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A

# Discrimination of Native and Non-Native Speech-Sounds by Newborns

by

Elissa Litwin

A dissertation submitted to the Graduate Faculty in Psychology
in partial fulfillment of the requirements for the degree of
Doctor of Philosophy, The City University of New York

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# Abstract

## DISCRIMINATION OF NATIVE AND NON-NATIVE SPEECH-SOUNDS BY NEWBORNS

by

Elissa Litwin

Advisor: Professor Gerald Turkewitz

This research was undertaken to investigate whether one-two day old infants born to American-English speaking mothers could discriminate the native /ba/ ([p'a]) - /pa/ ([pʰa]) contrast, and native /ba/ ([p'a]) - non-native /ba/ ([ba]) contrast. The high-amplitude sucking technique was used in both experiments. In Experiment I, infants were tested on speech-sound stimuli that ranged from -20 to +80 ms voice-onset-time (VOT).There was evidence that the infant subjects discriminated the native speech-sounds between +20 and +40 ms (VOT), which coincides with the adult boundary for bilabial stop consonants. In Experiment II, infants were tested speech-sound stimuli that ranged from -100 ms to 0 ms VOT. These infants failed to show evidence of discriminating a contrast. These findings support the view that speech-sound discrimination is due to pre-natal exposure rather than innate factors.

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# CHAPTER 1: In-Depth Abstract

This research was undertaken to investigate whether one-two day old newborns could discriminate the native /ba/ ([p'a]) - /pa/ ([pʰa]) contrast, and native /ba/ ([p'a]) - non-native /ba/ ([ba]) contrast. There was evidence that the infant subjects discriminated the native speech-sounds but failed to show evidence of discriminating the native/non-native contrast. These findings support the view that speech-sound discrimination is due to pre-natal exposure rather than innate factors.

Two experiments were carried out with infants born to English-American speaking mothers. In Experiment I, infants, whose mean age was 31 hours, were tested on their ability to discriminate speech-sound stimuli which ranged from -20 to +80 msec voice onset time (VOT). This segment of the VOT continuum includes the range of VOT values within which adult speakers of American-English demonstrate categorical perception for the short voicing lag /ba/ vs. the long-voicing lag /pa/ contrast. Adult speakers show peak discrimination for bilabial stop consonants that cross the +25 msec VOT category boundary and label two stimuli from within a single category as identical although they are capable of discriminating between them. It was hypothesized that infants' discrimination of speech-sounds that crossed the adult VOT boundary would be superior to their discrimination of within-category variants. In Experiment II, infants, whose mean age was 36 hours, were tested on their ability to discriminate a native short lag /ba/ vs. a non-native long voicing lead /ba/ (as in the Spanish word "basso") contrast among stimulus-pairs that ranged from -100 to +20 msec VOT. As these speech-sounds are not phonologically different in American-English, it was anticipated that infants would not discriminate these speech-sounds.

These experiments were conducted using a high-amplitude sucking (HAS) technique. As there was no known research that used the HAS technique with infants this young, prior to the formal data collection, a pilot study was carried out to establish that data could be gathered in this manner. For both the pilot and the two experiments, the same apparatus and general procedure were used: Infants sucked on a non-nutritive nipple that fed into a pressure transducer and then into a computer that was programmed to calculate the mean, standard deviation, and HAS criterion as the 67th percentile of the sucking amplitude distribution. A one-minute baseline distribution of sucking amplitudes was gathered from each infant. Following the baseline period, every suck that exceeded the HAS criterion was reinforced with a computer-generated speech-sound. A pre-shift or conditioning minute was defined as the minute that preceded an average of a 20% decrement in HAS for two consecutive minutes. This 20% decrement in the rate of HAS production constituted a habituation or decrement period. Once the decrement criterion had been achieved, in every condition except for the control condition in which the stimulus stayed the same throughout the test session, the stimulus shifted to a post-shift stimulus that differed from the pre-shift stimulus by 20 msec VOT.

In Experiment I, three conditions were run. In the control condition, there was no change in the speech-sound stimulus following achievement of the decrement criterion. In the between-category condition, following the criterial decrement in HAS, there was a stimulus shift which crossed the adult category boundary. If the pre-shift stimulus was a

+20 msec VOT /ba/-sound, the post-shift stimulus as a +40 msec VOT /pa/-sound. In the within-category condition, infants heard /ba/ or /pa/ variants, which ranged from -20 to +20 and +40 to +80 msec VOT, respectively. In Experiment II, in addition to a control condition, the stimulus-change conditions consisted of stimuli that ranged from -100 to 0 msec VOT.

In Experiment I useable data were gathered from 26 infants who were receptive to conditioning (i.e. produced significantly more HAS during the pre-shift minute relative to the baseline period). After the decrement criterion had been reached, the 10 infants in the control condition showed a further decrement in HAS, from which it was inferred that infants continued to habituate to the speech-sound stimulus. In the between-category condition (n = 8), there was a significant increase in HAS after the stimulus-shift, from which it was inferred that infants discriminated the /ba/-/pa/ boundary across the range of VOT values that coincides with the adult category boundary. In the within-category condition (n = 8), the was no significant difference in the rate of HAS production between the decrement and post-shift periods. Post-hoc tests indicated a significant difference in recovery of HAS between the between-category and control conditions and between the between-category and within-category conditions. Additionally there was no significant difference in recovery between the within-category and control conditions. From the significant difference in recovery in the between-category condition relative to the continued decrement in the control condition and the non-significant change in the rate of HAS in within-category condition, it was inferred that infants discriminated the speech-sounds and that the range across which the category boundary was discriminated coincides with adult category boundary for the bilabial stop consonants.

In Experiment II, data were collected from 42 infants who were responsive to conditioning. In the control condition (n = 10), there was a significant decrement in HAS production after habituation criterion had been reached, indicating continued habituation. Analysis of the recovery in each of the five stimulus-change conditions (n =32) failed to reveal any significant change in the rate of HAS during the post-shift period. When the data were collapsed across stimulus-change conditions, there was evidence of a continued decrement in HAS during the post-shift period, from which it was inferred that the newborns continued to habituate to a familiar speech-sound. In addition, there was a significant difference between the recovery in the between-category condition of Experiment I and the collapsed stimulus-change condition of Experiment II, indicating that the type of discrimination demonstrated in Experiment I did not occur in Experiment II.

These findings support the view that there is a difference in infants' discrimination of native and non-native speech-sounds and that such a difference is likely to have its origins in the infants' differential pre-natal exposure to such sounds.

# CHAPTER 2: Overview of the Literature

## *Statement of the Issues*

This research was undertaken to investigate newborn infants' ability to discriminate speech-sounds that are both native and non-native to their parents' language. The ability at birth, or shortly thereafter, to make discriminations used in any language could point to an ability to discriminate speech-sounds in the absence of previous exposure. The ability of the neonate to discriminate only differences used in its native language would imply that a great deal of language-relevant learning occurs in the immediate newborn period, or that learning has occurred pre-natally. The hypothesis tested here is that the neonate will discriminate native speech-sounds, but will not discriminate speech-sounds that do not present a phonemic contrast in its native linguistic environment. As it is unlikely that this much learning could occur within the first few days after birth, the ability to discriminate only those speech-sound contrasts that are phonemic in the native language would suggest pre-natal influences on the discrimination of speech-sounds. Specifically, the ability of one-two day old neonates of American parentage to discriminate either both or neither of the bilabial stop contrasts, the native English /b/ vs. the native English /p/ and a non-native /b/ as in the Spanish word "basso" vs. the native English /b/ will be investigated as a means of examining the factors that may underlie speech-sound discrimination.

The ability of the one- to six-month old infant to discriminate native speech-sound contrasts such as English /ba/-/pa/ (Eimas, Siqueland, Jusczyk, & Vigorito, 1971), /bae/-/dae/ (Eimas, 1974), /l/-/r/ (Eimas, 1975a), /ba/-/wa/ (Eimas & Miller, 1980), /ba/-

/ga/ (Moffit, 1971; Morse, 1972) as well as some vowel contrasts (Cameron-Marean, Werner, & Kuhl, 1992; Kuhl 1977; 1979) has been documented. However, research on non-native speech-sound discrimination within the first year of life has rendered mixed results. Eilers, Gavin, and Wilson (1979) demonstrated that infants of English-speaking parentage discriminate an English lag voicing boundary while infants of Spanish parentage discriminate a Spanish lead voicing boundary as well an English lag voicing boundary. There is additional evidence that infants discriminate non-native speech-sound boundaries (Streeter, 1976) and vowel contrasts (Trehub, 1976). However, Kuhl, Williams, Lacerda, Stevens, and Lindblom (1992) found that the generalization of learning for vowel categories is superior for native as opposed to non-native speech-sounds. The data gathered by Eimas (1975b) on discrimination of a non-native voicing lead boundary rendered contradictory results because while one sample of infants showed evidence of discriminating this boundary, these results were not replicated by Eimas' second sample. Lasky, Syrdal-Lasky, and Klein (1975) found that the voicing lead boundary discriminated by Guatemalan infants differs from that discriminated by Spanish-speaking adults. Lastly, Werker and colleagues (Polka & Werker, 1994; Werker, Gilbert, Humphrey, & Tees, 1981; Werker & Lalonde, 1988) have shown that four-to-eight month old infants can discriminate some non-native speech-sounds, but this ability declines toward the end of the first year of life.

In 1971, Eimas et al. demonstrated that infants as young as one-month of age could discriminate the bilabial stops /ba/ and /pa/. The researchers concluded that this ability was innate, because during the first month of post-natal life, there would not be sufficient time to learn speech sounds. This precludes the possibility that there could be exposure to sounds prior to birth, from which these discriminations could be learned and makes a questionable assumption concerning the amount of time and experience required for learning to occur.

### *Evidence of Fetal Responsiveness to Auditory Stimulation*

Since the earlier part of this century, there had been a number of demonstrations of fetal responsiveness to externally generated sound (Forbes & Forbes, 1927; Ray, 1932; Salk, 1962; Sontag & Wallace, 1936; Wedenberg, 1965). Somewhat paradoxically, when Eimas et al. published their findings in 1971, it was believed that there were internal sources which provided a constant source of noise that was so loud that the transmission to the fetus of externally generated sounds such as speech was masked (Walker, Grimwade, & Wood, 1971). More recently, with the use of better recording apparatus, it has been demonstrated that internally generated sounds are present at a lower intensity level than had been thought previously, and that there are periods of relative quiet in the womb (i.e. no digestive sounds above the always present vascular noises), which may enable transmission of externally generated sounds to the fetus (Armitage, Vince, & Baldwin, 1980; Gerhardt, 1989; Lecanuet & Granier-Deferre, 1993; Querleu, Renard, Bouteville, & Crepin, 1989; Querleu, Renard, Versyp, Paris-Delrue, & Crepin, 1988). In addition, the uterus becomes taut during the latter part of gestation, which seems to amplify externally generated sounds such as speech (Richards, Frenzten, Gerhardt, McCann, & Abrams, 1992; Turkewitz, 1988; 1991). In fact, 30% of externally generated speech sounds that were recorded in utero after rupture of the amniotic sac are identifiable by adult listeners (Querleu et al., 1988).

More recent research on fetal responsiveness to auditory stimulation has documented fetal reflex and limb movements following vibro-acoustic stimulation as early as the 24th week of gestation (Birnholz & Benacerraf, 1983) as well as an increase in fetal movements in response to vibro-acoustic stimulation by the 20th week of gestation (Shahidullah & Hepper, 1993). Perhaps even more to the point, there is evidence not only of fetal auditory responsiveness but of fetal learning of verbal material. DeCasper, Lecanuet, Busnel, Granier-Deferre, and Maugeais (1994) had mothers read aloud one of two rhyming passages three times daily from the 33rd to the 37th week of pregnancy. Thereafter, the 37 week-old fetuses demonstrated decreased heartrates upon hearing the passage that the mother had read, but there was no change in heartrate following a reading of the unfamiliar rhyming passage. These results are in agreement with those of Lecanuet, Granier-Deferre, Jacquet, & Busnel (1992), who found evidence of short-term cardiac decelerations or orienting responses immediately after the presentation of sentences to which the fetuses had been exposed. In addition, Lecanuet, Granier-Deferre, DeCasper, Maugeais, Andrieu, and Busnel (1987) had a text read to third trimester fetuses for a period of four weeks. After the familiarization period, when the familiar text and an unfamiliar text were read to the fetuses, higher levels of overall activation were recorded in response to the familiar text only. These response patterns were taken as evidence that the auditory stimuli had been perceived and stored.

Although to date there is only a skeletal body of research on fetal auditory perception and responsiveness, there is a more substantial literature on fetal learning of the speech signal that is demonstrated post-natally. DeCasper and Fifer (1980) and Fifer and Moon (1989) found that one-four day old neonates could be conditioned to lengthen or shorten the inter-burst sucking interval when the reward was the mother's voice while there was no effect of conditioning when the reward was the voice of a strange female. Fifer and Moon (1990) also documented that newborns prefer a filtered version of the mother's voice that had been available during the prenatal period to a normal version of a mother's voices in which there was no attenuation of frequencies over 500 Hz. It is inferred that the newborns expressed a preference for the mother's voice with which they had become familiar through fetal exposure. Furthermore, although neonates discriminate male voices, they do not express a preference for their father's voice in the immediate post-natal period (DeCasper & Prescott, 1984). The frequency with which the father's voice would be perceived may be insufficient for a preference to develop.

In another study, sections of text were read to fetuses twice daily during the last six weeks of pregnancy, totaling 3.5 hours of prenatal exposure. Shortly after birth, these infants were found to prefer the familiar text over an unfamiliar text (DeCasper & Spence, 1986). DeCasper et al. (1986) demonstrated that when a text that had been read to the fetuses during the latter part of gestation and a text to which there had been no prenatal exposure were used as a reinforcers, the familiar text was more effective in conditioning newborns to shorten or lengthen the interburst sucking interval than the reading of unfamiliar text, which effected significantly less of a change in the length of the interburst interval. In a similar vein, Spence and DeCasper (1987) showed that neonates demonstrated a preference for a maternal heartbeat in the form in which it is transmitted *in utero.* The intrauterine heartbeat used in this experiment was recorded by placing a microphone in the uterus next to the head of an eight month-old fetus. Although the spectral characteristics of the stimulus were not specified, it is probable that the heartbeat that was presented post-natally had been low- and high-band pass filtered so that it was devoid of low frequencies that would have been masked by gastrointestinal noises and higher frequencies that would be attenuated by the maternal uterine environment.

On a cross-linguistic basis, newborns were found to express a preference for their native language over a variety of non-native languages (Mehler, Jusczyk, Lambert, Halsted, Bertoncini, & Amiel-Tison, 1988). Non-nutritive sucking rates for untrained infants were found to increase spontaneously when the language changed from non-native to native and to decrease when the language changed from native to non-native. Mehler et al. (1988) inferred that the increase in non-nutritive sucking rates indicated that a higher level of arousal was induced by the familiar language.

In addition, Moon, Bever, and Fifer (1992) demonstrated that newborns discriminate the canonical syllables /paet/ and /taep/ but fail to show evidence of discriminating the consonantal clusters /tsp/ and /pst/ which provides evidence that newborns can discriminate phonetic information shortly after birth. These findings, however, do not address the role of pre-natal exposure.

As yet it is not known what the basis is for post-natal recognition of stimuli heard during gestation. Most of the abovementioned studies used spontaneous speech or segments of texts as stimuli, so that it is not known whether neonatal recognition is based on prosodic aspects of the speech signal such as intonation contour, or whether finer segmental contrasts such as those between the minimal pair /ba/ and /pa/ may be perceived *in utero*. Although there are virtually no empirical data relevant to this issue for human fetuses or neonates, research with chicks, whose auditory systems are functional in the pre-natal period, demonstrates that the range of stimuli that can be encoded by the basilar membrane is limited to the low-mid frequency range in the late fetal period, at which time a traveling wave will peak near the base or mid-basal region of the cochlea. Shortly after hatching, a shift in the area of maximal sensitivity is observed. Over the first post-natal month, successively more apical regions become sensitive to lower frequencies and the range of encodeable frequencies expands to encompass the higher frequency range whose area of maximal sensitivity moves toward the basal area of the cochlea (Rubel & Ryals, 1983). This progression of the place principle is also seen in the tonotopic organization of the central auditory system of chicks (Lippe & Rubel, 1983). In his research with human cadavers, von Bekesy (1960) demonstrated that lower frequencies, within which intonation contours are transmitted, seem to cause the entire membrane to vibrate. It is not known, however, whether the fetuses' range of encodable stimuli would be sufficient to enable perception of differences between speech-sounds. However, it does seem that the auditory and central nervous systems may be at least partially functional during the fetal period. The role of pre-natal exposure to speech-sounds needs to be taken into account in any theory of infant speech perception.

### *Perception of Speech-Sounds by Adults and Infants*

In addition to their questionable claim that neonates are naive listeners, a number of other assertions were made by Eimas et al. in their 1971 paper. These assertions require examination. The researchers held that the manner in which the infants perceived the difference between the speech-sounds /ba/ and /pa/ was similar to the way adults perceive these speech-sounds, and that these speech-sounds had been perceived linguistically, or as speech, by the infants.

The manner in which adults perceive the difference between minimal pairs such as /ba/-/pa/, /da/-/ta/, and /ga/-/ka/ as well as the similarity between different versions of each speech-sound is known as categorical perception (Liberman, Harris, Hoffman, and Griffith, 1957). In the traditional categorical perception paradigm, which has served as a model for many of the infant speech-sound discrimination studies, there is a peak in discrimination between stimuli drawn from two different speech-sound categories. This is to say that discrimination between categories is nearly perfect when stimuli from the middle of one category are contrasted with stimuli from the middle of another category. In addition, for equal step-size differences along an experimental continuum, discrimination of a pair of stimuli from different categories will be superior to discrimination of a pair from within one category (Liberman, Harris, Kinney, & Lane, 1961; Wood, 1976). Within-category discrimination, however, has been shown to increase as the distance between stimuli increases (Liberman et al., 1957). Furthermore, there is consistency between stimuli labeled as one phoneme or the other (e.g. /ba/ or /pa/) and those discriminated as that phoneme (e.g. /ba/ or /pa/), so that the ability to discriminate stimuli can be predicted fairly accurately from the labeling function. The ability to label stimuli, however, underestimates the ability to discriminate stimuli, simply because two stimuli that are labeled identically may be discriminably different (Liberman et al., 1957). This is analogous to labeling both "sky blue" and "navy blue" "blue", but acknowledging that the two are different stimuli.

The abovementioned stop-consonants fall on what is known as the *voice onset time* (VOT) continuum. VOT is a measure of the time between the release of oral closure and the onset of glottal vibration in syllable-initial stops (Lisker & Abramson, 1964). In terms of the English stop consonants /b/, /d/, and /g/, glottal vibration and the release of closure occur virtually simultaneously, defining the group of short voicing lag stops. For English /p/, /t/, and /k/, the onset of glottal vibration occurs more than 25 ms after the release of closure, which defines phonemes with long voicing lag. In certain languages such as Eastern Armenian, Spanish, and Thai, a category of stops is recognized in which the onset of glottal vibration precedes the release of oral closure (Lisker & Abramson, 1964). These stops are characterized as displaying voicing lead.

Adult listeners hear a distinct break at a given point on the VOT continuum, which distinguishes the short lag (/b, d, g/) from the long lag (/p, t, k/) stops in English or long lead (/b, d, g/) from short lag (/p, t, k/) stops in Spanish. Although this may vary as a function of the place of articulation and the co-articulated vowel, the short lag/long lag /ba/-/pa/ boundary is heard at 25 msec VOT (Liberman et al., 1961; Lisker & Abramson, 1970). Whereas it has been demonstrated that infants and adults recognize boundaries at approximately the same point on a variety of speech-sound continua (Eimas, 1975b;

Eimas et al. 1971; Liberman et al., 1957; Moffit, 1971), by virtue of the fact that infants are pre-articulate creatures, they cannot show the full set of data that provide evidence of categorical perception (i.e. produce labeling functions to be related to discrimination functions). Although it may well be the case that an infant's mode of speech-sound perception approximates that of adults, the degree to which this can be formally demonstrated should not be overstated.

Given that there are limitations to the type of information that can be gleaned from pre-articulate subjects, a modification of the classical categorical perception paradigm has generally been used to demonstrate discrimination between speech-sounds or minimal pairs. This procedure entails the operant conditioning of high-amplitude sucking (Bertoncini et al., 1988; Eimas, 1975b; Eimas et al., 1971; Jusczyk & Derrah, 1987). A baseline distribution of sucking amplitudes is gathered. This distribution is presumed to be normally distributed. A contingency is then established between the production of a high-amplitude suck (HAS) and the presentation of a speech-sound. If frequency of the sucks is plotted against amplitude, the resulting distribution is negatively skewed for the period during which the contingency is maintained. When the stimulus loses its reinforcing power, the frequency of HAS decreases. The distribution of sucking amplitudes approaches normal again. Once the criterion for habituation is reached, the stimulus is changed. If the infant discriminates the difference between the original (pre-shift) and change (post-shift) stimuli, the frequency of HAS increases.

The HAS paradigm used by Eimas et al. (1971) was executed as follows: A baseline sucking rate was gathered for each infant. Thereafter, a stimulus was presented contingent upon the sucking amplitude exceeding a pre-established criterion, which was set at the top 33% of the amplitude of each infant's baseline sucking pattern. (In the original HAS paradigm, which was developed to assess infants' visual discrimination, a stimulus was presented when sucking exceeded a universal mark [18 mm Hg] for all infants [Siqueland & DeLucia, 1969]. Eimas et al. (1971) modified the procedure so that the stimulus presentation was tailored to each infant's sucking pattern.) After a number of stimulus presentations, the frequency of HAS decreased, from which it was inferred that the infant had habituated to the stimulus, as the stimulus no longer maintained the infant's interest. When the frequency of HAS decreased by 20% for two consecutive minutes, a new stimulus was presented.

One- and four-month old infants were presented with three /ba/ variants (-20, 0, +20 ms VOT) and 3 /pa/ variants (+40, +60, +80 ms VOT), which fall on either side of the +25 ms VOT boundary for adults. The infants were divided into two experimental groups and one control group. One of the experimental groups, the DIFFERENT group, was presented with pre-and post-shift stimuli that fell on either side of the +25 msec VOT boundary (eg. +20 and +40). The other experimental group, the SAME group, listened to one pair of within-category /ba/ variants (-20 and 0 ms) or a pair of /pa/ variants ( +60 and +80 ms). The OTHER (control) group heard the same stimulus during pre- and post-shift periods.

Recovery was calculated as a difference score between the average rate of HAS produced during the two-minute decrement and the average rate of HAS produced during the first two minutes after the stimulus-shift. For the four-month old subjects, the results showed that in the DIFFERENT group, the frequency of HAS increased significantly in response to a between-category post-shift stimulus, from which it was inferred that a difference between the pre- and post-shift stimuli had been recognized. In the control condition, in which the pre-and post-shift stimuli were identical, there was a continued decrement in HAS production after the shift criterion had been achieved, as habituation to the post-shift stimulus continued. However, this decrement did not reach significance when the average rate of HAS production during the post-shift period was compared to average rate of HAS during the two decrement minutes, although the effect was significant when the average rate of HAS over the first four minutes during the post-shift period was compared to the decrement period. In the SAME group, for which the post-shift stimulus was a category variant, there was some decrement in the production of HAS, but this was statistically non-significant. Eimas et al. (1971) report that the only substantial difference between the results with the one- and four-month old infants was that for the younger infants there was a non-significant increase during the post-shift period for the SAME group. A between-group analysis of the recovery rates showed a significantly greater recovery rate for the DIFFERENT group compared to the control condition and no significant difference in the recovery rates for the SAME and control groups. In a more thorough review of the original research, Eimas (1975b) reported no significant age-by-treatment interaction, from which it may be inferred that these between-group results would also apply to the younger subjects.

Subjects in the SAME group were tested on their ability to discriminate only 2 of the 4 possible within-category contrasts (-20/0, 0/+20, +40/+60, and +60/+80 ms VOT), which is a further departure from the classical paradigm used with adults (Liberman et al. 1958). Although it may be the case that infants would produce the same discrimination function as adults, for many reasons that information cannot be gleaned from the available infant data. Eimas et al. (1971, p.306) state that infants perceive "...in a manner approximating categorical perception...". At best, it is possible to infer "categorical discrimination" for the infants (Jusczyk, 1981).

Eimas et al. (1971) also contended that infants perceive speech-sound contrasts as linguistic elements, because the categorical mode in which these speech-sounds are perceived is unique to speech (Liberman, 1982). In other words, according to Eimas, it is possible to discriminate only linguistic elements in a categorical manner. Therefore, it would seem that the ability to categorically discriminate between non-speech sounds would refute or at least weaken Eimas et al.'s claim that these sounds were recognized as linguistic elements.

Jusczyk, Pisoni, Walley, & Murray (1980) investigated ten-week old infants' mode of perception for non-speech stimuli. The researchers used a HAS paradigm to demonstrate that infants would hear two category boundaries or three categories when presented with two-tone composites on the *tone-onset-time* (TOT) continuum. The TOT continuum was created so that the lower frequency pure-tone started prior to, contemporaneous with, or after the higher frequency pure-tone. The TOT continuum was constructed as a non-speech analog to the voicing lead, short lag, and long lag categories of the *voice-onset-time* continuum. Stimuli were equally spaced from -70 to +70 ms TOT. The infants showed evidence of discrimination of a lead/short lag boundary between -70 and -40 ms and a short lag/long lag boundary between +40 and +70 msec TOT by increasing the number of HAS in the recovery conditions. Recovery from habituation for within-category stimuli was non-significant.

These data indicate that infants discriminate at least some classes of non-speech stimuli in much the same way as they discriminate speech-sounds, which is to say that speech-sounds do not seem to be discriminated in a manner that is unique to speech. However, when a comparison is made between the data gathered by Jusczyk et al. (1980) with infant subjects and those gathered by Pisoni (1977) with adults, who were also naive listeners to these same TOT stimuli, the role of exposure to auditory stimulation and/or refinement of physiological mechanisms becomes apparent, because the two boundaries discriminated by adults were closer together in TOT value than those recognized by infants.

The finding that infants' discrimination peak for the VOT stimuli is in the same place as the adults' but that the infants needed an even earlier onset of the lower formant (lead) and a greater delay in the onset of the lower formant (lag) than the adults in order to discriminate non-speech sounds on the TOT continuum may point up the crucial role of exposure. It is reasonable to assume that the one- and four-month old infants tested by Eimas et al. (1971) had had exposure to speech-sounds, including /ba/ and /pa/, by the time they were tested. This exposure would have been post-natal and could have been pre-natal as well. The ten week-old infants tested by Jusczyk et al. (1980), however, would not have had exposure to TOT stimuli, because such stimuli exist only in a laboratory. The discrimination of these non-speech boundaries may be analogous to the type of generalization found by Streeter (1976), who demonstrated that Kenyan infants could discriminate three voicing categories (voicing lead, short lag, and long lag) for bilabial stops. Although the native language, Kikuyuan, has no short lag bilabial stop per se, there is a lead/short lag distinction made for other phoneme categories. It would seem possible that the ability to discriminate speech and non-speech sounds is dependent upon some amount of exposure to speech, although the exposure need not be to the specific phoneme. Whereas the factors that underlie Kenyan infants' ability to discriminate a non-native phoneme boundary may or may not be the same as those that enable adults to hear less extreme TOT boundaries than do infants, it is apparent that exposure influences abilities. Although it is not possible to assess naive human discriminative abilities to speech-sounds without depriving subjects of stimulation, the group of subjects that would have had the least amount of exposure to speech is newborns. If the voicing boundary recognized by newborns (excluding, of course, the congenitally deaf) falls at the same place on the VOT continuum as that of adults and older infants, such as those tested by Eimas et al. (1971), this would suggest that the ability to discriminate the voicing boundary that adults recognize between short and long lag bilabial stops is in place at birth.

Another issue arises, which is the infant's ability to discriminate speech-sounds that are non-native to its linguistic environment. If discrimination of non-native speech sound contrasts is possible for pre-articulate infants, this suggests the possibility that they may be able to discriminate auditory stimuli, to which there has been little or no exposure. Languages differ in the number and type of VOT categories they employ.

English employs short voicing lag and long voicing lag categories and Spanish employs long voicing lead and short voicing lag categories (Lisker et al., 1964). If the ability to discriminate speech-sounds is not language-specific, all infants should be able to discriminate all boundaries. However, if newborns do not display the ability to discriminate speech-sounds to which there was no pre-natal exposure but are able to discriminate native speech-sounds, this would provide evidence that pre-natal exposure underlies the ability to discriminate speech-sounds at birth. Thus far, evidence of infants' discrimination of non-native boundaries is inconclusive.

Lasky et al. (1975) found that, at four-months of age, Spanish infants discriminated speech-sound boundaries between -60 and -20 ms and between +20 and +60 ms VOT. For Spanish infants, the voicing lead/short voicing lag boundary is native, but the short lag/long lag boundary is not. Eilers et al. (1979) found that seven month-old Spanish infants could discriminate among all three voicing categories, which might suggest an innate ability. However, their methodology and statistical analysis have been called into question (Aslin & Pisoni, 1980). The criticisms stem from the use of too few trials per subject which resulted in low cell frequencies. When Aslin et al. (1980) employed the appropriate correction for continuity, evidence of discrimination between even native voicing contrasts was not significant. As mentioned above, Streeter (1976) found evidence of discrimination across a non-native boundary, to which there had been indirect exposure. Lastly, Eimas (1975b) made two attempts to document discrimination of a non-native long lead/long lag apical stop (/da/) boundary by infants of American-English speaking parentage. In the first experiment, infants discriminated a boundary on the voicing lead portion of the continuum between -100 and -40 ms VOT. Eimas (1975b) concluded that the voicing lag boundary is around -50 ms VOT, which is more voicing lead than the amount of voicing lag used to differentiate between short and long lag stops in production (Lisker et al., 1967). The finding that a long lead/short lag boundary was recognized only with substantial amounts of long voicing lead would support the findings of greater difference limens for infants' discrimination of sounds to which there had been no direct exposure (Jusczyk et al., 1980). In a second experiment, infants were not able to discriminate the -70/+10 ms VOT stimulus pair, which encompasses the -50 ms VOT boundary Eimas had presumed would be recognized. The data surrounding the discrimination of non-native phoneme contrasts are truly equivocal.

### *Overview of the Present Studies*

The present studies were designed to investigate newborns' ability to discriminate speech-sounds that are both native and non-native to their linguistic environment. Experiment I tested newborns' ability to categorically discriminate the stop consonants /ba/ and /pa/, that have short and long voicing lag, respectively. It was anticipated that the infants' data would display a discrimination peak between the stimuli that encompass +25 ms VOT, which is the point at which adults discriminate bilabial stops with short and long voicing lag. Positive evidence would document that the ability to discriminate certain speech-sounds is in place at birth. The basis for any such discrimination would be indeterminate.

Experiment II was designed to shed some light on the possible basis for discrimination of speech-sounds that are not phonologically different in the infant's native linguistic environment. This experiment investigated whether newborns from an American-English linguistic environment could discriminate a long lead/short lag boundary, which is non-native to English but is native to languages such as Eastern Armenian, Spanish, and Thai. As no long lead/short lag boundary has been established, it was impossible to state *a priori* where the boundary should be heard. Given that Jusczyk et al. (1980) found that when there has been no exposure to the stimulus more voicing lead and lag are needed for recognition of a boundary, and stops with long voicing lead are not native to English, it can be assumed that more voicing lead would be necessary for recognition of a long lead category than the amount of voicing lag which is required for recognition of a long lag category. If a long lead/short lag boundary were recognized, it was predicted that the boundary would be discriminated at more than -25 ms VOT. However, the position taken here is that the ability to discriminate speech-sounds is due to pre-natal exposure to speech. As there is no long lead/short lag contrast that is phonemic in English, it was hypothesized that no boundary would be recognized by these infants.

# CHAPTER 3: Method

As this research is a replication of as well as an extension of the Eimas et al. (1971) research, it was necessary to adhere as closely as possible to the data gathering techniques used by Eimas et al. (1971). One major modification is that technological advances over the last 25 years have enabled automation of this research procedure. A second modification, used in Experiment I, was to run the subjects in the within-category (or SAME) condition on every possible within-category stimulus pair although Eimas (1975b) reports that in the original research, subjects were run on only two contrasts within this condition.

## *Subject Selection*

The data were collected in the newborn nursery at Jamaica Hospital in Queens. Informed consents were obtained from American-English speaking parents of infants in the well-baby nursery. Infants were considered suitable subjects if they were single-birth term babies (37-42 weeks estimated gestational age [EGA]), normal birthweight (2500-4200 grams), either Caesarean or vaginal births with no complications during pregnancy, labor, or delivery, and whose Apgar Test scores[1], were at least eight and nine (out of ten) at one and five minutes, respectively for vaginally delivered infants and nine at five minutes for infants delivered by Caesarian section. In addition, infants were selected only if their mothers had met minimum requirements for pre-natal care (three visits), the

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[1] Apgar scores are based on five measures of neonatal function: respiration, skin color, reflex, irritability, and cry.

infants did not meet the criteria for addiction/withdrawal to dangerous substances, infants showed no sign of medical complications, and circumcision had been performed at least 12 hours prior to testing. The initial protocol called for selecting only vaginally delivered infants whose mothers' ages ranged from 18-35. However, due to difficulty obtaining informed consents from the population at Jamaica Hospital, compounded by the high incidence of Caesarean births and teen and older mothers, consent was sought from mothers of all infants who met the above-stated criteria. As recent research (Bertoncini et al. 1988: Decasper et al., 1980; Fifer et al 1989; Moon and Fifer, 1990; Sansavini, Bertoncini, & Giovanelli, 1997) with newborns does not list mother's age or type of birth as exclusion criteria, Caesarian birth infants as well as those born to mothers younger than 17 and older than 35 years of age were included as potential subjects.

In addition, some possible medical complications (e.g. readmissions, delayed discharges) and positive drug toxicologies became apparent after infants participated in the experiment. Data from such infants were disqualified on a post hoc basis. These infants were accounted for as part of the attrition group.

*Apparatus*[2] (refer to Diagram 1)

A standard newborn nipple was attached to a series of tubes that ran to a pressure transducer (Ailtech Physiological Transducer), which converted sucking pressure from a

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[2] The instrumentation and computer program were designed by Mark Weiss, MSEE, Visiting Professor in Speech and Hearing Sciences at the Graduate Center of the City University of New York.

mechanical to an electrical signal. An amplifier (Hewlett-Packard 78205C) increased the strength of the signal for input to an analog-to-digital converter (ADC). This component transformed the signal to digital form for input into a portable computer (Micro Express Regal II). The data were sampled at a rate of 200 samples per second with 12-bit amplitude conversion accuracy. The data were then processed by a computer program which detected the occurrence of peaks in the temporal pattern of suction and computed the standard deviation and required threshold levels during a one-minute baseline period. The sounds that were presented to the infants were stored in the computer in digital form and at the appropriate time (when thresholds are exceeded) were converted to analog form. These stimuli were amplified through a standard amplifier (Optimus SA-15T Integrated) and presented through lightweight headphones (Sony Headphones MDR-24). Data related to the temporal pattern of sucking, identification of all peaks, including those exceeding threshold, were identified and the point of change from pre- to post-shift was noted.

### *Stimuli*

The ten stimuli were taken from a synthetic bilabial stop VOT continuum prepared by Lisker and Abramson at Haskins Laboratory. This was the same VOT continuum that served as a source of stimuli in the study by Eimas et al. (1971). All stimuli were presented at 80 dB SPL. The sound level was set to a level of 80 dB SPL as established by coupling the earphones through a 6cc coupler to a Bruel & Kjaer sound level meter. The following synthetic bilabial stop stimuli were used for both experiments: -100, -80, -60, -40,-20, 0, +20, +40, +60, and +80 ms VOT. In Experiment I, the control condition (which Eimas et al. 1971 called OTHER), in which infants listened to the same stimulus throughout the test session, consisted of the following stimuli: -20, 0, +20, +40, +60, and +80 ms VOT. In the two other conditions, the pre- and post-shift stimuli differed by 20 ms VOT. In the between-category condition (which Eimas et al. called DIFFERENT), infants were tested on +20/+40 ms VOT, order counterbalanced. These stimuli cross the adult boundary for bilablial stops. In the within-category condition (which Eimas et al. called SAME), infants were tested on the following pairs of stimuli: -20/0, 0/+20, +40/+60, and +60/+80 ms VOT (order counterbalanced). The first two stimulus pairs are members of the adult short lag category and the latter two belong to the adult long lag category. In Experiment II, control trials were run on 0, -20, -40, -60, -80, and -100 ms VOT. As no adult boundary had been established for speakers of American-English within the -100 to 0 ms VOT range, all conditions in which the pre- and post-shift stimuli differed by 20 ms VOT were called stimulus-change conditions. Stimulus-change trials were run on the following pairs: 0/-20, -20/-40, -40/-60, -60/-80, and -80/-100 ms VOT (order counterbalanced). The presentation of stimulus pairs was random across both experiments and all conditions. Each infant was randomly assigned to one of nine conditions (Experiment I: control condition, between-category condition, within-category condition; Experiment II: control condition, five stimulus-change conditions [0/-20; -20/-40; -40/-60; -60/-80; and -80/-100 ms VOT]).

### *Procedure*

This research used operant conditioning of high-amplitude sucks. Data were gathered in the following manner: Infants who could be brought to a quiet-awake state were tested between feedings. The infant was positioned comfortably in the researcher's lap. The non-nutritive nipple was placed in the infant's mouth and lightweight headphones were placed over the infant's ears. When the researcher judged that the infant was sucking with sufficient frequency and intensity, the computer program was activated. A suck was operationalized as a waveform consisting of an increase in pressure that produced a peak that was immediately followed by a complete release of pressure to a zero-pressure point. A one-minute baseline sucking rate was established for each infant. From the distribution of baseline sucks, a HAS criterion was established as any suck that was more intense (i.e. produced a greater pressure change) than 67% of an infant's baseline sucks. Once the one-minute baseline was established, the conditioning period began. The conditioning period consisted of the following: Those sucks that met the criterion for HAS (i.e. fell in the top third of the sucking distribution) were reinforced with a computer generated speech-sound. During the conditioning period, a pre-shift period was identified as the minute that preceded a 20% decrement in the frequency of HAS over two consecutive minutes. The rate of the HAS during this pre-shift minute was compared to the rate of HAS during the baseline minute. A higher rate of HAS during the reward contingent pre-shift minute provided evidence that the infant had been conditioned to produce a sucking response. From the 20% decrement in the average rate of HAS, it was inferred that the infant had habituated to or become satiated with the pre-shift stimulus. Once the decrement was observed, the infant entered the post-shift phase of the experiment. In all conditions except for the control condition, in which the pre- and post-shift stimuli were identical, a post-shift stimulus, which differed from the pre-shift stimulus by 20 msec VOT, was presented. The mean rate of HAS production for the first two minutes of the post-shift or recovery phase was then compared to the mean rate of HAS during the two decrement minutes.

In the control condition, in which there was no change in the stimulus, it was anticipated that the rate of HAS production would continue to decrease after the shift criteria had been met as the infant continued to habituate to the stimulus. In the conditions in which the pre- and post-shift stimuli differed by 20 ms VOT, divergent recovery effects were anticipated. A category-change was considered to have occurred when the post-shift stimulus produced a significant increase in the average rate of HAS. That is, a significant increase in the frequency of HAS was interpreted as a sign of renewed interest in a noticeably different stimulus. The stimulus pair that produced a significant recovery of HAS during the post-shift period identified the range on the VOT continuum within which there was a perceptual shift in speech-sound categories from a short lag /ba/ to a long lag /pa/ and vice versa. It is possibile that an additional set of results could be obtained for which there would be neither an increase or a decrease in the mean rate of HAS in response to the post-shift stimulus. This leveling off could result when a stimulus-pair fails to cross a category boundary but is still discriminable so that some level of interest in the new stimulus is maintained. The stimulus-pairs which, in response to the stimulus shift, produced neither a continued increase nor decrease in the average rate of HAS would define an adult speech-sound category, such as /ba/, /pa/, or long lead /ba/ as the members of this category are discriminated as non-identical but categorically equivalent speech-sounds. Within-category variants are those speech-sounds that are produced by contextual and individual articulatory differences, but which adult speakers label as the same speech-sound. It was not anticipated that any stimulus pair from the long lead/short lag part of the VOT continuum would produce a significant recovery of HAS in response to the post-shift stimuli. Rather, it was hypothesized that these stimulus pairs would be heard either as identical, in which case there would be continued habituation to the post-shift stimuli, or as within-category variants, in which case infants would show no evidence of dishabituation to the post-shift stimulus.

### *Pilot Study*

Although the HAS technique is commonly used with infants up to six months of age, it is much less common with infants under one month of age. Bertoncini et al. (1988) used the technique successfully with newborns whose average age was 4.2 days. However, as Wolff (1968) states that the non-nutritive sucking pattern, which consists of bursts of sucks alternating with pauses, does not mature until the third post-natal day, there was some concern that the HAS technique would not be suitable for one-to-two day old infants. Therefore, prior to the formal data collection, a pilot study was conducted to see if the HAS technique could be used to condition a sucking response with newborns. Useable data (a minimum of five sucks during baseline and maintenance of sucking throughout the test sessions) were obtained from 13 (22.4%) of the 58 infants whose parents signed consent forms. These infants had a mean EGA of 39.8 weeks; a mean birthweight of 3445.0 grams, and were a mean of 34.6 hours old at time of testing. Eleven of the 13 (84.6%) infants showed an increase in the rate of HAS from the baseline to the pre-shift period. Overall, the infants demonstrated a reliable conditioning effect: a dependent measures t-test showed that during the pre-shift period there was a significantly higher rate of HAS than during the baseline period ($t[12] = 2.24$, $p < .025$, one-tailed).

The overall attrition rate (77.6%; n=45) was considerably higher than the 43% attrition rate reported by Bertoncini et al. (1988) for somewhat older newborns. In the pilot study, data from 21 infants (46.7% of the attrition group) were excluded because they did not maintain sucking throughout the test session. Ten (47.6%) of these cases occurred during the baseline period. Bertoncini et al. (1988) reported that 4% of the attrition group with older newborns was due to cessation of sucking during the trial. As the high attrition rate with newborns may have been in part due to an immature non-nutritive sucking pattern, certain modifications were made to facilitate efficient data gathering. The computer program was modified so that the number of sucks produced by the infant appeared on the computer screen at the end of the baseline period. In the event that the number of sucks produced during the baseline period did not meet the minimum criterion of five sucks, the test could be restarted prior to the infant hearing a pre-shift stimulus. Additional modifications included discouraging parents from attending test sessions and asking the nursery staff to delay heelstick and other similar routine procedures as well as supplemental feedings until after the infant had been tested.

During both the pilot and the ensuing experiment proper, the infants' ears were sufficiently occluded by the headphones so that the experimenter could not hear the speech-sounds. Although the phase of the experimental session (i.e. baseline, pre-shift, or post-shift) was posted on the computer screen, the experimenter was positioned with her back to the computer screen. In addition, although the HAS criterion appeared on the computer screen at the conclusion of the baseline period and the infant's sucking pressure registered on the pressure transducer, the two measures were on different scales.

### *A Note about the Participants*

As it was difficult to find infants who met the selection criteria and whose mothers were willing to consent to their participation, when possible, the same infant was tested for both experiments. Data were gathered during the session for both experiments with priority given to completing Experiment I and then Experiment II. Infants were tested a maximum of four times, with the intention of getting one set of data from the infant for each experiment, while allowing for one set of unusable data for each experiment. The data were used if the infant produced a minimum of 5 peaks during baseline and maintained sucking through the pre- and post-shift periods. A total of 191 subjects was run in order to gather 61 data sets for both experiments combined. Multiple trials were run with 38 infants. Six of these infants produced useable data that were analyzed in both Experiments I and II because there was some overlap in the trials (see Table 1). The same data for four of the control trials (two for 0/0 ms VOT and two for -20/-20 ms VOT) were analyzed for both experiments. Data for two of the within-category trials in Experiment I (-20/0 and 0/-20 ms VOT) were also analyzed as stimulus-change trials in Experiment II. The percentile ranks of the recovery data for these six sets of data average 44.7% for Experiment I and 62.3% for Experiment II within the pertinent condition. In one case, an infant provided two sets of data (281/282) that were analyzed in Experiment II (see Table 2). As the rank of the second set of data from infants who provided more than one set of data could indicate order effects, the percentile rank of the recovery data within each condition for the second data set was computed. The average of these percentile ranks is 55.5%. Only one of the six subjects (Subject #303) produced data within the 4th quartile; the five remaining second sets of data were closer to the mean. As infants were not run more than one time on a systematic basis, data from subjects that were analyzed in both experiments due to the overlap in trials and data from subjects who produced two separate useable data sets were treated as if they were independent events.

# CHAPTER 4: Experiment I

## *Participants*

Ninety-seven infants were tested for Experiment I. Data could not be obtained from 71 infants or 73.2% of the sample group. Data from 33 (46.5%) of these infants could not be used because they did not respond to conditioning (e.g. the rate of HAS during the pre-shift period was the same as or less than the rate of HAS during the baseline period). The mean EGA of these 33 infants was 39.6 weeks (SD = 1.08), their mean weight was 3394 grams at birth (SD = 347.4), and the mean age at the time of testing was 33.9 (SD = 13.70). Twenty-four infants (33.8%) ceased to suck at some point during testing, so their data could not be included. The mean EGA of these infants was 39.4 weeks (SD = 1.33); their mean weight was 3351 grams (SD = 382.6) at birth; and they were a mean of 35.3 hours old at the time of testing (SD = 12.92). Data from an additional 14 infants (19.7%) were not used for miscellaneous reasons: bowel movement (3); computer error (2); crying (2); falling asleep (2); hiccoughs (1); noise in the testing room (1); and positive drug toxicology/possible medical complications (3). Of the three infants who were disqualified on a post hoc basis, in no case could the data have been analyzed; two infants did not show an effect of conditioning and one infant failed to maintain sucking throughout the test session. The final sample of 26 (26.8%) infants who rendered useable data were a mean EGA of 39.5 weeks (SD = .95), weighed a mean of 3274 grams at birth (SD = 387.9), and were tested at a mean age of 31.4 hours after birth (SD = 11.04) with a range of 16-54.75 hours. Thirteen infants were male and 13 were female, 19 had been delivered vaginally and seven were Caesarean births. As determined by maternal report, 16 infants were exclusively bottle-fed, nine were both breast- and bottle-fed, and one infant was breast-fed only. (See Tables 5 and 6.)

Comparisons of estimated gestational age, age at time of testing, birthweight, gender, type of birth, and mode of feeding were made between the infants from whom useable data were gathered and the attrition groups combined, excluding the 13 infants who were disqualified for miscellaneous reasons (see Tables 3 and 5). Independent samples t-tests found no significant differences in EGA, age at time of testing, or birthweight between the sample of infants from which useable data were gathered and the infants in the combined attrition group. Chi-Square tests also failed to find significant differences in gender or type of birth between the infants from whom useable data were gathered and the infants in the combined attrition groups (see Table 5). In order to evaluate differences in the mode of feeding, because the number of infants who were exclusively breast-fed was small (8.4%), for statistical purposes, "breast-fed only" was combined with "both breast- and bottle-fed". Again, the Chi-Square test failed to find a significant difference between the mode of feeding for infants who provided useable data and those who did not (see Table 5).

These same comparisons were made between infants from whom useable data were gathered and from those in each attrition group (see Tables 4 and 6). No significant differences in EGA, age at time of testing, or birthweight between those infants who provided useable data and those who failed to show an effect of conditioning or ceased sucking were found by Dunnett's t-tests for unequal samples sizes (Myers, 1966). Tests of Chi-Square on gender, type of birth, or mode of feeding failed to find significant differences between the infants from whom useable data were gathered and the infants who ceased to suck or did not show an effect of conditioning.

*Results*

The conditioning effect was analyzed for the 26 subjects who rendered useable data. The rate of HAS production during the one-minute baseline period was compared to the rate of HAS during the pre-shift period. As expected, given that data were eliminated if infants failed to increase the number of HAS during the reward-contingent pre-shift minute relative to the baseline period, a dependent-measures t-test indicated that these infants, who produced a mean of 4.54 HAS during the baseline minute and 11.00 HAS during the pre-shift minute (see Table 7), demonstrated a significant increase in HAS during the pre-shift period ($t[25] = 6.66$, $p<.005$, one-tailed).

In order to analyze the recovery rate for each condition, the rate of HAS during the two-minute decrement period was compared to the rate of HAS during first two minutes of the post-shift period starting from the first HAS produced after the stimulus-change.[3] Dependent- measures t-tests were performed on the differences for the control, between-, and within-category conditions (see Table 8). In the control condition, as anticipated, there was a continued decrement in the rate of HAS production during post-

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[3] This is another way in which this research differs from Eimas et al., 1971, who analyzed the rate of HAS during the first two minutes of the post-shift period. The reason for starting the post-shift interval with the first suck during this period is that a decrement in sucking would be expected to endure into the post-shift period until the availability of a new stimulus was indicated following the initial post-shift HAS.

shift, (t[9] = 3.57, p<.005, one-tailed). These ten infants produced a mean of 7.05 HAS per minute during the decrement period and a mean rate of 3.60 HAS per post-shift minute (see Table 7). For the eight infants in the between-category condition (+20/+40 ms VOT), there was a significant increase in the rate of HAS production during post-shift (t[7] = 2.42, p <.025, one-tailed) from a mean of 5.06 HAS per decrement minute to a mean of 13.12 HAS per minute during the post-shift period (see Table 7)[4]. This finding provides evidence that the infants discriminated the difference between the adult /ba/ and /pa/ categories. In the within-category condition, in which it was hypothesized that there would be no change in the rate of HAS in response to the post-shift stimulus, the difference between the rate of HAS during the decrement and post-shift periods (mean rate of 7.50 and 7.93 per decrement and post-shift minute, respectively [see Table 7]) was non-significant (t[7] = .14, p >.05, two-tailed) for this sample of eight infants.

In order to analyze the difference in the recovery rates between the control, between-, and within-category conditions, a one-factor ANOVA was performed on the recovery rates between these three conditions. The ANOVA indicated that there were significant differences between the recovery rates in these conditions (F[2, 23] = 7.74, p<.01). In the control condition, there was a mean decrease of 6.9 in the rate of HAS from the two decrement minutes to the post-shift period. The within- and between-

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[4] The data for two subjects in the between-category condition were gathered from a second run. To eliminate any possibility that carryover effects influenced the findings, an additional dependent measures t-test was run on the recovery rate for this condition with the data from these two subjects collapsed, thereby reducing the "n" to seven. This t-test also demonstrated a signficant effect of recovery (t[6] = 2.15, p < .05, one-tailed).

category conditions had mean increases of .9 and 16.1, respectively, in the rate of HAS from the two decrement minutes to the post-shift period (see Table 8). As it was hypothesized that there would be significant differences between the recovery rates in the control and between-category conditions, and the between- and within-category conditions, but not between the control and within-category conditions, a Kramer-Tukey post-hoc test for unequal sample sizes was carried out (Kirk, 1995) (see Table 9). The difference between the recovery rates in the between-category and control conditions was highly significant ($p<.01$), which demonstrated a significantly greater increase in recovery for the between-category condition compared to the control condition. There was an absolute difference 23.02 HAS between the between-category and the control conditions during the post-shift period. The Kramer-Tukey test also showed that the difference between the recovery rates in the between- and within-category conditions was significant ($p<.05$), which is evidence of a greater rate of recovery in the between-category condition. The absolute difference in the rate of HAS during the post-shift period for the between- and the within-category conditions was 15.25 HAS, which is less than the absolute difference between the between-category and control conditions (23.02 HAS). Lastly, the Kramer-Tukey test failed to show that the difference in the recovery between the control and within-category conditions was significant. Although there was a significant decrement in the frequency of HAS in the post-shift period in the control condition, there was a negligible increase in HAS production during the post-shift period in the within-category condition.

### *Discussion*

The results of Experiment I indicate that one-to-two day-old neonates not only discriminate speech-sounds that are native to their linguistic environment, but may do so in a categorical manner. The fact that the infants demonstrated a significant recovery from habituation in the between-category condition but not in either the control or the within-category condition provides evidence that they discriminated the between-category post-shift stimuli as though they belonged to different speech-sound categories. Moreover, the range of values on the VOT continuum across which the infants discriminated the short lag/long lag voicing boundary includes the VOT boundary across which adult listeners perceive the /b/-/p/ distinction (Liberman et al., 1961). Performance in the control condition, namely a continued decrement in HAS during the post-shift period failed to provide evidence that the neonates discriminated a difference between the pre- and post-shift stimuli in this condition. Rather, it is suggested that the neonates continued to habituate to a familiar speech-sound. In the within-category condition, the non-significant recovery (mean increase = .9) suggests that the infants did not discriminate the members of these stimulus pairs.

Relative to performance during the post-shift period in the between-category condition, there was no evidence of recovery to the post-shift stimulus or discrimination of a categorical difference between the pre-and post-shift stimuli in the within-category condition. The infants' performance in the within-category condition may be comparable to data from adult listeners who label these stimuli as the same phoneme but would discriminate the two as non-identical speech-sounds (Liberman et al., 1961). With adults, the probability that within-category stimuli will be discriminated increases as the VOT between the stimuli increases. As the adult data were not reported as per VOT distance between the stimuli, it is not possible to make a direct comparison between adult and infant responses to within-category stimuli that differ by 20 msec VOT.

The results of Experiment I are in accordance with those of Eimas et al. (1971). Overall, there is evidence that the neonates tested in Experiment I and the infants tested by Eimas et al. (1971) categorically discriminated the short lag/long lag voicing boundary. There are, however, some differences between the recovery data of the present study and those reported by Eimas et al. (1971). In the Eimas et al. study, the recovery data in the control condition failed to show a significant decrement in the rate of HAS during the post-shift period over the first two minutes, but did show evidence of continued habituation when the post-shift period was extended to four minutes. The data gathered from the newborns in this study demonstrated a significant decrement in HAS production during the first two minutes of the post-shift period. One possible explanation for the difference between the newborns and the older infants is that Eimas et al. (1971) started the post-shift period immediately after the decrement criterion was reached, but possibly before the post-shift or comparison stimulus was elicited by a HAS. With the newborns, the post-shift period started with the first HAS after the criterion for stimulus-shift was achieved and the comparison stimulus had been presented. Alternatively, the discrepancy in the results of the control conditions between the newborns and the older infants may be due to a variety of factors: it could be sample-specific, because of the way in which HAS was operationalized in this research as a suck that peaked and then fell to a zero-pressure point, and/or may be attributed to the exact measurement of HAS afforded by technological advances used in the current studies.

There is one additional methodological difference of note. The within-category condition run by Eimas et al. (1971) consisted of testing one- and four-month old infants on only two stimulus pairs (-20/0 and +60/+80 ms VOT). The newborns in this research were tested on five pairs (-20/0, 0/+20, +40/+60, +60/+80, and +80/+100 msec VOT). Both Eimas et al. (1971) and this research found that there was no evidence of a systematic change in the rate of HAS during the post-shift period in the within-category condition. As both studies showed evidence of similarity in the response patterns in the recovery data for the between-category vs. the control conditions and the between-category vs. the within-category conditions, although a more complete range of stimulus-pairs was used in this research, there is no evidence that this change made a difference.

Over and above the methodological differences between the research with newborns and the older infants, these data provide evidence that newborns categorically discriminate between adult native speech-sound categories. It is unlikely that this manner of speech-sound discrimination could have been learned within the first 31 hours after birth during which time these infants had some exposure to their native language. These results are not inconsistent with the view that the neonates' ability to discriminate speech-sound categories at some point on the VOT continuum that is near adults' location of this boundary is attributable to pre-natal exposure to and learning of native speech-sounds. As these findings are also consistent with the view that experience with speech is irrelevant to the infants' ability to make these distinctions between speech-sounds, stronger evidence concerning the possible role of pre-natal exposure in establishing the neonates' ability to recognize speech-sound boundaries would be provided by examining neonates' responses to non-native speech-sounds.

# CHAPTER 5: Experiment II

Experiment II was carried out to investigate whether neonates would demonstrate discrimination, possibly of a categorical nature, of speech-sound contrasts to which there had been no pre-natal exposure. The speech-sound contrasts (0 to -100 ms VOT) used in Experiment II included those that have long voicing lead. While these speech-sounds are distributed between two phonemic categories in languages such as Eastern Armenian, Spanish, and Thai, in American-English production falls off at 0 ms VOT and occurs very rarely at VOT values of more than 20 ms of voicing lead in initial position (Lisker et al., 1964). In other words, infants of American-English speaking parentage would not have had pre-natal exposure to speech-sounds on the long lead part of the VOT continuum. Whereas evidence of categorical discrimination of these non-native speech-sound contrasts would suggest an innate basis for this type of recognition, the inability to detect differences along this part of the VOT continuum would suggest that lack of pre-natal exposure to these speech-sounds may account for the inability to recognize these speech-sound differences.

## *Participants*

Data were gathered from 96 infants. Of the 54 infants (56.2%) from whom useable data were not obtained, 26 (50.0%) failed to show an effect of conditioning. The mean EGA for this group was 39.2 weeks (SD = 1.47), the mean birthweight was 3121 grams (SD = 356.6), and the infants' mean age was 30.4 hours at the time of testing (SD = 12.58). Sixteen infants (30.8%) did not maintain sucking through the test session. The mean EGA was 39.8 weeks (SD = 1.45), the mean birthweight was 3152 grams (SD = 456.0), and the infants' mean age was 38.7 hours at the time of testing (SD = 14.20). In addition, data from 12 infants (23.1%) were excluded for miscellaneous reasons: computer error (4); crying (2); falling asleep (1); hiccoughs (2); possible medical complications (2); and spitting-up (1). As in Experiment I, data from the two infants who were disqualified on a post hoc basis because of possible medical complications were not useable: one infant did not show an effect of conditioning and the other failed to maintain sucking throughout the test session. The characteristics of the 42 infants (44.7%) who rendered useable data are as follows: the mean EGA was 40.3 weeks (SD = 1.13); the mean birthweight was 3352 grams (SD = 397.5); the mean age at the time of testing was 35.8 hours (SD = 13.10) with a range of 15-56 hours (see Table 11). Seventeen infants were female, 25 were male; 28 were delivered vaginally, 14 were delivered by Caesarian section; 35 infants were exclusively bottle-fed, and seven were breast-and-bottle fed (see Table 13).

Independent samples t-tests were carried out on EGA, age at time of testing, and birthweight for the sample of infants from whom useable data were gathered and the combined attrition group of infants who ceased sucking and did not respond to conditioning. As in Experiment I, data from the 12 infants who were excluded for miscellaneous reasons were not included in this analysis. The only significant difference that emerged between these groups was for EGA ($t[80] = 2.15$, $p<.05$, two-tailed). The mean EGA of infants in the useable data sample (mean = 40.3 weeks; SD = 1.13) was higher than the mean EGA for infants in the combined attrition group (mean = 39.4

weeks; SD = 1.46), which provides evidence that infants who are born closer to term are more likely to render useable data (see Table 10).

Chi-Square tests were used to look at differences in the gender, type of birth, and mode of feeding for infants from whom useable data were gathered and those in the combined attrition group. The significant difference for type of birth ($\chi^2$ [1] = 12.45, $p <$ .005) indicated that although useable data were gathered from a sample of which 66.7% were vaginal births and 33.3% Caesarian sections, vaginal birth infants (83.3%) were also more likely to render unusable data. For mode of feeding, as only 7.1% of the infants in the samples combined were exclusively breast-fed, this category was combined with "breast-and-bottle-fed" for statistical purposes. There was a significant difference in mode of feeding between the useable data sample and the sample of infants who ceased sucking ($\chi^2$ [1] = 14.60, $p < .005$). The higher percentage of bottle-fed infants in the useable data sample (83.3%; 16.7% breast- and bottle-fed; unusable data group: 69.1% bottle-fed; 30.9% breast- and bottle-fed) suggests that bottle-feeding may facilitate success with the HAS procedure (see Table 12).

Dunnett's t-tests for unequal sample sizes were used to compare differences in EGA, birthweight, and age at time of testing for infants from whom useable data were obtained and the two groups of infants who did not show an effect of conditioning or who ceased to suck during testing (see Table 11). The only comparison that achieved statistical significance was that for EGA between the infants from whom useable data were gathered and the infants who failed to show an effect of conditioning ($t_D$ [3, 84]= 2.37, $p < .025$, two-tailed). The mean EGA for the infants who did not show an effect of conditioning (39.2 weeks; SD = 1.47) was significantly less than the mean EGA for the infants who provided useable data (40.3 weeks; SD = 1.13), which may indicate that gestational age is a factor in conditioning infants' HAS. As in Experiment I, Chi-Square tests were used to assess differences between the samples in gender, type of birth, and feeding (see Table 13). There were no significant differences between the proportion of male and female babies in the data-providing group and in the other two groups. For type of birth, however, there was a significant difference between the proportion of vaginal and Caesarian births in the data-providing group vs. the group of infants that ceased to suck ($\chi^2$ [1] = 7.29, $p < .01$). Although useable data sample had a higher incidence of vaginal births (66.7%; 33.3% Caesarian births), vaginal birth infants were more likely to cease sucking (87.5%) than infants delivered by Caesarian section (12.5%). There was also a significant difference in feeding between the sample that produced useable data (83.3% bottle-fed only; 16.7% breast-and-bottle fed) and the sample that ceased to suck (62.5% bottle-fed only; 37.5% breast-and-bottle fed). This highly significant difference ($\chi^2$ [1] = 11.67, $p < .005$) suggests infants who have had some experience breast-feeding are more likely to cease sucking during the course of the experiment.

In order to look at possible differences among these characteristics for the entire sample, data on EGA, infant's age at time of testing, birthweight, gender, type of birth, and mode of feeding were collapsed across the useable and unusable data samples for Experiments I and II. An independent samples t-test indicated that there was a significant difference in EGA between the useable and unusable data samples (t[165] = 2.07, $p<.05$, two-tailed). (See Table 14.) The mean age for the sample from which useable data were gathered (mean = 40.0 weeks; SD = 1.14) was significantly higher than the EGA for the combined attrition group (mean = 39.4, SD = 1.34). In addition, a Chi-Square test showed that infants who had been bottle-fed were more likely to render useable data ($\chi^2$ [1] = 5.79, $p < .025$). Bottle-fed infants accounted for 75.0% of the useable data sample and 64.6% of the unusable data sample. The incidence of breast- and bottle-feeding was 25.0% for the useable data sample and 35.4% for the sample that did not render useable data (see Table 16).

### *Comparison of Participants:Experiments I and II*

In order to look at possible differences between the samples of infants that participated in Experiments I and II, the sample categories (useable data, did not condition, and ceased sucking) were combined. Dunnett's t-test showed that there were no significant differences in EGA, infants' age at time of testing, or birthweight between the infants from which useable data were gathered and the infants who did not condition or ceased sucking when these samples were collapsed across Experiments I and II (see Table 15). Chi-Square tests showed that there were no significant differences between the samples for subjects' gender or type of birth. The one significant difference that did emerge was in mode of feeding between the sample which provided useable data and the sample that ceased to suck ($\chi^2$ [1] = 8.57, $p < .005$). Of those infants from whom useable data were gathered, 75.0% were exclusively bottle-fed and 25.0% were breast-and-bottle fed. In the ceased-sucking group, 60.0% were bottle-fed only and 40.0% were breast-and-bottle fed. This finding would seem to strengthen the suggestion that those infants who have had greater experience with a bottle nipple are more likely to maintain sucking throughout the test session and to show the effect of conditioning (see Table 17).

### *Results*

As anticipated, given the mode of data elimination, a dependent measures t-test demonstrated that the effect of conditioning was significant for the 42 subjects who rendered useable data (t[41] = 5.38, p <.005, one-tailed). These subjects produced a mean of 5.07 HAS during the baseline minute and 12.19 HAS during the pre-shift minute (see Table 18). In order to look at recovery in the control (n = 10) and five stimulus-change conditions run in this experiment (0/-20 [n = 4]; -20/-40 [n = 8]; -40/-60 [n = 8]; -60/-80 [n = 8]; and -80/-100 [n = 4] msec VOT), as in Experiment I, dependent-measures t-tests were run to compare the difference in the mean rate of HAS between the decrement and post-shift periods. The ten infants in the control condition produced a mean of 9.70 HAS per minute during the decrement period and a mean of 4.05 HAS per minute during the post-shift period (see Table 18). The t-test indicated that this was a significant decrement in HAS production from the decrement to the post-shift period (t[9] = 2.30, p <.05, one-tailed). Although performance in all the stimulus-change conditions showed a decrement in the rate of HAS during the post-shift period, dependent measures t-tests showed that in no condition was the effect significant (0/-20: t[3] = 1.89; -20/-40: t[7] = 1.56; -40/-60: t[7] = 1.53; -60/-80: t[7] = .56; -80/-100: t[3] = 1.69). All tests on the stimulus-change conditions were run two-tailed (see Table 20). Mean rate of HAS production for decrement and post-shift periods per minute are as follows: 0/-20 = 10.25/4.25; -20/-40 = 5.69/3.56; -40/-60 = 13.25/7.44; -60/-80 = 5.31/4.62; -80/-100 = 3.75/1.50 (see Table 19).

As no significant difference in the rate of HAS between the two decrement minutes and the post-shift period emerged in any of the stimulus-change conditions, given that the sample sizes were small, the data were collapsed across the stimulus-change conditions and a dependent-measures t-test was carried out to see whether there was a significant change in the rate of HAS between the decrement and post-shift periods. The infants produced a mean of 7.81 HAS per minute during the decrement period and 4.62 HAS per minute during the post-shift period (see Table 18). A t-test of this indicated that the infants to produce fewer HAS after the stimulus shift (t [31] = 2.78, $p < .01$, two-tailed).

Although it was not anticipated that a speech-sound boundary would be discriminated in any of the stimulus-change conditions, had this occurred, there might have been a significant recovery from habituation in at least one of the stimulus-change conditions as occurred in the between-category condition of Experiment I. A one-factor ANOVA was carried out to look at differences in recovery between the stimulus-change conditions. The ANOVA failed to demonstrate a signficant difference in recovery between the stimulus-change conditions (F [4,27] = .88, $p > .05$). The mean difference in recovery of HAS between the decrement and post-shift periods are as follows: 0/20 = -12.0; -20/-40 = -4.2; -40/-60 = -11.6; -60/-80 = -1.4; and -80/-100 = -4.5 (see Table 20).

The t-tests that were performed on the recovery in the control and each of the stimulus-change conditions failed to show a significant change in the rate of HAS between the decrement and post-shift periods. In order to investigate possible differences between the stimulus-change conditions as a whole and the control condition, the data were collapsed across all of the stimulus-change conditions and an independent samples t-test was run to compare differences in the recovery rates between the control condition (mean recovery = -11.3 HAS) and the combined stimulus change conditions (mean recovery = -6.4 HAS). The t-test indicated that there was no significant difference in the recovery rates between these conditions (t [40] = 1.00, p > .05, two-tailed).

### *Comparison of Results: Experiments I and II*

The stimulus-pairs used in Experiment II consisted of pre- and post-shift stimuli that differed by 20 msec VOT (0/-20, -20/-40, -40/-60, -60/-80, -80/-100). It was not anticipated there would be a significant recovery from habituation for any of these stimulus-pairs; recovery rates for each condition failed to demonstrate a significant effect. In addition, the data failed to show evidence of a significant difference between recovery in the control and collapsed stimulus-change conditions. An independent-measures t-test between the recovery rates of the between-category condition in Experiment I and the collapsed stimulus-change condition in Experiment II, however, revealed a significant difference (t [38] = 4.00, p < .001, two-tailed); the mean difference in recovery rate in the between-category condition of Experiment I and the collapsed stimulus-change conditions of Experiment II were 16.1 HAS and -6.4 HAS, respectively.

Furthermore, the infants in both the within-category condition in Experiment I and the stimulus-change conditions in Experiment II failed to demonstrate a significant change in HAS production between the two decrement minutes and the post-shift period; an independent-measures t-test showed that the difference in recovery between the within-category condition of Experiment I (mean recovery = .9 HAS) and the collapsed stimulus-change condition of Experiment II (mean recovery = -6.4 HAS) was not significant (t [38] = 1.48, p >.05, two-tailed).

The speech-sound stimuli used in Experiment I were presumably familiar to the infants and those in Experiment II were less so. Therefore, in order to address possible differences in the time to habituate to these two groups of speech-sounds, an independent samples t-test was carried out between the duration of the pre-shift periods collapsed across the three conditions in Experiments I and the six conditions in Experiment II. The mean duration of the pre-shift period in Experiment I was 272.83 seconds (4.55 minutes; SD = 48.77 seconds). In Experiment II, the mean duration was 277.79 seconds (4.63 minutes; SD = 61.61 seconds). The t-test on this difference was non-significant (t[66] = 0.00, p > .05, two-tailed).

### *Discussion*

Experiment II was undertaken to determine if newborns discriminate speech-sound stimuli that are non-native to their linguistic environment. Had the newborns discriminated these stimuli, a significant recovery from habituation might have been observed during the post-shift period in at least one of the stimulus-change conditions (0/-20, -20/-40, -40/-60, -60/-80, or -80/-100 ms VOT) similar to the significant increase in HAS during the post-shift period observed in the between-category condition (+20/+40 ms VOT) in Experiment I. No effect of this nature was observed; each of the stimulus-change conditions in Experiment II failed to elicit a significant recovery from habituation. This finding fails to provide evidence that the pre- and post-shift stimuli in the stimulus-change conditions were discriminated as different. Moreover, when the data were collapsed across all the stimulus-change conditions, the rate of HAS showed a continued decrement during the post-shift period, as was observed in the control condition. The continued decrement in the rate of HAS during the post-shift period of the control condition makes it seem likely that the infants treated the pre- and post-shift stimuli as equivalent and therefore continued to habituate to the familiar sound. Additionally, a comparison of the recovery rates between the control and the collapsed stimulus-change conditions failed to reveal a significant difference. These results fail to provide evidence that discrimination of the pre- and post-shift stimuli in the collapsed stimulus-change conditions differed from discrimination of the speech-sounds used in the control condition.

As the newborns were essentially naive listeners and failed to provide evidence of discrimination of any of the non-native speech-sound pairs, and as the results from Experiment I provide evidence of discrimination of a native speech-sound to which there could have been pre-natal exposure, it is possible that experience with speech-sounds is required for infants to discriminate differences between them.

Although there was some post-natal exposure to speech-sounds, the nature of the post-natal exposure was to many languages. Through intermittent conversation among the multi-lingual staff in the Newborn Nursery at Jamaica Hospital, these infants were also exposed to a variety of languages of which those spoken in Haiti, Jamaica, and the Phillipine Islands were most common. Whereas American-English was presumably spoken by the infants' mothers and her visitors, infants spent a total of six hours per day in the mother's hospital room. In light of the fact that the eldest infant was 55 hours at the time of testing, if conversation was constant during the six daily feeding sessions, there was a maximum of nine hours of exposure to speech in the mother's room. While it is possible that the infants' post-natal exposure to speech engendered learning these speech-sounds, data on English-speaking adults' discrimination of non-native Hindi speech-sounds show that even when adult subjects were actively trained to make the discriminations, the effect on performance varied. While there was no effect on a place of articulation contrast performance improved somewhat for a 190 ms VOT difference (Werker et al. 1981). These stimuli had much greater voicing lag and lead values (+131.3 for the voiceless aspirated dental stop [tʰ] and -121.5 for the breathy voiced dental stop [dʱ], respectively) than any of the speech-sounds used in the current study as well as a greater VOT difference between them. It is therefore unlikely that the limited post-natal exposure of the infants, which did not entail active training, could account for their ability to discriminate native speech-sounds. Rather, it is likely that pre-natal exposure may underlie the ability to discriminate speech-sounds. It is further suggested that only when speech-sounds are phonologically distinct in the native environment, as was the case in Experiment I but not in Experiment II, can newborns show evidence of discrimination.

# CHAPTER 6: General Discussion

Experiments I and II were carried out to investigate if newborns would discriminate native and non-native speech-sounds on the VOT continuum and to determine the manner in which they make these discriminations. Experiment I used short lag/long lag stops that were native to the infants' linguistic environment and could have been learned through prenatal exposure. Experiment II used long lead/short lag stops. As the stops with negative VOT are rarely produced by speakers of American-English, the infants had little, if any, exposure to most of the speech-sounds in Experiment II.

In Experiment I, the newborns demonstrated a significant increase in the rate of HAS during the post-shift period for the +20/+40 ms VOT stimuli, which provides evidence that they discriminated these speech-sounds. This +20/+40 ms region includes the value on the VOT continuum at which adults locate the /ba/-/pa/ boundary and at which discrimination scores are high for stimuli drawn from opposite sides of the boundary (Liberman et al., 1961[5]; Lisker et al, 1964). Infants' performance in the within-category condition, in which the stimuli varied by a comparable 20 ms VOT but did not cross the adult category boundary, failed to demonstrate a significant change in the rate of HAS between the decrement and post-shift periods and, therefore, fails to provide evidence that these speech-sounds were discriminated. The recovery rate in the between-category condition was found to be reliably greater than that in the within-category condition, whereas no such difference between the recovery rates in the within-category

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[5] Although the principle for discrimination of a category boundary remains the same, the results obtained by Liberman et al. were based on discrimination of the apical stops /d/ and /t/, which differ by place of articulation.

and the control conditions was found.

The newborns' discrimination of the +20/+40 ms VOT stimulus-pair that signals the /ba/-/pa/ adult category boundary may correspond to the peak in discrimination that adults display for this range of VOT values. The evidence, however, is inconclusive as to how well the manner in which these newborns as well as the older infants tested by Eimas et al. (1971) discriminated the range of speech-sounds actually approximates the adult mode of categorical perception. Although the results of Experiment I are in agreement with those of Eimas et al., and both are consistent with Jusczyk's (1987) use of the term categorical discrimination, it is questionable whether data gathered in this manner from the newborns or the older infants can provide evidence that within-category discrimination differs from non-discrimination of these speech-sounds.

While the data from both Experiment I and Eimas et al. (1971) provide evidence that recovery in the between-category condition increased significantly when compared to the continued decrement in the control condition, and that recovery in the between-category condition differed significantly compared to the within-category condition, the non-significant difference between the recovery rates in the within-category and the control conditions fails to provide evidence that speech-sounds drawn from the same adult category are discriminated any differently from the speech-sounds in the control condition.

The within-category discrimination data for adults were derived as one-, two-, and three-step functions, with discrimination increasing with the distance between the stimuli. Whereas the correlation between the discriminations predicted by labelling and the obtained discriminations were significant for the two- and three-step functions, for the one-step function, the correlation was not significant (Liberman et al., 1961). Furthermore, because no control condition was run with the adults, it is not known whether the one-step function would differ from a hypothesized control function. Discrimination, however, increases with step-size, so that it is probable that discrimination for the two- and three-step sizes would be superior to a control function. As neither labelling nor step-wise discrimination functions were gathered from infants, the infant data cannot be analyzed in a manner that is directly comparable to the adult data.

The data from the newborns and the older infants provide evidence that speech-sounds were discriminated at the region on the VOT continuum which coincides with adult category boundary. In addition, a poorer level of within-category discrimination relative to the between-category that Eimas reported (Eimas 1975b, Eimas et al., 1971) emerges for the older infants and the newborns tested in the current study. The data, however, fail to provide evidence that within-category discrimination differs from the non-discrimination of these speech-sounds that was obtained in the control condition. Whereas it is not possible to compare the difference between stimuli presented by Liberman et al. (1961) to adult subjects with the difference between the stimuli presented to the infants, it is not known whether the infant data would be consistent with the adult function.

In Experiment II, in none of the stimulus-change conditions was there a significant recovery from habituation, which fails to provide evidence that these speech-sounds were discriminated. Furthermore, the continued habituation in the collapsed stimulus-change condition of Experiment II suggests that there was no detection of the stimulus-change. Moreover, the significant difference between the recovery rates in the collapsed stimulus-change condition of Experiment II and the between-category condition of Experiment I provides evidence that discrimination of a stimulus-pair that crosses the adult /ba/-/pa/ category boundary was reliably greater than recovery to the stimulus-pairs which do not cross an American-English category boundary. The difference between these recovery rates suggests that the differences between speech-sounds in Experiment II were not discriminated.

In Experiment I, from the significantly greater recovery in the between-category condition relative to the control condition, it was possible to infer that a difference between the speech-sounds had been discriminated. The analysis of Experiment II, however, renders an absence of evidence of discrimination of those speech-sound stimuli and raises questions about possible differences between the speech-sound stimuli used in both experiments.

A known factor that distinguishes the speech-sound stimuli used in Experiment I from those used in Experiment II is availability in the linguistic environment. The short lag/long lag speech-sounds used in Experiment I are native to American-English and could have been heard by the infants in this study during their pre-natal period. Those stimuli with voicing lead used in Experiment II, however, are not commonly produced by speakers of American-English and would not have been part of the pre-natal environment. The results of Experiment I provide evidence of newborns' discrimination of speech-sounds to which there was exposure during the pre-natal period. The results of Experiment II fail to provide evidence of discrimination of speech-sounds that were not part of the pre-natal environment. It is, therefore, possible that pre-natal exposure could underlie the newborns' ability to discriminate these speech-sounds. These results support the hypothesis that discrimination of speech-sounds is not innate, but rather that it is based on exposure and learning.

Over and above the pre-natal availability factor, the effects of possible masking *in utero* of the low frequency range in which the voicing lead portion of the speech-sound is contained must be considered. If the VOT cue for long lead stops was not available pre-natally, it is reasonable to assume that speech-sounds with long voicing lead would be more novel to the newborns than those that were available pre-natally and that the unfamiliar speech-sounds would require a longer time for the newborn to reach the habituation criterion. A comparison of the duration of the pre-shift periods in Experiments I and II failed to provide evidence of any such difference. As there was evidence of discrimination of stimuli that are differentiated by short and long voicing lag, which is also in the low frequency region, it is improbable that the failure to discriminate the long lead stops was due to masking. Rather, it is possible that the discrimination of native and non-discrimination of non-native stops was due to pre-natal availability. For short lag bilabial stops, speakers of American-English show a peak in production at 0 ms VOT, which accounts for approximately 75% of production. The remaining 25% of production occurs between -80 and -130 ms VOT. In Thai, in which the long voicing lead category is phonemic, production peaks between -100 to -110 ms VOT. Similarly in

Spanish, production of bilabial stops with long voicing lead begins at -60 ms VOT, with the majority of these stop consonants produced with a greater amount of voicing lead (Lisker & Abramson, 1970). Whereas in languages that recognize a voicing lead category production of stops with long voicing lead is frequent, stops with long voicing lead are not commonly produced by speakers of American-English. It is, therefore, possible that the infrequent exposure to these stops with long voicing lead was not sufficient enough to enable the newborns to become familiar with them and to discriminate them from stops with short voicing lag.

An additional possibility to consider is that neonates would categorically discriminate non-native speech-sounds if members of a stimulus-pair differed by more than the 20 msec difference used in this study. Although Eimas (1975b) found some evidence that two-to-three month old infants could discriminate a lead boundary for apical stops when the VOTs differed by 60 and 80 ms VOT, in neither case were the results conclusive. With a 60 ms VOT difference between the speech-sound stimuli, Eimas reported a tendency toward greater recovery for the stimulus-pair (-100/-40 ms VOT) that crossed the hypothesized -20 ms VOT boundary than for the within-category stimulus-pair (-40/-20 ms VOT), but no significant difference between the recovery rates for the these two conditions. More specific measures were not reported. In a second attempt to locate a lead boundary at -50 ms VOT, speech-sound stimuli that differed by 80 ms VOT were used. Although recovery to the stimulus-pair that crossed the -50 ms VOT boundary increased significantly, and performance in the condition drawn from within a category (-70/-150 ms VOT) failed to elicit a significant recovery, the difference between the recovery rates in the two conditions was not significant.

The data on non-native speech-sound discrimination, in which the speech-sound stimuli differed by 20 to 80 ms VOT, fail to provide evidence of different levels of discrimination between the between- and within-category conditions, as in Eimas' research, or between the stimulus-change and the control condition, as in the present study. Eimas' omission of a control condition in both of these studies leaves open the question of how control subjects would have performed as well as whether performance in the within-category conditions would have differed from that of the control condition. As different levels of discrimination between the control and within-category conditions have been established for categorical perception (Liberman et al., 1961), any research that claims to show evidence that pre-articulate subjects approximate the adults' mode of speech-sound discrimination needs to demonstrate significant differences between performance in the within-category and control conditions in order to justify the claim.

The data that suggest infants categorically discriminate (Eimas et al., 1971 - bilabial stops; Eimas, 1975b - apical stops) or discriminate speech-sounds (the present study - bilabial stops) were gathered using synthetic speech-sound stimuli that approximate native VOT values. As Eimas (1975b) reported similar recovery data for the between- and within-category conditions of the native bilabial and apical stops, whose stimuli differed by 20 and 50 ms VOT, respectively, and a comparison of preliminary data gathered for the Eimas et al. (1971) study showed that recovery magnitudes for speech-sound stimuli that differed by 20, 60, and 100 ms VOT were similar for between-category stimulus-pairs, it is doubtful that the absolute difference in VOT between the pre-and post-shift stimuli accounts for the type or magnitude of recovery.

While some of the data on non-native speech-sounds may suggest discrimination, these studies fail to provide clear-cut evidence of categorical discrimination, irrespective of the VOT distance between the stimuli. In addition, Jusczyk et al. (1980) found evidence of discrimination of a non-speech -40/-70 ms TOT lead boundary and a +40/+70 ms TOT lag boundary by ten-week-old infants. Whereas the recovery from habituation for these two groups of stimuli differed significantly from the control condition, there is no evidence of a within-category level of discrimination in which the magnitude of recovery would differ significantly from both that of the control condition and from that of the stimuli-pair that crosses a boundary. In other words, these data fail to provide evidence that non-speech sounds are discriminated categorically.

The ability to discriminate native speech-sounds that differ by 20 ms VOT seems to be in place very soon after birth, with very little post-natal exposure to these speech-sounds. Research that has used the same as well as larger VOT differences with native speech-sounds has rendered similar evidence for discrimination in one-to-four month old infants (Eimas et al, 1971, Eimas, 1975b). Research on the discrimination of both non-native and non-speech sounds has failed to provide conclusive evidence of categorical discrimination for infants ranging from one-to-two post-natal days, as in the current study, or up to four months of age using differences of up to 80 ms VOT between the stimuli (Eimas et al, 1971; Eimas, 1975b; and Jusczyk et al., 1980). It would seem that the ability to discriminate speech-sound stimuli in early infancy is not dependent upon the distance between the stimuli, but rather, it is based on exposure to these speech-sounds, which in this case would be pre-natal. As it can be assumed that there was little or no pre-natal exposure to the non-native speech-sounds used in this study or in that of Eimas (1975b), and the data that purport to offer evidence of categorical discrimination of non-native speech sounds that differ by up to 80 ms VOT are considerably weaker than those on native speech-sounds, it would be doubtful that newborns would categorically discriminate non-native speech-sounds even if the difference between the stimuli were quite large.

The finding that newborns failed to show evidence of discrimination of the non-native VOT-cued speech-sound categories used in this study obviously does not contradict the findings that older infants discriminate non-native speech-sounds (Best, McRoberts, & Sithole, 1988; Lasky et al., 1975; Polka et al. 1994; Streeter, 1976; Werker, 1989; Werker et al., 1988; 1981). The infants in these studies ranged from four to twelve months at the time at which they showed evidence of discrimination of non-native speech-sound boundaries while the newborns tested in the current study failed to show evidence of discriminating non-native stop consonants. Although caution is necessary when generalizing from one set of data on non-native stop consonants to a broader range of non-native speech-sounds, it is possible that the ability to make non-native discriminations may develop due to post-natal exposure to other languages or to other forms of auditory stimulation as well as to stimulus generalization from sounds to which they are exposed. This ability may then dissipate toward the end of the first year due to a perceptual reorganization as the infant's attention turns to language learning (Jusczyk, 1993; Werker & Tees, 1984).

It would seem that native speech-sounds are unique relative to non-speech and non-native speech-sounds. There is evidence that native speech-sounds can be discriminated in a categorical fashion by newborns, whose post-natal exposure to language is limited. Although the newborns tested in Experiment II failed to demonstrate discrimination of non-native speech-sounds, there is some, albeit equivocal, evidence that older infants can make these discriminations, but not in a categorical manner. It is possible that the difference between discrimination data on native and non-native/non-speech-sounds may parallel the type of data obtained by Kuhl et al. (1992) on the generalization of learning of native and non-native vowel categories. Kuhl et al. demonstrated that by 6 months of age infants could generalize their learning to larger native vowel categories, to which there had most probably been pre-natal exposure and definitely post-natal exposure, than to non-native vowel categories, to which there had most probably been no pre- or post-natal exposure. This may be analogous to the evidence that suggests that newborns as well as older infants can discriminate native speech-sounds in a categorical manner, whereas the data on discrimination of non-native speech-sounds are less conclusive.

Although the current studies were limited to bilabial stops, Eimas (1975b) found that two-to-three month old infants could discriminate native apical stops. As the data for newborns on the discrimination of bilabial stops were consistent with those of the older infants tested by Eimas et al. (1971), it is plausible that newborns could discriminate apical stops they heard pre-natally. One way in which this research could be extended would be to test neonates in whose native language a lead/short lag voicing boundary is phonemic. As the results of the present studies suggest that newborns are able to discriminate only those speech-sounds that they heard pre-natally, it is possible that infants from a linguistic environment in which a lead/short lag boundary is phonemic, e.g. Spanish, would discriminate these speech-sounds, but would fail to show evidence of discriminating a non-native boundary, such as the short lag/long lag boundary discriminated by infants of American-English parentage.

It is suggested that pre-natal exposure to speech-sounds underlies newborns' ability to discriminate native speech-sounds very soon after birth. As the ability to discriminate speech-sounds seems to be due to learning rather than to innate factors, the pre-natal period may be a critical period of development. In that it would seem that the absence of certain stimuli, e.g. non-native speech-sounds, may account for newborns' inability to discriminate differences between them, it is possible that pre-natal exposure may be a necessary condition for discrimination of speech-sounds. This would underscore the importance of maintaining a healthy environment for the fetus in which speech-sounds are salient. As yet it is not known to what degree, if at all, pre-natal exposure may effect later language learning. However, in light of the fact that children tend to become proficient in their native language, it is possible that providing the fetus with sufficient exposure to speech-sounds could be essential to later language development.

Table 1

Percentile Ranks of Recovery Scores for Data that Were Analyzed in Both Experiments because of Overlapping Conditions

| Subject Number | Experiment | Condition | Percentile Rank in Condition |
|---|---|---|---|
| 223 | Exp. I | Within-Category (0/-20) | 31% |
| 223 | Exp. II | Stimulus-Change (0/-20) | 76% |
| 253 | Exp. I | Within-Category (-20/0) | 50% |
| 253 | Exp. II | Stimulus-Change (-20/0) | 91% |
| 294 | Exp. I | Control (-20/-20) | 51% |
| 294 | Exp. II | Control (-20/-20) | 59% |
| 295 | Exp. I | Control (0/0) | 33% |
| 295 | Exp. II | Control (0/0) | 41% |
| 296 | Exp. I | Control (-20/-20) | 44% |
| 296 | Exp. II | Control (-20/-20) | 57% |
| 340 | Exp. I | Control (0/0) | 59% |
| 340 | Exp. II | Control (0/0) | 50% |

| | |
|---|---|
| Average percentile rank for recovery data for Experiment I | 44.7% |
| Average percentile rank for recovery data for Experiment II | 62.3% |

Table 2

Percentile Ranks for Scores from Subjects Who Produced Data for Both Experiments

| Subject Number | Experiment | Condition | Percentile Rank in Condition |
|---|---|---|---|
| 278 | Exp. I | Between-Category (+40/+20) | 49% |
| 279 | Exp. II | Stimulus-Change (-60/-40) | 46% |
| 281 | Exp. II | Stimulus-Change (-40/-60) | 70% |
| 282 | Exp. II | Stimulus-Change (-40/-20) | 61% |
| 301 | Exp. I | Control (-40/-40) | 64% |
| 303 | Exp. II | Stimulus-Change (-60/-80) | 89% |
| 322 | Exp. I | Within-Category (+60/+80) | 58% |
| 323 | Exp. II | Stimulus-Change (-20/-40) | 50% |
| 343 | Exp. II | Stimulus-Change (-40/-60) | 54% |
| 344 | Exp. I | Between-Category (+40/+20) | 68% |
| 354 | Exp. II | Stimulus-Change (-60/-40) | 67% |
| 355 | Exp. I | Control (+80/+80) | 31% |
| 361 | Exp. II | Control (-40/-40) | 38% |
| 362 | Exp. I | Between-Category (+40/+20) | 43% |

Table 3

### EXPERIMENT I - Comparison of Estimated Gestational Age, Infant's Age at Time of Testing, and Birthweight Between the Useable and Unusable Data Samples

| | | Estimated Gestational Age (in weeks) | Infants' Age at Time of Testing (in hours) | Birthweight (in grams) |
|---|---|---|---|---|
| USEABLE | mean | 39.5 | 31.4 | 3274 |
| DATA | SD | .95 | 11.04 | 387.9 |
| n = 26 | | | | |
| UNU- | mean | 39.5 | 34.5 | 3376 |
| SABLE | SD | 1.16 | 13.28 | 362.5 |
| DATA | | t=.15 | t=.77 | t=.85 |
| N=57 | | | | |

No t-value achieved statistical significance.

Table 4

### EXPERIMENT I - Comparison of Estimated Gestational Age, Infant's Age at Time of Testing, and Birthweight Between the Useable Data Sample and Each Attrition Group

| | | Estimated Gestational Age (in weeks) | Infants' Age at Time of Testing (in hours) | Birthweight (in grams) |
|---|---|---|---|---|
| USEABLE DATA | mean | 39.5 | 31.4 | 3274 |
| | SD | .95 | 11.04 | 387.9 |
| n = 26 | | | | |
| CEASED SUCKING | mean | 39.4 | 35.3 | 3351 |
| | SD | 1.33 | 12.92 | 382.6 |
| n = 24 | | $t_D = .30$ | $t_D = 1.50$ | $t_D = .52$ |
| DID NOT CONDITION | mean | 39.6 | 33.9 | 3394 |
| | SD | 1.08 | 13.70 | 347.4 |
| n = 33 | | $t_D = .24$ | $t_D = .51$ | $t_D = .87$ |

No t-value achieved statistical significance.

Table 5

## EXPERIMENT I - Comparison of Sex, Type of Birth, and Mode of Feeding Between the Useable and Unusable Data Samples

| | Gender: | n = | % | Birth: | n = | % | Feeding: | n = | % |
|---|---|---|---|---|---|---|---|---|---|
| USEABLE DATA | Males | 13 | 50.0% | Vaginal | 19 | 73.1% | Bottle | 16 | 61.5% |
| n = 26 | Females | 13 | 50.0% | C-section | 7 | 26.9 % | Breast & Bottle | 10 | 38.5% |
| UNUSABLE DATA | Males | 23 | 40.4% | Vaginal | 40 | 70.2% | Bottle | 35 | 61.4% |
| N = 57 | Females | 34 | 59.6% | C-section | 17 | 29.8 % | Breast & Bottle | 22 | 38.6% |
| | $\chi^2 = 3.69$ | | | $\chi^2 = 0.22$ | | | $\chi^2 = 0.003$ | | |

No comparison was significant

Table 6

## EXPERIMENT I - Comparison of Gender, Type of Birth, and Mode of Feeding Between the Useable Data Sample and Each Attrition Group

| | Gender: | n = | % | Birth: | n = | % | Feeding: | n = | % |
|---|---|---|---|---|---|---|---|---|---|
| USEABLE DATA | Males | 13 | 50.0% | Vaginal | 19 | 73.1% | Bottle | 16 | 61.5% |
| n = 26 | Females | 13 | 50.0% | C-section | 7 | 26.9 % | Breast & Bottle | 10 | 38.5% |
| DID NOT CONDITION | Males | 11 | 33.3% | Vaginal | 25 | 75.8% | Bottle | 21 | 63.6% |
| n = 33 | Females | 22 | 66.7% | C-section | 8 | 24.2% | Breast & Bottle | 12 | 36.4% |
| | $\chi^2 = 2.26$ | | | $\chi^2 = 0.008$ | | | $\chi^2 = 0.003$ | | |
| CEASED SUCKING | Males | 12 | 50.0% | Vaginal | 15 | 62.5% | Bottle | 14 | 58.3% |
| n = 24 | Females | 12 | 50.0% | C-section | 9 | 37.5% | Breast & Bottle | 10 | 41.7% |
| | $\chi^2 = 0.00$ | | | $\chi^2 = 0.99$ | | | $\chi^2 = 0.02$ | | |

No comparison was significant.

Table 7

EXPERIMENT I - Recovery Data by Condition: Mean Rate of HAS Produced During the Baseline, Pre-Shift, Decrement and Post-Shift Periods

| | Controls n = 10 | Between-Group n = 8 | Within-Group n = 8 | Total N = 26 |
|---|---|---|---|---|
| Baseline Minute | 4.40 | 4.37 | 4.87 | 4.54 |
| Pre-Shift Minute | 11.00 | 11.62 | 10.37 | 11.00 |
| Decrement Period: | | | | |
| Two-Minutes | 14.10 | 10.12 | 15.00 | |
| Mean Rate Per Minute | 7.05 | 5.06 | 7.50 | |
| Post-Shift Period: | | | | |
| Two-Minutes | 7.20 | 26.25 | 15.87 | |
| Mean Rate Per Minute | 3.60 | 13.12 | 7.93 | |

Table 8

### EXPERIMENT I - Recovery Data by Condition: Mean Difference in the Rate of HAS Between the Two Decrement Minutes and the Two Post-Shift Minutes

| | Control Condition | Between-Category Condition | Within-Category Condition |
|---|---|---|---|
| n = | 10 | 8 | 8 |
| Mean Difference in the Rate of HAS | -6.9 | 16.1 | 0.9 |
| S.D. | 6.10 | 18.85 | 10.22 |
| t = | 3.57** | 2.42* | .14 |

* p <.025, one-tailed
** p < .005, one-tailed

Table 9

### EXPERIMENT I - Between-Group Differences in Recovery Data: Absolute Value of Differences in the Rate of HAS

| Conditions Contrasted | Absolute Value of Difference |
|---|---|
| Control vs. Between Category Conditions | 23.02** |
| Between Category vs. Within Category Conditions | 15.25* |
| Control vs. Within-Category Conditions | 7.78 |

* p< .05
** p< .01

Table 10

### EXPERIMENT II - Comparison of Estimated Gestational Age, Infant's Age at Time of Testing, and Birthweight Between the Useable and Unusable Data Samples

| | | Estimated Gestational Age (in weeks) | Infants' Age at Time of Testing (in hours) | Birthweight (in grams) |
|---|---|---|---|---|
| USEABLE | mean | 40.3 | 35.8 | 3351 |
| DATA | SD | 1.13 | 13.10 | 397.5 |
| n = 42 | | | | |
| UNU- | mean | 39.4 | 33.5 | 3133 |
| SABLE | SD | 1.46 | 13.21 | 396.8 |
| DATA | | t=2.15* | t=.55 | t=1.78 |
| n = 42 | | | | |

*p<.05

Table 11

### EXPERIMENT II - Comparison of Estimated Gestational Age, Infant's Age at Time of Testing, and Birthweight Between the Useable Data Sample and Each Attrition Group

| | | Estimated Gestational Age (in weeks) | Infants' Age at Time of Testing (in hours) | Birthweight (in grams) |
|---|---|---|---|---|
| USEABLE | mean | 40.3 | 35.8 | 3351 |
| DATA | SD | 1.13 | 13.10 | 397.5 |
| n = 42 | | | | |
| CEASED | mean | 39.8 | 38.7 | 3152 |
| SUCKING | SD | 1.45 | 14.20 | 456.0 |
| n = 16 | | tD = .91 | tD = .53 | tD = 1.21 |
| DID NOT | mean | 39.2 | 30.4 | 3121 |
| CONDITION | SD | 1.47 | 12.58 | 356.6 |
| n = 26 | | tD = 2.37** | tD = 1.17 | tD = 1.64 |

**p < .025

Table 12

### EXPERIMENT II - Comparison of Gender, Type of Birth, and Mode of Feeding Between the Useable and Unusable Data Samples

| | Gender: | n = | % | Birth: | n = | % | Feeding: | n = | % |
|---|---|---|---|---|---|---|---|---|---|
| USEABLE DATA | Males | 25 | 59.5% | Vaginal | 28 | 66.7% | Bottle | 35 | 83.3% |
| n = 42 | Females | 17 | 40.5% | C-section | 14 | 33.3 % | Breast & Bottle | 7 | 16.7% |
| UNUSABLE DATA | Males | 23 | 54.8% | Vaginal | 35 | 83.3% | Bottle | 29 | 69.1% |
| N=42 | Females | 19 | 45.2% | C-section | 7 | 16.7% | Breast & Bottle | 13 | 30.9% |
| | $\chi^2 = .93$ | | | $\chi^2 = 12.45$*** | | | $\chi^2 = 14.60$*** | | |

***$p < .005$

Table 13

## EXPERIMENT II - Comparison of Gender, Type of Birth, and Mode of Feeding Between the Useable Data Sample and Each Attrition Group

| | Gender: | n = | % | Birth: | n = | % | Feeding: | n = | % |
|---|---|---|---|---|---|---|---|---|---|
| USEABLE DATA | Males | 25 | 59.5% | Vaginal | 28 | 66.7% | Bottle | 35 | 83.3% |
| n = 42 | Females | 17 | 40.5% | C-section | 14 | 33.3 % | Breast & Bottle | 7 | 16.7% |
| DID NOT CONDITION | Males | 15 | 57.7% | Vaginal | 21 | 80.8% | Bottle | 19 | 73.1% |
| n = 26 | Females | 11 | 42.3% | C-section | 5 | 19.2% | Breast & Bottle | 7 | 26.9% |
| | $\chi^2 = .007$ | | | $\chi^2 = 3.15$ | | | $\chi^2 = 2.47$ | | |
| CEASED SUCKING | Males | 8 | 50.0% | Vaginal | 14 | 87.5% | Bottle | 10 | 62.5% |
| n = 16 | Females | 8 | 50.0% | C-section | 2 | 12.5% | Breast & Bottle | 6 | 37.5% |
| | $\chi^2 = 1.21$ | | | $\chi^2 = 7.29^*$ | | | $\chi^2 = 11.67^{**}$ | | |

* $p < .01$

** $p < .005$

Table 14

EXPERIMENTS I and II - Comparison of Estimated Gestational Age,
Infant's Age at Time of Testing, and Birthweight
Between the Useable and Unusable Data Samples

| | | Estimated Gestational Age (in weeks) | Infants' Age at Time of Testing (in hours) | Birthweight (in grams) |
|---|---|---|---|---|
| USEABLE | mean | 40.0 | 34.1 | 3322 |
| DATA | SD | 1.14 | 12.43 | 393.9 |
| n = 68 | | | | |
| UNU- | mean | 39.4 | 34.0 | 3273 |
| SABLE | SD | 1.34 | 13.27 | 377.4 |
| DATA | | t = 2.07* | t = .02 | t = .06 |
| N = 99 | | | | |

*p<.05

Table 15

EXPERIMENTS I and II - Comparison of Estimated Gestational Age,
Infant's Age at Time of Testing, and Birthweight
Between the Useable Data Sample and Each Attrition Group

| | | Estimated Gestational Age (in weeks) | Infants' Age at Time of Testing (in hours) | Birthweight (in grams) |
|---|---|---|---|---|
| USEABLE | mean | 40.0 | 34.1 | 3322 |
| DATA | SD | 1.14 | 12.43 | 393.9 |
| n = 68 | | | | |
| CEASED | mean | 39.5 | 36.6 | 3271 |
| SUCKING | SD | 1.42 | 13.40 | 413.1 |
| n = 24 | | $t_D = 1.44$ | $t_D = .70$ | $t_D = .76$ |
| DID NOT | mean | 39.4 | 32.3 | 3274 |
| CONDITION | SD | 1.30 | 13.21 | 351.4 |
| n = 33 | | $t_D = 1.9$ | $t_D = .57$ | $t_D = .50$ |

No t-value achieved statistical significance.

Table 16

### EXPERIMENTS I and II - Comparison of Gender, Type of Birth, and Mode of Feeding Between the Useable and Unusable Data Samples

| | Gender: | n = | % | Birth: | n = | % | Feeding: | n = | % |
|---|---|---|---|---|---|---|---|---|---|
| USEABLE DATA | Males | 38 | 55.9% | Vaginal | 47 | 69.1% | Bottle | 51 | 75.0% |
| n = 68 | Females | 30 | 44.1% | C-section | 21 | 30.9 % | Breast & Bottle | 17 | 25.0% |
| UNU-SABLE | Males | 46 | 46.5% | Vaginal | 75 | 75.8% | Bottle | 64 | 64.6% |
| DATA n = 99 | Females | 53 | 53.5% | C-section | 24 | 24.2% | Breast & Bottle | 35 | 35.4% |
| | $\chi^2 = 3.58$ | | | $\chi^2 = 2.10$ | | | $\chi^2 = 5.79$** | | |

**p < .025

Table 17

EXPERIMENTS I and II - Comparison of Gender, Type of Birth, and Mode of Feeding Between the Useable Data Sample and Each Attrition Group

| | Gender: | n = | % | Birth: | n = | % | Feeding: | n = | % |
|---|---|---|---|---|---|---|---|---|---|
| USEABLE DATA | Males | 38 | 55.9% | Vaginal | 47 | 69.1% | Bottle | 51 | 75.0% |
| n = 68 | Females | 30 | 44.1% | C-section | 21 | 30.9 % | Breast & Bottle | 17 | 25.0% |
| DID NOT CONDITION | Males | 26 | 44.1% | Vaginal | 46 | 78.0% | Bottle | 40 | 67.8% |
| n = 59 | Females | 33 | 55.9% | C-section | 13 | 22.0% | Breast & Bottle | 19 | 32.2% |
| | $\chi^2 = 3.38$ | | | $\chi^2 = 2.1$ | | | $\chi^2 = 2.09$ | | |
| CEASED SUCKING | Males | 20 | 50.0% | Vaginal | 29 | 72.5% | Bottle | 24 | 60.0% |
| n = 40 | Females | 20 | 50.0% | C-section | 11 | 27.5% | Breast & Bottle | 16 | 40.0% |
| | $\chi^2 = 0.73$ | | | $\chi^2 = 0.22$ | | | $\chi^2 = 8.57$*** | | |

*** $p < .005$

Table 18

## EXPERIMENT II - Mean Rate of HAS Produced During the Baseline, Pre-Shift, Decrement and Post-Shift Periods

| | Controls<br>n = 10 | Stimulus-Change (Collapsed)<br>n = 32 | Total<br>N = 42 |
|---|---|---|---|
| Baseline Minute | 6.66 | 4.59 | 5.07 |
| Pre-Shift Minute | 13.6 | 11.75 | 12.19 |
| Decrement Period: | | | |
| Two-Minutes | 19.40 | 15.62 | |
| Mean Rate Per Minute | 9.70 | 7.81 | |
| Post-Shift Period: | | | |
| Two-Minutes | 8.10 | 9.25 | |
| Mean Rate Per Minute | 4.05 | 4.62 | |

Table 19

## EXPERIMENT II - Mean HAS Production During the Decrement and Post-Shift Periods of the Stimulus-Change Conditions

| | 0/-20<br>-20/0<br>n = 4 | -20/-40<br>-40/-20<br>n = 8 | -40/-60<br>-60/-40<br>n = 8 | -60/-80<br>-80/-60<br>n = 8 | -80/-100<br>-100/-80<br>n = 4 |
|---|---|---|---|---|---|
| Decrement Period: | | | | | |
| Two Minutes: | 20.50 | 11.37 | 26.50 | 10.62 | 7.50 |
| Mean Rate Per Minute: | 10.25 | 5.69 | 13.25 | 5.31 | 3.75 |
| Post-Shift Period: | | | | | |
| Two Minutes: | 8.50 | 7.12 | 14.87 | 9.25 | 3.00 |
| Mean Rate Per Minute: | 4.25 | 3.56 | 7.44 | 4.62 | 1.50 |

Table 20

EXPERIMENT II - Recovery Data by Condition:
Mean Difference in the Rate of HAS Between
the Two Decrement and the Two Post-Shift Minutes

| | Control Condition n = 10 | 0/-20 -20/0 n = 4 | -20/-40 -40/-20 n = 8 | -40/-60 -60/-40 n = 8 | -60/-80 -80/-60 n = 8 | -80/-100 -100/-80 n = 4 |
|---|---|---|---|---|---|---|
| Mean Difference in the Rate of HAS | -11.3 | -12.0 | -4.2 | -11.6 | -1.4 | -4.5 |
| S.D. | 15.58 | 12.67 | 7.74 | 21.53 | 6.86 | 5.32 |
| t = | 2.29* | 1.89 | 1.56 | 1.53 | 0.56 | 1.69 |

* $p < .05$, one-tailed

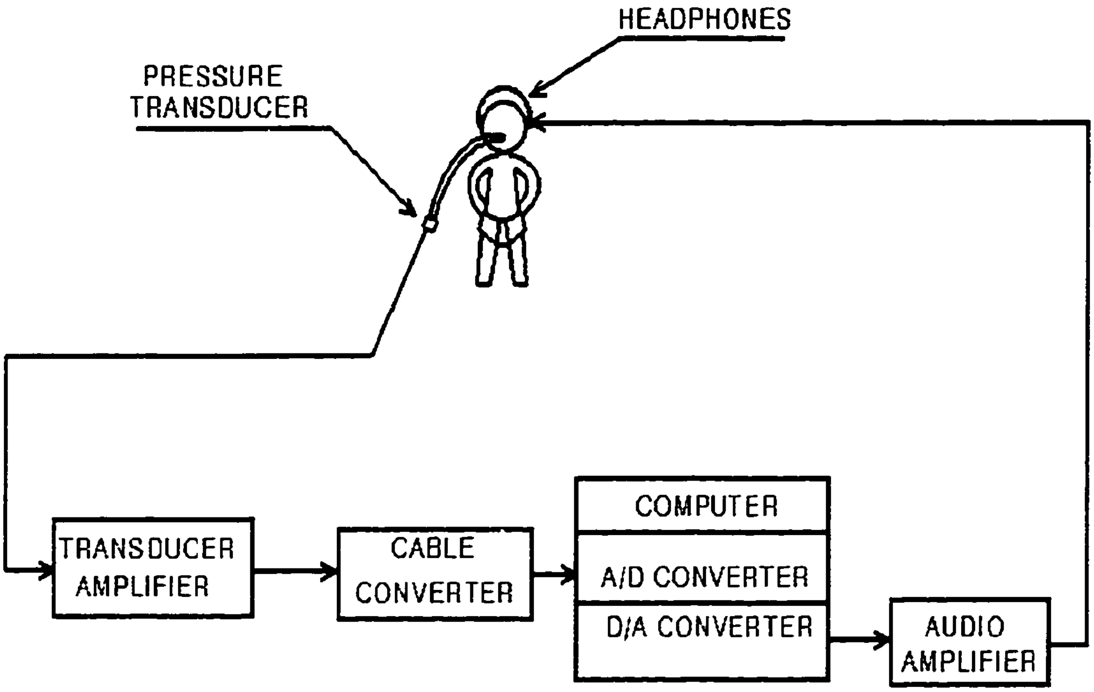

Diagram 1 Template of Equipment

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# IMAGE EVALUATION
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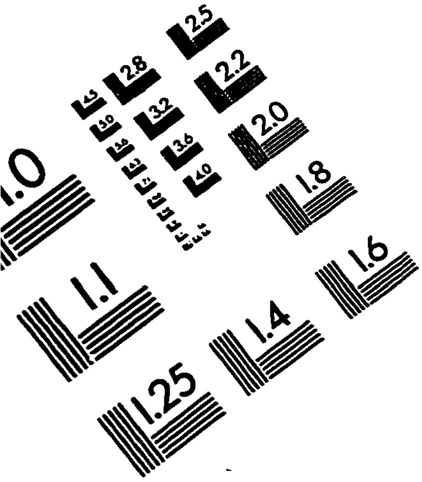

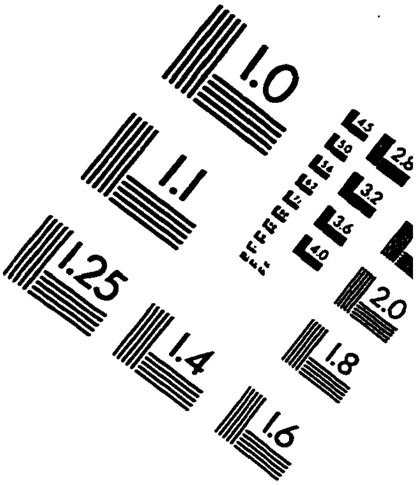

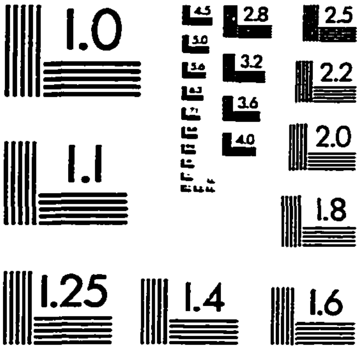

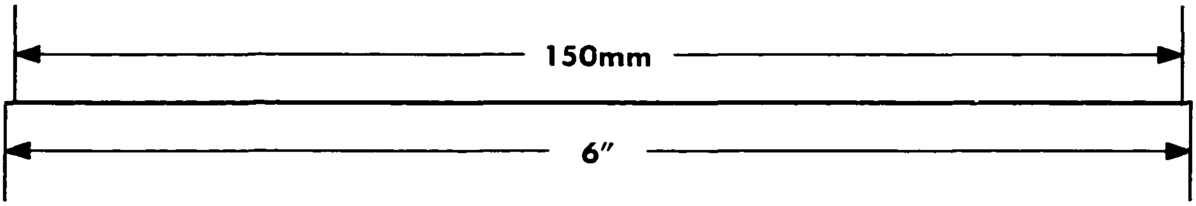

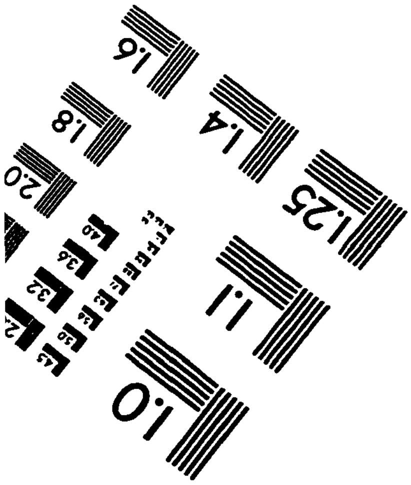

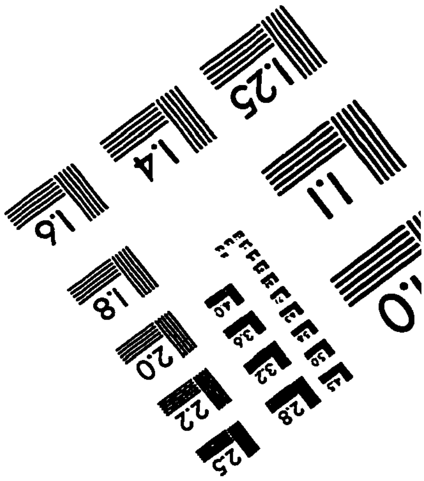

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