less time sucking, possibly as a result of the stimulation given them by the mother. It is also suggested that this occurs more frequently with female than male offspring.

Although this finding is not likely to influence the one minute of sucking amplitude, it could affect the consistency of the sucking pattern in the present study.

Recording of Infant Vocalizations. The influence of the person carrying out the recordings has not been considered in the majority of

studies. One exception is the study by Laufer & Horii (1977) who had the mothers tape their offspring and indicate the date, location, time, activity and position of the infant during recording. The mothers were instructed to vocalize to the infant to ensure maximal vocal production.

As the aim of the present study is to detect the earliest age at which certain vocalizations occur, the maximal response from the neonate is necessary. It was therefore decided to have the mothers record their infant. This decision was influenced by the finding that neonates as young as 6 weeks of age will cease vocalizing when they hear a strange voice (Laufer and Horii 1977).

The Present Study

The literature suggests there are physiological similarities between neonatal sucking and the use of early vocalizations by the infant. While various parameters of sucking, such as rate and duration of sucking have been used extensively as dependent measures in the literature, those of amplitude and consistency of the sucking pattern have only been used in isolated studies. There is some suggestion that a relationship may exist between these sucking measures and the onset of stop vocalizations, but no research has attempted to empirically determine the existence and nature of such a relationship.

The purpose of the present study was to provide normative data on amplitude and pattern of sucking, and the date of onset of stop vocalizations in an attempt to determine whether these sucking measures could be used to identify neonates who may be at high risk for speech development.

The literature suggests that NNS is a more appropriate measure

of neonatal sucking for this study in that it may be elicited in all states except crying, and the pattern of NNS is less affected by changes in state than NS. There is some evidence also that NNS is less affected by obstetric sedation than NS. In addition, the effects of reinforcement by use of nutrients during NS are avoided when NNS is measured for these reasons, and as the majority of prospective mothers in this study requested that no nutrients be given their offspring between feeding schedules, NNS was measured rather than NS.

The instrument used to measure NNS needed to differentiate between sucking and mouthing in order to obtain an accurate recording of the negative intra-oral pressure, and the Kron and Litt apparatus fitted this description while having the added advantage of recording negative intra-oral pressure by use of one tube rather than three. Thus an adapted form of the Kron and Litt apparatus was used.

To increase the chances of obtaining a reliable and maximal amplitude measurement, plus a consistent pattern of sucking response, the study tested four day old neonates, in an awake state, immediately prior to feeding. The literature suggests that the pattern of NNS is stable by four days of age and that effects of obstetric medication, which may decrease sucking amplitude and affect the consistency of the sucking pattern are no longer significant by the fourth day.

The decision to measure the sucking response immediately prior to feeding was made on the basis that a hungry neonate is more likely to suck than a satisfied one. In addition the closer the time to a feeding schedule, the more aroused the neonate is likely to be and thus the maximum amplitude measure should be obtained. Breast fed babies only were included in the study to avoid adding another variable

in the statistical analysis and because the majority of available mothers breast-fed their neonates.

Two one-minute trials of NNS were measured for each neonate. Although the literature and current pilot work suggests that a one-minute trial is sufficient to obtain an accurate amplitude measure, a two-minute trial was necessary to examine the consistency of the sucking pattern.

The decision to look at the date of onset of stop vocalizations in the infant was based on the physiological similarities between sucking amplitude and the production of these vocalizations plus the evidence in the literature that the majority of vegetative sounds are composed of stop and fricative-like sounds (Stark et al 1975). Further research indicates that the greatest number of stop vocalizations appear between 8-12 weeks of age (Stark et al 1978). Thus vocalizations were recorded from 6 to 12 weeks to ensure the possible early use of stop-like vocalizations were not missed.

The method of analysis of vocalizations was two-fold. Phonetic analysis using the International Phonetic Alphabet (I.P.A.) was conducted, as was also a descriptive technique originally used by Stark et al (1975) to record those vocalizations that were not definable using the I.P.A.

Although the literature is not conclusive regarding possible sex differences in sucking behaviour, the work by Hwang (1978) suggests that males may show a less consistent sucking pattern than females. It was therefore considered advisable for this study to control for possible sex differences by equating for sex. The position of the neonate in the family was controlled statistically as the study by Thoman et al (1972) suggests that mothers talk more to primiparous offspring

(particularly females) and that these neonates spend less time sucking at the breast. This could have influenced the measures obtained for consistency of the sucking pattern in the present study.

Finally, pilot work suggests that infants vocalize more to their mothers than to strangers and thus the mothers recorded their infant's vocalizations to ensure maximal vocal response.

Multiple regression analyses were conducted to test the two specific hypotheses of this study. The first was to investigate the relationship between amplitude of sucking and the date of onset of stop vocalizations; and the second was to demonstrate that four day old neonates with a consistent NNS pattern show co-ordinated use of the musculature necessary for vocalizations at six weeks, and may therefore be expected to vocalize earlier than neonates with inconsistent sucking patterns.

Chapter II

Method

Subjects

Eleven of the 13 babies in this study were neonates concurrently undergoing observation and testing in a larger study by Fried and Knights, in which the mother's use of cigarettes, alcohol and marijuana during pregnancy was examined in relation to their possible effects on the offspring. Only the neonates of control mothers were included in the present study. A control mother was defined as one who had not smoked cigarettes or marijuana, and who had consumed .45 to 1.05 ounces of alcohol per week throughout the pregnancy. Two of the 13 mothers totally abstained from alcohol during the pregnancy. The two mothers who were not involved in the larger study were personal friends of the author, and met the above criteria.

It has been suggested that obstetric sedation can interfere with some sucking behaviours (Kron et al 1966) and therefore the drugs received by the mothers were documented (see Appendix A). Seven of the 13 mothers received medication up to and including the fourth day after delivery, and two of these seven delivered by Caesarian section. Three mothers received no medication either during or following delivery, while three used medication only on the first day after the birth.

The fourth day of life was chosen to obtain sucking measures to ensure that the NNS pattern had stabilized. Of the neonates in the Fried and Knights study, 85-90% are breast fed and only these were included in the study. This was to control for differences in response to a standard nipple which might be found between bottle and breast-fed babies.

Any neonates exhibiting oro-facial malformations such as cleft lip and/or palate were not included in the study. Premature infants defined as those weighing less than 2500 gms. were also excluded in view of the correlation between weak sucking, prematurity and slow onset of vocalizations. Neonates whose parents had a history of slow speech development or misarticulations as children, were also omitted from the study.

Apparatus

The apparatus for measuring the sucking responses of the neonates was a modified version of the equipment designed by Kron, Stein and Goddard (1963). A special nipple was connected to a length of capillary tubing by means of a short hollow metal rod, through the nipple opening at one end and the capillary tube at the other. The tubing fed into a pressure transducer (Stoelting 56442) which was modified to allow calibration by use of a sphygmomanometer. Thus negative intra-oral pressure created as the neonate sucked, was converted into mmHg. The signal from the transducer was then fed into an amplifier and then to a graphic recorder (Stoelting Physioscribe).

Vocalizations. Infant vocalizations were recorded using a Panasonic Tape Recorder, model no. RQ-413MS, with accompanying microphone. Ultra low noise tapes (Maxell 46) were used, which are designed to record the spoken voice. A wind-sock was placed over the microphone during recording, to cut down on extraneous noises..

Procedure

Sucking Measures. Neonatal sucking responses were recorded on the

fourth day after birth. Each neonate was carried, bundled, to the testing room by Miss Marg Buckingham, R.N., the nurse responsible for recording all sucking measures in the Fried and Knights study. The sucking measures were carried out approximately half an hour prior to a feeding schedule. This time was chosen to ensure maximal sucking response from the neonates. Each neonate was placed in a bassinette and was recorded under the same lighting and sound conditions.

The chart recorder monitoring the sucking response was set at the same sensitivity level for each neonate. This was to ensure a suck at a specific amplitude would register the same amount of pen deflection for all babies. Calibration of the sucking pressure to mmHg. was achieved by squeezing the sphygmomanometer and recording the different heights in mmHg at which it registered on the output paper of the physioscribe. The nipple was then placed in the neonate's mouth and two continuous one minute sucking trials were recorded.

Amplitude. The visual print out from the chart recorder was analysed using the following criteria. A single suck was defined as a change of at least 10 mmHg. from baseline, with a return toward baseline of at least 5 mmHg. within one second (Kaye 1972; Martin et al 1978). The pressure data was analysed by scoring the average pressure per suck for each of the one minute trials of NNS. The minute trial which demonstrated the higher average peak pressure was taken as the neonate's amplitude score. Neonates exhibiting less than three sucks per minute were excluded from the study.

The amplitude of sucking was scored using both mmHg. and millimeters of pen deflection as measurements. This was to offset any difficulties encountered in obtaining reliable calibration using the

sphygmomanometer. Repeated calibration revealed a consistent amount of pen deflection however, and amplitude scores are therefore given in mmHg. (see Appendix B).

Pattern. The rhythmicity of the sucking pattern was analyzed using the three point scale devised by Kron (1972) and was determined by two independent examiners. A score of 1 was given for no rhythmicity; two for rhythmicity which varied during the two minute trial period, and three for sustained rhythmic sucking. 83% inter-rater reliability was obtained which increased to 98% after discussion. (see Appendix B).

A questionnaire concerning the sucking habits of the neonates was given to the mothers during their stay in the hospital (see Appendix C). The sucking habits as reported by the mothers were then compared with the objective sucking data, and when conflicting results were obtained, the neonates were excluded from the study.

The mothers of those neonates meeting the criteria described, were telephoned approximately one month after their return from the hospital to determine their willingness to participate in the study. Two main issues were discussed with them: first, the purpose of the study and secondly, what was required of them i.e. taping their baby's vocalizations once a week. The purpose of the study was explained as the necessity for collecting data on early vocalizations.

Vocalizations. The mothers were visited immediately before their babies were six weeks old, when a demonstration of the method of taping was given. The mothers were instructed to record their infant's vocalizations for six minutes, once a week, from six to twelve weeks of age. During the first two minutes spontaneous vocalizations of the infant were recorded; for the following two minutes the mothers

attempted to elicit vocalizations by talking to their infants in their customary manner. Finally, the stop vocalizations "p", "b", "t", "d", "k", "g" were repeated for two minutes in the rhythmical sequence outlined. Both spontaneous and elicited vocalizations were recorded to control for the variability between mothers in their ability to elicit vocalizations from their infants.

The stop vocalizations were recorded on the tape to provide the mother with an example of how to repeat the sound sequence. Then a written list of instructions was given to the mother stating method of recording plus taping of mother's comments required after each recording. (see Appendix D).

Auditory analysis of the recorded segments was carried out in two ways. The sounds were transcribed using the International Phonetic Alphabet (I.P.A.) where possible (see Appendix E). Those sounds which did not fall into one of the categories specified by the I.P.A. were described using the four features denoted by Stark et al (1975). These included breath direction; vowel or consonant sounds caused by degree of supraglottal constriction; type of vowel sound such as glide, or glottal stop; and type of consonant such as nasal stop, or fricative. It was noted that no voiceless stops, "p" or "k" were heard and there were only three occurrences of "t". Thus statistical analyses were performed only on the voiced stop vocalizations "b", "d" and "g".

The dates on which these three sounds were vocalized were recorded for each infant, and the earliest date of onset of any of the sounds was noted. The occurrence of different sounds during the three different recording intervals was analysed to determine whether different sounds predominated in any one of the three time intervals.

Inter-rater reliability was established by playing three sounds segments from each tape. One segment included the first stop vocalizations heard during the six week period; the second contained no stop vocalizations and the third segment included a stop vocalization heard toward the end of the taping period. Inter-rater reliability was 95%.

The comments made by the mothers following each recording session were also noted in order to detect any patterns in the amount and type of vocalizations produced by the neonate.

Statistical Analyses

Multiple regression analyses were conducted to determine the importance of sucking amplitude, pattern of suck and position of the neonate in the family, in predicting the date of onset of stop vocalizations. As the numbers in the study were small, it was decided to limit the number of predictor variables in the regression equation in an attempt to provide more power. Factors such as sex, age of the neonate, prematurity and history of speech disorders in the family, were thus controlled for in the design of the experiment.

Non-parametric correlation co-efficients were then determined for 18 perinatal, sucking and vocalization variables. It was decided to examine non-parametric rather than parametric correlations as scores are not required to be normally distributed using this approach. As the sample size in this study was small, it was unlikely that the scores were normally distributed. In addition, only nominal and ordinal scales are required in non-parametric correlations, whereas parametric correlations require interval scales. The intervals between the rhythmicity of sucking scores in the present study for example, reflect an ordinal but not an interval scale, and therefore non-parametric

statistics were considered more appropriate.

Analysis of variance was conducted to determine whether a difference in sucking scores existed between those mothers who received medication up to and including the fourth day after delivery, and those who did not. This was necessary as the existing literature suggests that maternal medication at birth can have a depressant effect on newborn feeding behaviour (Kron et al 1968).

The literature also suggests that there may be feeding differences related to the sex of the neonate, and therefore, an analysis of possible differences in the sucking scores of male and female babies was also conducted.

Finally the data suggested that differences existed in the frequency of different sounds during each of the different time intervals. An analysis of variance was therefore carried out to determine if an interaction existed between the sounds vocalized and the minutes during which vocalizations occurred.

Chapter III

Presentation of Results

The multiple regression analyses which looked at the relative importance of the sucking amplitude and sucking pattern in predicting the date of onset of stop vocalizations are first discussed. The non-parametric correlation co-efficients for the perinatal sucking and vocalizations variables are then examined to determine whether relationships exist between the sucking measures and the date of onset of stop vocalizations; and to investigate possible relationships with other perinatal variables. Subsequently a two-way analysis of variance investigating the main effects and interaction between the type of stop vocalizations and the minutes during which vocalization occurred are considered. Finally the results of two one-way analyses of variance examining possible differences in sucking due to use of maternal medication or to sex are considered.

Multiple Regression Analyses

Multiple regression analyses were conducted to determine the importance of amplitude and pattern of suck; and position in the family in predicting the date of onset of stop vocalizations. When each of the predictor variables were entered separately into the regression equation, the R^2 obtained was .023 for sucking amplitude, .002 for pattern of sucking, and .190 for position of the neonate in the family (see Appendix F). Thus with an N of 13, it appears that the date of onset of vocalization is determined by factors other than amplitude and pattern of sucking, and position in the family.

Correlational Analyses

Originally Kendall correlation co-efficients were determined for 18 variables and these are presented in Table 1. The perinatal variables examined were as follows: type of delivery; sex; position in the family, and the baby's two Apgar scores. The remaining variables were those of sucking and vocalization. The only significant correlation among the perinatal variables was between type of delivery and sex of the neonate. Overall deliveries involving caesarian sections and use of mid and low forceps were correlated with the birth of female babies.

The onset date of "g" was related to both the frequency of occurrence of "b", and to the total frequency of all sounds. The correlations were negative and indicate that the earlier the onset of "g" the higher the frequency of "b", "d" and "g". The date of onset of "g" was also negatively correlated with the specific stop vocalizations repeated by the mother during minutes five and six of recording, suggesting that the onset of "g" tended to occur when mothers provided the specific stop consonants as the vocal stimulus. A high positive correlation was found between the date of onset of "g" and the earliest onset of any stop vocalization, indicating that "g" was the sound most often produced the earliest.

The frequency of "b" sounds was correlated with both the number of "g", and the overall number of sounds vocalized. The frequency of "b" was also related to the first two minutes of the recording sessions and the last two minutes indicating more "b" sounds were made during these times. A negative correlation existed between the frequency of "b" sounds, and the earliest date of onset of any stop vocalization, showing that more "b" sounds occurred when onset of vocalizations was

Table 1 - Correlation Matrix of Perinatal, Sucking and Vocalization Variables (N = 13)

	Apgar 1	Apgar 2	Del.	Sex	Pstn Family	Suck. Amp.	Suck. Pattn.	Onset "b"	Onset "d"	Onset "g"	Eon	Freq. "b"	Freq. "d"	Freq. "g"	Total Freq.	Mins. 1-2	Mins. 3-4	Mins. 5-6
Apgar 1	1.000																	
Apgar 2	ns	1.000																
Del.	ns	ns	1.000															
Sex	ns	ns	.69**	1.000														
Postn. Family	ns	ns	ns	ns	1.000													
Suck Amp.	ns	ns	ns	ns	ns	1.000												
Suck Pattn.	ns	ns	ns	ns	ns	ns	1.000											
Onset "b"	ns	ns	ns	ns	ns	ns	ns	1.000										
Onset "d"	ns	ns	ns	ns	ns	ns	ns	ns	1.000									
Onset "g"	ns	ns	ns	ns	ns	ns	ns	ns	ns	1.000								
Eon	ns	ns	ns	ns	ns	ns	ns	ns	ns	.98***	1.000							
Freq. "b"	ns	ns	ns	ns	ns	ns	ns	ns	ns	-.56**	-.58**	1.000						
Freq. "d"	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	1.000					
Freq. "g"	ns	ns	ns	ns	ns	ns	ns	ns	ns	-.69**	-.71***	.67**	ns	1.000				
Total Freq.	ns	ns	ns	ns	ns	ns	ns	ns	ns	-.65**	-.67**	.68**	ns	.89***	1.000			
Mins. 1-2	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	.45*	.58*	ns	.43*	1.000		
Mins. 3-4	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	1.000	
Mins. 5-6	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	.54*	ns	.56*	.49*	ns	ns	1.000

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

Eon = Earliest date of onset of any stop vocalizations

early.

The frequency of occurrence of "d" was correlated with the first two minutes of recording, indicating that more "d" sounds were made when the babies were left on their own to vocalize.

The frequency of occurrence of "g" was positively correlated with the total frequency of sounds and with the third section of the recording sessions, indicating a greater frequency of "g" sounds during the vocal stimuli of specific stop consonants. The vocalization "g" was the sound which occurred most as the earliest stop vocalization, as shown by a negative correlation.

The overall frequency of sounds was correlated with the first and the last two minutes of recording sessions, indicating that more sounds were made during these minutes. The final correlation was noted between the total frequency and the overall earliest date of onset showing that those babies with the earliest date of onset had a higher frequency of vocalizations during the six week period.

A separate correlational analysis was conducted to determine the relationship between the rate and amplitude of sucking, in view of the existing literature which suggests that the fast rate of NNS is related to a lower sucking amplitude. No such relationship was found in the present study.

Analyses of Variance

A two-way analysis of variance using type of vocalizations and recording segments was conducted to determine whether different stop vocalizations occurred more predominantly in any one of the three

recording intervals. The analysis revealed a significant main effect for sounds vocalized ($F(2,108) = 10.06, p < .001$). No significant main effect of time interval was noted, and no significant interaction between any specific stop vocalization and any two minutes time interval. This indicates that a significant difference occurred in the type of vocalizations made by the infant, as is shown in Table 2. Further tests of multiple comparisons indicated that the stop sound "g" occurred more frequently than either "b" or "d".

A one-way analysis of variance failed to show any significant differences between sucking scores of neonates born to mothers using medication up to and including the fourth day after delivery, and neonates of mothers who did not.

Likewise a one-way analysis of variance to examine differences in sucking scores due to sex, revealed no significant differences between male and female sucking measures (see Appendix G).

Table 2

Comparison of Stop Vocalizations during Different Recording Segments
(N = 13)

	Mins. 1-2	Mins. 3-4	Mins. 5-6
"b"	$\bar{X} = .846$	$\bar{X} = .692$	$\bar{X} = .308$
	sd = 1.57	sd = 1.18	sd = .63
"d"	$\bar{X} = .769$	$\bar{X} = .308$	$\bar{X} = .000$
	sd = 1.16	sd = .63	sd = .000
"g"	$\bar{X} = 1.846$	$\bar{X} = 2.154$	$\bar{X} = 3.385$
	sd = 2.51	sd = 2.764	sd = 5.09

Chapter IV

Discussion of Results

Multiple Regression Results

Amplitude and consistency of the sucking pattern, plus the position of the neonate in the family, did not predict the date of onset of stop vocalizations in the present study. It is difficult to compare these findings with other studies, as no previous studies have used the same criteria for subject selection or for methodology. The study by Martin et al (1978) found significant reduction in sucking amplitude of neonates born to mothers who smoked or drank during their pregnancies. The actual sucking amplitude is not given and thus the control neonate's scores cannot be compared with the neonates in the present study.

Another factor which makes comparison with this study difficult, is that the neonates underwent sucking trials midway between a feed in the Martin et al study, whereas those in the present study were tested immediately prior to a feeding. The present study found that neonates were not as eager to suck immediately before a feed as had been hypothesized, and some infants had to be aroused to obtain a sucking measure. For future research, it would be more realistic to obtain maximal sucking responses by recording sucking amplitude at any time after the first hour of feeding, when the neonate is awake but not crying.

The fact that the NNS pattern was not a significant predictor of onset of vocalizations appears to refute the suggestion made by Ribble (1944), Wolff (1968), Olmsted (1971) and Dellow (1976), that the rhythmic nature of sucking may be related to the onset of speech. None of these studies collected data to specifically test this hypothesis

however. The present study found that only three of the neonates revealed a consistent rhythmicity to their sucking pattern, while five showed inconsistent rhythmicity, and five showed none. One possible explanation is that the rhythmicity of sucking may be more related to the rhythmic nature of speech rather than the date of onset of specific sounds. The rhythmicity of speech becomes particularly important at about four months of age, when the infant begins to babble, and a correlation between sucking and babbling might well occur at that time. Alternatively, the relationship that was not found in the present study may have been due to the few numbers of neonates in the study.

It was noted that where sucking measures were available on the neonates at two days of age, in the present study, there was an 87% agreement of rhythmicity of suck with the four day measurement. This tends to refute Wolff's finding (1968) that the NNS pattern is not stable until four days of age. In addition there were neonates excluded from the present study owing to lack of sucking data on day four, who had consistently rhythmic sucking patterns at day two.

Wolff based his conclusions on the sucking patterns of only ten neonates, four of which showed a stable pattern at day two, and therefore his results are even more likely to be due to small sample size than the present study. When the sucking data of other neonates in the larger study by Fried and Knights was examined, consistent sucking patterns at two days of age were also noted, which supports the finding of the present study.

It has been suggested that a definite pattern exists in NNS, which Wolff has termed the peak interval time (PIT) (1968). He found a rise in time from the peak of one suck to the peak of the next,

which increased just prior to the end of a burst of sucks, and was not related to the length of a burst. The patterns of the 13 neonates in this study were examined and only one showed an increase in PIT. This was also the only neonate who showed a very specific burst of sucking, followed by a definite pause. It would appear from this study that PIT may only be seen in very obvious burst-~~pause~~ sucking patterns, and that such bursts and pauses may not be as definite as has been previously suggested. Differences in recording techniques between the Wolff study and the present one may be responsible for the differences in pattern, in that the latter study measured the stripping action of the tongue and gums.

The finding that the position of the neonate in the family does not account for any significant proportion of variance in the date of onset of stop vocalizations is interesting in view of both the clinical observation of slower developing speech sound in the second child of the family, and the results of the Thoman et al (1972), and the Ellison (1979) studies. As both these and the present study used neonates of middle to upper class families, the differences cannot be explained by SES variation. The lack of findings in the present study may indicate that parity does not affect the type and amount of stimulation given an infant at 6-12 weeks, when the care-giver, of necessity, is in the company of the infant and has continual opportunity to vocalize the baby. Alternatively, the lack of effects may be due to small sample size.

Correlation Results

The finding that the stop vocalization "g" was correlated with the total number of sounds produced by the infant, is in keeping with other research on the production of infant sounds (Oller 1978; Stark et al 1978; Stark 1979). The study by Oller refers to the second and third month of development as the "GOOing stage" where some vocalizations are vowel-like but other have a "velar or uvular consonant-like element". Stark et al (1978) found a predominance of velar stop vocalizations in infants between the eighth to twelfth week of life, and in a later study, (Stark 1979) the velar or back of the mouth stops were heard between eight and twenty weeks. It is not surprising that velar sounds such as "g" are frequently heard from the infant when one considers the anatomy of the vocal tract. Stark (1979) has suggested that velar consonants are heard as the tongue and palate are in positions to contact each other. Kent (1979) suggests that velar stops occur in infant vocalizations due to the engagement of the epiglottis and palate. Such approximation has been described as "broad and somewhat indiscriminate" (Fletcher 1973), and occurs frequently as much of the neonate's time is spent in the prone position, thus increasing the chance of velic-pharyngeal contact. It was interesting to note that 68 "g" vocalizations were made with the infant lying on his/her back as opposed to only 26 when sitting in a chair, and 10 of these 26 were made by one infant in one recording session alone. It should be noted however, that more recordings occurred with the infant in the prone position; and thus more sounds were to be expected in this position.

As it is anatomically convenient for the infant to produce "g" it is not surprising that there was a correlation between the date of

onset and the frequency of "g". In fact this sound was the earliest sound vocalized by 12 of the neonates, although five of them produced one of the other sounds on that same day of recording.

It is interesting to note the correlation between the occurrence of "g" during the last two minutes of each recording session, when the mothers were repeating specific stop consonants to their infants. This could have been due to a warm-up effect with the infants possibly rehearsing vocalizations during the first four minutes. Thus they would be likely to make the sound which was easiest to produce and the one which was first acquired. An argument against such a practice effect is that there were recording sessions where the sequence was interrupted, and then the last two minutes would be recorded on another day. An alternative explanation may be in keeping with the motor control theories of sound acquisition (Kent 1979). Once an infant can make a sound, e.g. "g", he/she can then be receptive to others in the environment using the sound, and then through reinforcement can make that sound again. Ten of the 13 mothers commented that their infants listened more attentively and reduced extraneous movements during the last two-minute recording segments, suggesting that the infant first establishes the auditory-motor link by producing the sound, and subsequently is ready to benefit from listening and imitation of the adult model. The fact that the infant chose the last two-minute segment in which to listen attentively, rather than the second period where "conversation" was the input, could be due to either the readiness of the infant's auditory system to attend to specific sounds and/or to the novelty of hearing stop vocalizations uttered in isolation.

The number of "b" and "d" vocalizations were correlated with the

first two minutes of each recording session, when the infant was left alone to vocalize. The use of "b" can be explained by the observation that infants showed closer approximations of the lips when alone and in a relaxed state. When their mothers vocalized it was noted that increased ingressive breathing as a function of arousal or excitement occurred, and seven of the mothers commented that their infant's mouth was held in an open position, during maternal vocalization, thus preventing the use of bilabial vocalizations such as "b". It is likely that lowering of the jaw also occurred when the infants were in an aroused state, thus lessening the chances of tongue contact with the hard palate to produce "d". Conversely, in a relaxed state, the tongue would be in close proximity to the hard palate (Du Brul 1977), thus increasing the likelihood of producing the vocalization "d". The total numbers of "b" and "d" vocalizations however, were small and the correlations may well reflect an artefact due to limited numbers. A correlation was noticed for instance, between the last two minutes of recording and the number of "b" vocalizations made, although the total number of "b" sounds made during this period was only four. Similarly, while "d" occurred ten times during the first two minutes of all recordings, five during the second recording segment, it was not heard at all during the last two minutes.

The small numbers involved in this study are also likely to account for the correlation between type of birth delivery and sex of the neonate. Of the six females born, one was delivered by Caesarian section, two by use of mid forceps, two with low forceps, and one was a spontaneous vaginal delivery. Only one of the seven male neonates was born by Caesarian section, the other six being spontaneous vaginal

deliveries. It was interesting to note that the baby born with the aid of mid forceps obtained the lowest sucking amplitude (i.e. 14.83 mmHg, the mean = 38.53 mmHg) and showed no rhythmical sucking pattern. A study by Dubignon et al (1969) found that neonates delivered by mid forceps also sucked less, compared with those babies delivered spontaneously or with low forceps. However, the number of vocalizations made by this same baby was only slightly below the group mean, namely nine, with the mean = 10.07, and the baby's score for date of onset of vocalizations approximated the group mean.

In a study by Dubignon et al (1969) it was found that NNS measures of amplitude were not affected by maternal anaesthesia, while a study by Ellison et al (1979) showed no differences in NNS amplitude of neonates born to mothers who had received minimal or moderate amounts of medication or sedation. The present study confirms these findings, as no significant differences in sucking amplitude between the neonates were found as a function of maternal medication. It should be noted that the standard dose of barbiturates given to mothers in the present study, was 100 mg. considerably less than the 200 mg. of Secobarbital given to mothers in a study by Kron et al (1966) and less than the 150 mg. of barbiturates given in a study by Brazelton (1961). The Kron et al study found sucking amplitude in NS was decreased and the Brazelton study found alertness to feedings and effectiveness of feedings was affected.

It may be important to note that in the present study, the neonates of two mothers who experienced natural childbirth obtained the second and third highest amplitude scores, while the neonate of one mother who received drugs up to and including the fourth day after delivery obtained

the second lowest amplitude score. This low score was possibly influenced by an increase in medication on or following the third day when a tubal ligation was performed. This same neonate was one of the earliest to use stop vocalizations, although the number of vocalizations made was small.

Studies which have looked at the relationship between NNS amplitude and sex have revealed no significant differences (Dubignon et al 1969; Ellison et al 1979) and the results of this study support these findings.

Analyses of Variance

The finding that "g" occurred more than the sounds "b" and "d" has already been discussed in relation to the physiology of the infant's vocal tract. Although no significant interaction was noted between stop vocalizations and the three two-minute time intervals, there was a definite trend for "g" to occur during the fifth and sixth minutes of recording. A total of 48 "g" vocalizations were heard at this time compared with only 20 during the first recording interval, and 26 during the second. This was probably because the infants vocalized more in response to their mother than when alone, an indicator that at even 6 to 12 weeks, socialization is important for the infant.

Further Considerations

There appeared to be a discrepancy between the mother's ability to encourage vocalizations from their infants, which was not related to maternal parity. Some mothers over-vocalized and did not pause long enough for the infant to respond. Other were ineffective in their vocalizations in that they were unable to stimulate the infant

sufficiently to obtain a vocalization. It had been intended that the last two-minute segment of each recording would control for this, but even with a taped demonstration giving the speed and intonation of repetition of stop vocalizations the mothers varied in their manner of presentation of these sounds.

The difficulties involved in analyzing infant sounds using an adult phonological system have been described in the literature (Lynip 1951; Crystal 1976). In the present study however, these were easily overcome by use of the I.P.A. plus the four descriptive features of infant vocalizations devised by Stark et al (1978). Use of both methods allowed for descriptions of all vocalizations. In addition no difficulties were found in obtaining inter-rater reliability, and therefore this study supports the suggestion by Crystal (1973) that phonetic analysis is an appropriate way of recording infant vocalizations.

One important aspect of the present study is that it provides additional information regarding the continuity/discontinuity debate. The infant vocalizations in this study revealed a very structured system of development, ranging from vegetative sounds at six weeks, to vowel-like sounds between 6-8 weeks, and then an increasing number of consonant-like vocalizations up to 12 weeks, indicative not only of structure but of continuity in the sounds used. It has been suggested by Oller (1978) that these early sound elements and sequences are similar in kind to those elements preferred by the child who is speaking meaningfully. Infants of 6 and 13 months for instance, use more unaspirated than aspirated initial stop sounds. It would be interesting to determine whether 6 to 12 week infants also used unaspirated initial stops, which, if this was the case, would support

the continuity approach.

The studies by Sasaki et al (1977) and Du Brul (1977) provide strong evidence for changes in vocalizations resulting from physiological adaptations of the infant's vocal tract. It is interesting that the age at which the larynx takes up a lower position in the vocal tract is the time at which Bever (1970) and McNeill (1970) suggest a period of abrupt changes in the type and amount of vocalizations made.

It is therefore likely that changes in the vocalizations during the first year of life are dependent upon the physiological alterations occurring to the infant's vocal tract, and do not reflect an abrupt change in the linguistic system used by the infant. It has been suggested that ~~the~~ continuity/discontinuity debate has been overstated:

"It is obvious that the development of true speech is continuous with babbling in some ways and discontinuous in others. It seems that Jakobson and many who were influenced by him have overstated their discontinuity case by claiming that there is no phonetic relationship between babbling and speech. What they should have said is that there are important phonetic differences between babbling and speech". (Oller 1978).

Future Research

One of the purposes of the present study was to add to the sparse literature on sucking amplitude and patterns in normal healthy newborns. Further studies are now necessary to evaluate these same sucking measures in neonates who have undergone perinatal distress and in those who are

born prematurely, and then to determine the relationship between such measures and the date of onset of vocalizations. Studies conducted by Wolff (1968), Kron (1972) and Cowett (1978) suggest that different parameters of sucking pattern are affected in neonates suffering from perinatal anoxia, hyperbilirubinemia, metabolic disorders and low birth-weight infants. There are no existing studies that examine the amplitude of NNS and the overall consistency of the sucking pattern, in such infants, nor in the date of onset of early vocalizations.

Further normative data to replicate or refute the findings in the present study are necessary using a larger sample where possible. It is suggested that the sucking pattern is consistent at two days of age and may be examined at that time. This should prevent subject attrition due to early discharge of mothers and neonates from the hospital, a factor which was largely responsible for the reduced sample size in the present study. It is now the practice of hospitals to encourage discharge home as soon as possible.

It is possible that delivery with use of mid-forceps may affect both sucking amplitude and pattern, and it is therefore important to either examine or control for this variable in future studies.

Although no significant drug effects were found in the present study, there was some suggestion that amplitude and pattern of sucking may be affected by maternal medication. Future studies are indicated to determine whether the type or amount of drug given, or the time of its administration, are critical variables, and whether an interaction between them is present.

In view of the rhythmic nature of the sucking pattern, and the rhythmicity of early babbling, further research is indicated to

determine whether a relationship exists between the two. If, as has been suggested by Kent (1980), the neonate is primarily a subcortical organism with reflexive behaviour, then it is conceivable that control of early babbling, as well as sucking, may well be carried out by pattern regulators at the brain stem level.

Further research on infant vocalizations might also include an analysis of the effectiveness of different types of vocalizations produced by the care-giver, in eliciting a vocal response from the infant. The infants in the present study demonstrated an increased response during one of the three minute recording segments, although the specific one varied between infants. If a particular kind of vocalization did elicit more vocal responses from the infant, then such information would be useful for those involved in setting up infant stimulation programmes. It would be particularly important to have a specific type of vocalization as a control for differences in care-givers' vocalizations, in such a study. The present study indicates that considerable practice on the part of the care-giver is necessary to achieve adequate control.

Additional information regarding the continuity or lack of it in developing speech sounds could be obtained by comparing the vocalizations of infants at 6 to 12 weeks with those at six months. These findings could then be compared with the sounds used by the year old infant.

Summary and Conclusions

The first hypothesis suggested that a relationship existed between amplitude of sucking and the date of onset of stop vocalizations, but the findings of the present study did not support this. The second

hypothesis, which indicated that neonates with a consistent sucking pattern could be expected to vocalize stop sounds earlier than those with an inconsistent pattern was also not supported.

The main significant findings involved the type and number of vocalizations made, in that "g" was heard to occur earlier than the sounds "b" and "d", and also occurred more frequently. This indicates that once the neonate began to use a particular sound, it was repeated with increasing frequency. There was only isolated use of the voiceless vocalizations "p", "t" and "k" and these were therefore not analyzed in this study.

There was a trend toward different vocalizations occurring during different recording segments. "g" occurred most frequently during the last two minutes while "b" and "d" were heard more frequently during the first two minutes.

No significant differences in sucking amplitude and pattern related to the sex of the neonate, nor to maternal medications administered prior to or following delivery, were found.

It is possible that the results were due to use of a small sample size. However, this does not negate the importance of the study in adding to the existing literature on normal sucking and vocalization measures. Earlier studies have used even smaller sample sizes such as the one by Wolff (1968) where the conclusion that a stable sucking pattern did not occur until four days of age, was based on the sucking patterns of only ten neonates. Likewise the studies of early vocalizations of infants have been conducted on only two or three babies (Lewis 1963).

The strength of the present study lies in the control of variables such as sex, age of the neonate, prematurity and history of speech disorders, in the design of the experiment. Thus only the most essential variables, those of amplitude and pattern of suck, and position of the neonate in the family were entered into the regression equation, thereby increasing the power of analysis.

Although this study did not find a relationship between the sucking and vocalization variables, it did provide information on sucking amplitude and overall consistency of sucking pattern, as well as detailed vocalization data on normal infants, which had been lacking in the literature. In addition it pointed the way for future research in other areas where sucking and vocalizations may well show a relationship.

Bibliography

- Abbs, J.H., and Eilenberg, G.R.: Peripheral Mechanisms of Speech Motor Control. In N.J. Lass (ed.), Contemporary Issues in Experimental Phonetics. New York: Academic Press Inc., 1976.
- Balint, M. Individual Differences in Behaviour in Early Infancy and an Objective Method for Recording Them. Journal of Genetic Psychology. 1958, 73, 53-117.
- Bever, T. The Cognitive Basis for Linguistic Structure. In J. Hayes (ed.), Cognition and the Development of Language. 279-362, 1970.
- Bosma, J.F. Form and Function in the Infant's Mouth and Pharynx. In J.F. Bosma (ed.), Third Symposium on Oral Sensation and Perception: The Mouth of the Infant. Springfield, Illinois: Charles C. Thomas, 1972.
- Bosma, J.F. Anatomic and Physiologic Development of the Speech Apparatus. In D.B. Tower (ed.), The Nervous System. Vol. 3: Human Communication and its Disorders. New York: Raven Press, 1975.
- Bosma, J.F. and Fletcher, S.G. The Upper Pharynx. Oto-Rhino-Laryngology. 1962, 71, 134-157.
- Brazelton, J.V.: Psychophysiologic reaction in the neonate. II. Effect of Maternal Medication on the Neonate and his Behaviour. Journal of Pediatrics. 1961, 58, 513-518.
- Brown, J.V. Non-Nutritive Sucking in the Great Ape and Human Newborns: Some Phylogenetic and Ontogenetic Characteristics. In J.F. Bosma (ed.), Fourth Symposium on Oral Sensation and Perception: Development in the Fetus and Infant. Bethesda, Maryland: Department of Health, Education and Welfare, 1973.
- Cowett, R.M., Lipsitt, L.P., Vohr, B., and Oh, W. Aberrations in Sucking Behaviour of Low Birth Weight Infants. Developmental Medicine and Child Neurology. 1978, 20, 701-709.
- Cramer, H. Über die Nahrungsaufnahme des Neugeborenen, 1900. Cited by R.E. Kron & M. Litt in Medical and Biological Engineering. 1971, 9, 45-60.
- Crook, C.K. The Organization and Control of Infant Sucking. Advances in Child Development and Behaviour. 1979, 14, 209-252.
- Crystal, C.K. Linguistic Mythology and the First Year of Life. British Journal of Disorders of Communication. 1973, 8, 1, 29-36.
- Crystal, D. Developmental Intonology. In W. Von Raffler-Engel & Y. Lebrun (eds.), Baby Talk and Infant Speech: Neuro-linguistics 5. Amsterdam: Swets & Zeitlinger B.V. 1976.

Delack, J. Infant Vocalizations. In W. Von Raffler-Engel & Y. Lebrun (Eds.), Baby Talk and Infant Speech: Neuro-linguistics 5. Amsterdam: Swets & Zeitlinger B.V. 1976.

Dellow, P.G. The General Physiological Background of Chewing and Swallowing. In B.J. Sessle & A.G. Hannam (eds.), Mastication and Swallowing. Toronto: University of Toronto Press, 1976.

Dreier, T., and Wolff, P.H. Sucking State and Perinatal Distress in Newborns: A Preliminary Report. Biology of the Neonate. 1972, 21, 16-24.

Dreier, T., Wolff, P.H., Cross, E.E. and Cochran, W.D. Patterns of Breath Intervals during Non-Nutritive Sucking in Full-Term and at Risk Pre-Term Infants with Normal Neurological Examinations. Early Human Development. 1979, 3, 187-199.

Dubignon, J., and Campbell, D. Sucking in the Newborn under Three Conditions: Non-Nutritive, Nutritive and a Feed. Journal of Experimental Child Psychology. 1968, 6, 335-350.

Dubignon, J., Campbell, D., Curtis, M. and Partington, M.W.: Relationship between Laboratory Measures of Sucking, Food Intake and Perinatal Factors during the Newborn Period. Child Development. 1969, 40, 1107.

Dubner, R., Sessle, B.J. and Storey, A. The Neural Basis of Oral and Facial Function. New York: Plenum Press, 1978.

Du Brul, E.L. Origin of the Speech Apparatus and its Reconstruction in Fossils. Brain and Language. 1977, 4, 365-381.

Ellison, S.L., Vidyasagar, D., Anderson, G.C. Sucking in the Newborn Infant During the First Hour of Life. Journal of Nurse-Midwifery. 1979, 24, 18-25.

Fletcher, S.G. Maturation of the Speech Mechanism. Folia Phoniatrica. 1973, 25, 161-172.

Fried, P., and Knights, R.M. Prospective Investigation of Social Use of Soft Drugs, 1980.

Fry, D. The Development of the Phonological System in the Normal and Deaf Child. In F. Smith & G. Miller (eds.), The Genesis of Language. Cambridge, Mass.: M.I.T. Press, 1966.

Hwang, C.P. Mother-Infant Interaction: Effects of Sex of Infant on Feeding Behaviour. Early Human Development. 1978, 241, 341-349.

Irwin, O.C. Infant Speech. Journal of Speech and Hearing Disorders. 1948, 13, 224-255, 320-326.

Irwin, O.C. Phonetical Description of Speech Development in Childhood. In L. Kaiser (ed.) Manual of Phonetics. Amsterdam: N. Holland Publishers, 1957.

Jakobson, R. Kindersprache, Aphasie und Allgemeine Lautgesetze. (Child Language, Aphasia and Phonological Universals), 1941. Translated by A.R. Keiler, The Hague, Mouton, 1968.

Kaplan, H.M. Anatomy and Physiology of Speech. Toronto: McGraw-Hill, 1960.

Kaplan E. and Kaplan, G. The Prelinguistic Child. In J. Elliot (ed.), Human Development and Cognitive Processes. New York: Holt, Rinehart and Winston, 1970.

Kaye, H. The Effects of Feeding and Tonal Stimulation on Non-Nutritive Sucking in the Human Newborn. Journal of Experimental Child Psychology. 1966, 3, 131-145.

Kaye, H. Infant Sucking Behaviour and its Modification. In L.P. Lipsitt and H.W. Reese (eds.), Advances in Child Development and Behaviour. Volume III. New York: Academic Press. 1967.

Kaye, H. Effect of Variations of Oral Experience upon Suckle. In J.F. Bosma (ed.), Third Symposium on Oral Sensation and Perception: The Mouth of the Infant. Springfield, Illinois: Charles C. Thomas, 1972.

Keene, M.C.L., and Willis, J.W. Anatomy for Dental Students. London: Edward Arnold & Co., 1950.

Kenny, D.J., and Platt, L.J. A Screening Test for the Clinical Assessment of Cranial Nerve Function. Paper presented at the Third International Congress on Cleft Palate and Related Craniofacial Anomalies, 1977.

Kent, R.D. Articulatory-Acoustic Perspectives on Speech Development. Paper presented at Conference on Language Behaviour in Infancy and Early Childhood, 1979.

Kent, R.D. Sensorimotor Aspects of Speech Development. In R.N. Aslin and J.P. Alberts and M.R. Peterson (eds.), Sensory and Perceptual Development: Influences of Genetic and Experimental Factors. Illinois: Charles C. Thomas, 1980.

Korner, A.F. Neonatal Startles, Smiles, Erections, and Reflex Sucks as Related to State, Sex, and Individuality. Child Development. 1969, 40, 4, 1039-1053.

Korner, A.F. Sex Differences in Newborns with Special Reference to differences in the organization of Oral Behaviour. Journal of Child Psychological Psychiatry. 1973, 14, 18-29.

- Korner, A.F. Methodological Considerations in Studying Sex Differences in the Behavioural Functioning of Newborns. In R.C. Friedman, R.M. Richards, R.L. Vahde Wiele (eds.), Sex Differences in Behaviour. New York: J. Wiley & Sons, 1974.
- Kron, R.E. Prognostic Significance of Sucking Dysrhythmias. In J.F. Bosma (ed.), Third Symposium on Oral Sensation and Perception: The Mouth of the Infant. Springfield, Illinois: Charles C. Thomas, 1972.
- Kron, R.E. and Litt, M. Fluid Mechanics of Nutritive Sucking Behaviour: the Sucking Infant's Oral Apparatus Analysed as a Hydraulic Pump. Medical and Biological Engineering. 1971, 9, 45-60.
- Kron, R.E., Stein, M., Goddard, K.E. A Method for Measuring Sucking Behaviour in Newborn Infants. Psychosomatic Medicine. 1963, 25, 181-191.
- Kron, R.E., Stein, M., Goddard, K.E. Newborn Sucking Behaviour Affected by Obstetric Sedation. Pediatrics. 1966, 37, 1012-1016.
- Kron, R.E., Ipsen, N.J., Goddard, K.E. Consistent Individual Differences in the Nutritive Sucking Behaviour of the Human Newborn. Psychosomatic Medicine. 1968, 30, 2, 151-161.
- Latif, I. The Physiological Basis of Linguistic Development and of the Ontogeny of Meaning: Part 1. Psychological Review. 1934, 41, 55-85.
- Laufer, M.Z. and Horii, Y. Fundamental Frequency Characteristics of Infant Non-Distress Vocalizations during the first 24 weeks. Journal of Child Language. 1977, 4, 171-184.
- Lernberg, E.H. Biological Foundations of Language. New York: J. Wiley and Sons, 1967.
- Lewis, M.M. Language, Thought and Personality, in Infancy and Childhood. New York: Basic Books Inc., 1963.
- Lewis, M.M. Infant Speech: A Study of the Beginnings of Language. New York: Harcourt Brace, 1968.
- Lieberman, P. Speech Physiology and Acoustic Phonetics. New York: MacMillan Pub. Co. Inc., 1977.
- Lund, R.D. Development and Plasticity of the Brain: An Introduction. New York: Oxford University Press, 1978.
- Lynip, A.W. The Use of Magnetic Devices in the Collection and Analysis of the Preverbal Utterances of an Infant. Genetic Psychological Monographs. 1951, 44, 221-262.

Martin, D.C., Martin, J.C., Streissguth, A.P., Lund, C.A. Sucking Frequency and Amplitude in Newborns as a Function of Maternal Drinking and Smoking. Currents in Alcoholism. 1978, 5, 359-366.

McNeill, D. The Acquisition of Language: A Study of Developmental Psycholinguistics. New York: Harper and Row, 1970.

Mowrer, D.H. Hearing and Speaking: An Analysis of Language Learning. Journal of Speech and Hearing Disorders. 1958. 23, 143-151.

Myklebust, H.R. Auditory Disorders in Children. New York: Grune and Stratten, 1954.

Netsell, R. Speech Motor Control: Searching for Specialized Neural Mechanisms. Paper presented to Conference on Speech Motor Control, Madison, Wisconsin, 1980.

Netter, F.H. The Ciba Collection of Medical Illustrations: Volume 1. The Nervous System. New Jersey: CIBA Pharmaceutical Co., Division of CIBA-Geigy Corporation, 1977.

Oller, D.K. Infant Vocalizations and the Development of Speech. Allied Health and Behavioural Sciences. 1978, 1, 523-549.

Oller, D.K., Wieman, L.A., Doyle, W. and Ross, C. Infant Babbling and Speech. Journal of Child Language. 1975, 3, 1-11.

Olmsted, D.L. Out of the Mouth of Babes: Earliest Stages in Language Learning. Paris: Mouton, 1971.

Peiper, A. Cerebral Function in Infancy and Childhood. New York: Consultants Bureau, 1963.

Rees, N.S. The Role of Babbling in the Child's Acquisition of Language. British Journal of Disorders of Communication. 1972, 7, 17-23

Rheingold, H.L., Gewirtz, J.L., Ross, H.W. Social Conditioning of Vocalizations in the Infant. Journal of Comparative and Physiological Psychology. 1959, 52, 68-73

Ribbe, M.A. Infantile Experiences in Relation to Personality Development. In J. McV. Hunt (ed.), Personality and the Behaviour Disorders. New York: 1944.

Sameroff, A.J. An Apparatus for Recording Sucking and Controlling Feeding in the First Days of Life. Psychonomic Science. 1965, 2, 355-356.

Sameroff, A.J. The Components of Sucking in the Human Newborn. Journal of Experimental Child Psychology. 1968, 6, 607-623.

Sameroff, A.J... Reflexive Operant Aspects of Sucking Behaviour in Early Infancy. In J.F. Bosma (ed.), Fourth Symposium on Oral Sensation and Perception: Development in the Fetus and Infant. Bethesda, Maryland: Department of Health, Education and Welfare. 1973.

Sasaki, C.T., Levine, P.A., Laitman, J.T., Crelin, E.S. Postnatal Descent of the Epiglottis in Man. Archives of Otolaryngology. 1977, 103, 169-171.

Sessle, B.J. How are Mastication and Swallowing Programmed and Regulated? In B.J. Sessle and A.G. Hannam (eds.), Mastication and Swallowing. Toronto: University of Toronto Press, 1976.

Sessle, B.J. and Hannam, A.G. Mastication and Swallowing. Toronto: University of Toronto Press, 1976.

Sessle, B.J. and Kenny, D.J. Control of Tongue and Facial Motility: Neural Mechanisms that may Contribute to Movements such as Swallowing and Sucking. In J.F. Bosma (ed.), Fourth Symposium on Oral Sensation and Perception: Development in the Fetus and Infant. Bethesda, Maryland: Department of Health, Education and Welfare, 1973.

Sheets, B.V. Anatomy and Physiology of the Speech Mechanism. Indianapolis: Bobbs-Merrill Educational Publishing, 1973.

Sheppard, W.C., and Lane, H.L. Prosodic Features of Infant Vocalizing. Journal of Speech and Hearing Research. 1968, 11, 94-108.

Skinner, B.F. Verbal Behaviour. New York: Appleton, 1957.

Stark, R.E., Rose, S.N., and McLagen, M. Features of Infant Sounds: the First Eight Weeks of Life. Journal of Child Language. 1975, 205-221.

Stark, R.E., Rose, S.N., Benson, P.J. Classification of Infant Vocalizations. British Journal of Disorders of Communication. 1978, 13(1), 41-47.

Stark, R.E. Prespeech Segmental Feature Development. In P. Fletcher and M. Gorman (eds.), Language Acquisition. Cambridge University Press. 1979.

Thoman, E.B., Leiderman, P.H., and Olson, J.P. Neonate-Mother Interaction during Breast Feeding. Developmental Psychology. 1972, 6, 110-118.

VanRiper, C. Speech Correction: Principles and Methods. Englewood Cliffs, N.J.: Prentice-Hall Inc., 1963.

Wasz-Hockert, O., Lind, J., Vuorenkoski, V., Partanen, T., Valanne, E.
The Infant Cry: A Spectrographic and Auditory Analysis. Clinics
in Developmental Medicine. No. 29. Lavenham, Suffolk, U.K.:
W. Heinemann Medical Books Ltd., Lavenham Press. 1968.

Winitz, H. Articulatory Acquisition and Behaviour. New York: Appleton,
1968.

Wolff, P.H. The Causes, Controls, and Organization of Behaviour in
the Neonate. In Psychological Monographs: 17. No. 1, New York:
I.U. Press, 1966.

Wolff, P.H. The Role of Biological Rhythms in Early Psychological
Development. Bulletin of the Meninger Clinic. 1967. 31, 197-268.

Wolff, P.H. The Serial Organization of Sucking in the Young Infant.
Pediatrics. 1968, 42, 6, 943-956.

Wolff, P.H. The Interaction of State and Non-Nutritive Sucking. In
J.F. Bosma (ed.), Third Symposium on Oral Sensation and Perception:
The Mouth of the Infant. Springfield, Illinois: Charles C. Thomas,
1972.

Wolff, P.H. and Simmons, M.A. Non-Nutritive Sucking and Response
Thresholds in Young Infants. Child Development. 1967, 3, 631-637.

Appendix A

Type of Maternal Medication

Subject	Drug	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
1	Tyrenol #2	02*					
	Seconal		01	01	01		
2	Demerol	01					
	Xylocaine	01					
3	-						
4	Marcaine	01					
	Xylocaine	01					
5	Bupivacaine	02					
	Seconal	01		02			
	Tyrenol #2	01		01			
	Tyrenol #3				01		
6	Marcaine	01					
	Tyrenol #2		02	02	01		
	Tyrenol #3	01					
	Demerol			02			
7**	Marcaine	01					
	Xylocaine	03					
	Fentanyl	02					
	Seconal	01	02				
	Demerol	04	01				
	Tyrenol #2			06	08	06	02
8	Marcaine	01					
	Seconal	01					
	Tyrenol #2	02	06		04		
9	Marcaine	01					
10**	Marcaine	01					
	Xylocaine	01					
	Pitocin	01					
	Dioperidol	01					
	Demerol	02	02				
	Tyrenol #3		03	06	04		
11***	Marcaine	01					
	Xylocaine	01					
	Seconal	01	01	01			
	Tyrenol #2		01	01	04		
	Demerol			02			
	Torecan			01			
	Atropine			01			
	Morphine			01			
12	-						
13	-						

* indicates the number of times a particular drug was given in a day

** Caesarian section

*** tubal ligation

Appendix B

Raw Scores on Sucking and Vocalization Variables (N = 13)

Subject	Sucking Amplitude in mmHg	Sucking Pattern	Date of Onset of Vocalizations
1	42.85	1	72
2	50.00	2	64
3	30.16	1	82
4	25.00		63
5	47.48	3	78
6	68.81	2	51
7	31.09	2	43
8	14.63	1	72
9	42.50	1	78
10	40.48	2	60
11	20.91	2	64
12	37.30	3	87
13	46.67	3	86
$\bar{X} = 38.30$			
$\bar{X} = 1.85$			
$\bar{X} = 69.23$			
SD = 13.77			
SD = .76			
SD = 12.80			

Appendix C - Questionnaire on Sucking Behaviour

Sucking Behaviour in the Neonate: A Questionnaire

1. What does your baby do when first presented with the nipple at feeding?

☐ suck☐ lips around nipple
but does not suck☐ not touch
it

2. What does your baby do approximately two minutes after feeding has begun?

☐ still
sucks☐ starts
to suck☐ breaks from
sucking☐ other

3. When the baby begins to suck, does he/she suck

(i) ☐ very fast ☐ fast ☐ slow ☐ very slow ☐ other ☐ inconsistent

(ii) ☐ very hard ☐ hard ☐ gently ☐ other

4. What, if any, changes occur in sucking behaviour in the first few minutes of sucking?

5. What other comments do you have concerning your baby's
(i) sucking behaviour
(ii) pattern of sucking

Appendix D
Instructions for Tape Recording

NOTES ON TAPING

A. Recording your Baby's Vocalizations.

1. Leave tape recorder plugged into the wall overnight, before the day of recording. This will recharge the batteries and allow you to move the recorder freely on the day of taping. If, for some reason, this is not possible, just ensure the recorder is plugged into the wall while recording.
2. Set up microphone a few inches away from your baby, with wind sock in place.
3. Press the button on the extreme left of the machine, and start to record.
4. Try to ensure no other house noises are occurring while you are recording, e.g. vacuum cleaner, washing machine etc.

B. How to Record Spontaneous and Elicited Vocalizations.

1. For the first two minutes of recording, do not vocalize to your child at all. If at all possible, try to record and remain out of sight.
2. For the next two minutes talk to your baby while recording to encourage his vocalizations, but stop talking once he/she starts to vocalize. This will help us obtain a clear recording of your baby's vocalizations.
3. For the last two minutes, vocalize only those sounds on the next sheet. Begin with those in the first row, then the second row, and finally the third row.
4. If you are unable to obtain six minutes of vocalizations at one time, then record later in the day. Always continue in the sequence outlined above, at the place where you stopped.
5. Record your baby once a week.

C. Comments on your Baby's Vocalizations.

1. With the tape-recorder still recording, give the following information once a recording session has been completed:
 - a. the date of recording
 - b. the time of day
 - c. how many hours since the baby's last feed

- d. the baby's activity immediately prior to recording.
- e. the place where the recording occurred
- f. the position the baby was in, e.g. lying on his back in the crib, sitting up in a baby chair.
- g. add any observations you may have made during his vocalizations, e.g. (i) vocalizations accompanied by vigorous body movements, (ii) vocalizations occurred after seeing a toy or a mobile.

D. Specific Vocalizations - for the last two minutes of Recording.

<u>1st.Row.</u>	<u>2nd.Row.</u>	<u>3rd.Row.</u>
b-b-b-b-b-	d-d-d-d-d-	g-g-g-g-g-
p-p-p-p-p-	t-t-t-t-t-	k-k-k-k-k-
d-d-d-d-d-	g-g-g-g-g-	b-b-b-b-b-
t-t-t-t-t-	k-k-k-k-k-	p-p-p-p-p-
g-g-g-g-g-	b-b-b-b-b-	d-d-d-d-d-
k-k-k-k-k-	p-p-p-p-p-	t-t-t-t-t-

A

Appendix F

Contribution of Sucking Amplitude, Sucking Pattern and
Position of the Neonate in the Family to the Prediction
of Date of Onset of Stop Vocalizations (N = 13)

Variable	Date of Onset of Vocalizations R^2	Significance Level
Sucking Amplitude	.023 $F(1,11) = .255$	ns
Sucking Pattern	.002 $F(1,11) = .021$	ns
Position of Neonate in Family	.189 $F(1,11) = 2.58$	ns

Appendix G

Summary of Two-Way Analysis of Variance: Effects of Time Intervals on Stop Vocalizations (N = 13)

Source	df	SS	MS	F	Sig
Type of Sound	2	102.63	51.32	10.06	$p < .001$
Time Intervals	2	8.02	4.01	.79	ns
Sound by Time Interval	4	15.11	3.78	.74	ns
Error	108	550.77	5.10		

Appendix H

Summary of One-Way Analyses of Variance (N = 13)

Variable	Group Effect	Significance Level
Medication	$F(1,11) = 1.70$	ns
Sex	$F(1,11) = .41$	ns

END

0 610 6.8 3

FIN