M.A. PSYCHOLOGY

AUDITORY-LINGUISTIC SENSITIVITY IN EARLY INFANCY

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Three investigations are reported which indicate that infants between four and seventeen weeks of age are able to detect some differences in sounds upon which phonemic contrasts are based. Using a procedure where the presentation of sound was contingent on non-nutritive sucking, the babies demonstrated their ability to detect the difference between /b/ and /p/ and between /d/ and /t/. The implications of these findings for Jakobson's theory of phonemic development are discussed.

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by

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INTRODUCTION

Language acquisition has, in recent years, become a popular focus of research and speculation. However, relatively little attention has been directed to the perceptual capacities which must underlie all language growth (Friedlander, 1970). Jakobson (1968) has proposed that the phonemes of all languages are acquired in universal and invariant order. He suggests that the child's receptive abilities parallel those of production, the process of progressive differentiation beginning at approximately eleven months of age. Prior to this the child would presumably fail to hear differences between the various phonemic contrasts (Ervin-Tripp, 1967, p. 67). The only empirical support for this position comes from a Russian study by Shvachkin (1948) which independently confirmed the sequence of acquisition of auditory-linguistic discriminations and specified the time of acquisition at eleven to twenty-four months of age.

Kaplan and Kaplan (1970) concur with the Jakobsonian formulation of phonemic development. However, they question the linguistic irrelevance of early infancy, suggesting alternatively, that suprasegmental (e.g., pitch, stress, duration) as opposed to segmental (phonemes and sound classes) information is being processed throughout the first year.

While the maturation of articulatory mechanisms might explain the sequence of acquisition of productive features, there is no known mechanism which would constrain receptive development to the identical sequence. Furthermore, it is plausible that receptive capacities mature more rapidly than productive capacities. Three recent studies of early infancy suggest that this might be the case. Moffitt (1969) employed heart rate as the dependent measure and found that infants twenty to twenty-four weeks of age could discriminate between the phonemes /b/ and /g/. McCaffrey (cited in Friedlander, 1970) used a similar procedure and found that differences in several vowel and consonant contrasts could be detected by infants four to twenty-eight weeks of age. Eimas, Siqueland, Jusczyk and Vigorito (1971) found that one- and four-month-old infants could distinguish between the voiced and voiceless stop consonants /b/ and /p/. They used a modified version of a technique developed by Siqueland and De Lucia (1969) for investigating infants' discriminative abilities. Eimas _et al_. (1971) trained infants to suck non-nutritively for sound reinforcement. When the sucking rate diminished by a specified amount they substituted a contrasting sound. The magnitude of recovery of the sucking response was used as a measure of discriminability. In both the Moffitt (1969) and Eimas *et al*. (1971) studies, stimuli had been generated by a speech synthesizer and computer which minimized the possibility of suprasegmental differences accounting for the results.

The present studies were designed to replicate and extend the work of Eimas *et al*. (1971). The first study was the replication and employed synthesized samples of /b/ and /p/ as stimuli. The two other experiments differed from the first only in the selection of stimuli. The second employed natural speech versions of /b/ and /p/; the third used a second exemplar of the voiced-voiceless distinction, /d/ and /t/. The phonemic contrasts in all three studies were embedded in a common vocalic environment.

METHOD

Methodological Modification

The present studies incorporated a basic methodological modification of the Eimas *et al*. (1971) technique. Eimas *et al*. (1971) had set the stimulus intensity proportional to sucking rate and had employed a gradual fade-in and out for stimulus presentation. The present design was simplified by presenting sound-on at fixed intensity for high amplitude sucking, sound-off at all other times.

<u>Apparatus</u>

Two testing rooms separated by one-way glass were used, one for equipment, operator and observers, the second for subjects. In the subject room an adjustable semi-reclining infant seat was located on a table facing the glass. A Knight 15 watt/8 ohm speaker was centered 6 in. to the rear of the seat. A brightly colored poster affixed to the glass was visible to seated infants. A blind Evenflo nipple was attached to a Statham physiological pressure transducer (Model P23AA). Ambient noise level at the site of the infant's head was 40 decibels as measured by a General Radio Company sound level meter (type 1551-C) weighted at A.

In the equipment room, the transducer fed into a DC preamplifier (set to bridge) of a Grass polygraph (model 79) which provided a graphic record of all sucking behavior. A criterion level was mechanically set on the polygraph. Pen deflections beyond this level, which reflected specified amounts of positive pressure exerted on the nipple, activated a Uher Royal Deluxe Stereo tape recorder, the output of which was wired to the speaker in the subject room. Relay circuits responding to the offset of control signals on the tape caused the recording unit to be shut off after a single sound stimulus, ready to be reactivated by further pressure on the nipple. Two such deflections per second were required for continuous operation of the tape recorder. Sucks of sufficient pressure to activate the recorder (criterion sucks) were counted automatically by two Simpson Electric 12-volt DC counters, each counting alternate minutes as timed by a Lafayette interval and repeat cycle timer. Counters and timer were powered by a 12-volt Electro power supply (Model EC-2).

The experimental tapes were loops, 30 in. in circumference, with 1/2 second sound alternating with 1/2 second silence. Each sound was recorded on one channel of the same tape face. Recording and playing speed were 7 1/2 in. per second. Signals (diapilot) were recorded on a control track corresponding to the silent intervals between stimuli. These control signals guided the sound shut-off, thereby ensuring that the complete stimulus sound would always be played.

Stimuli

The stimuli employed in the first experiment (heard as "bah" and "pah") were re-recordings of stimuli used by

Eimas *et al.* (1971). These stimuli had been prepared at Haskins Laboratories in Connecticut by means of a parallel resonance synthesizer and computer and differed by 80 msec. voice onset time[1] (the interval between release burst and laryngeal pulsing or voicing).

The second and third experiments employed natural speech versions of bah/pah and dah/tah, respectively. Both stimulus pairs were recordings of adult male voices (on a Uher Royal Deluxe Stereo Unit) which were matched visually on non-critical features such as duration, intensity and frequency, by means of mingographic records.

Stimuli for all experiments were 500 msec. in duration and were presented at 24 decibels above ambient noise level (measured at A weighting).

Subjects

The subjects were 60 infants, 4 through 17 weeks of age, all from English-speaking families who volunteered in response to mail solicitation. (Letters had been sent to families placing birth announcement listings in the Montreal Star.) Every infant was tested without respect to health history. Infants were excluded from the study if they failed to reach an a priori minimum of 20 sucks per minute or if their mothers requested the termination of the session. Infants were assigned at random to experimental or control groups, each group comprising 10 subjects with approximately equal numbers of males and females.

Procedure

The infant was loosely strapped into the seat and remained there for a few minutes. An assistant then inserted and held the nipple in the infant's mouth, replacing it immediately when ejected. The assistant was unaware of the infant's assignment to experimental or control conditions and could not hear the sound stimulus because she wore earphones connected to a radio. After recording approximately 30 seconds of sucking, the experimenter designated the stronger sucks of that infant as "criterion" sucks, adjusting the equipment accordingly. After one further minute to obtain a baseline level of criterion sucking, the sound stimuli, in counterbalanced order, were delivered contingent upon criterion sucking. Habituation to the stimulus was defined as a decreased sucking rate, at least 33% below the infant's highest rate, maintained for two consecutive minutes. (The Eimas et al., (1971) habituation criterion was a 20% decrement compared to the previous minute. Preliminary testing indicated the advisability of adopting a more stringent criterion.) When the habituation criterion was reached, the contrast stimulus was substituted for infants in the experimental condition. An equal number of control babies received the same stimulus throughout. Five minutes after habituation the testing session was terminated. Sensitivity to the change in stimulus was inferred from recovery of sucking rate of experimental as compared to control subjects.

RESULTS

Data for each infant consisted of criterion sucks per minute over successive minutes. To minimize scale differences between infants, all scores were converted to percentages of that individual's maximum pre-habituation sucking rate. Mean sucking scores for the five minutes before and after the habituation criterion are shown in Figure 1.

Since subjects had been assigned at random to experimental or control conditions, their pre-habituation performance was presumed to be equivalent and only post-habituation sucking behavior was submitted to statistical analysis. A two-factor analysis of variance with repeated measures on one factor (Winer, 1962, p. 302) was performed on the five

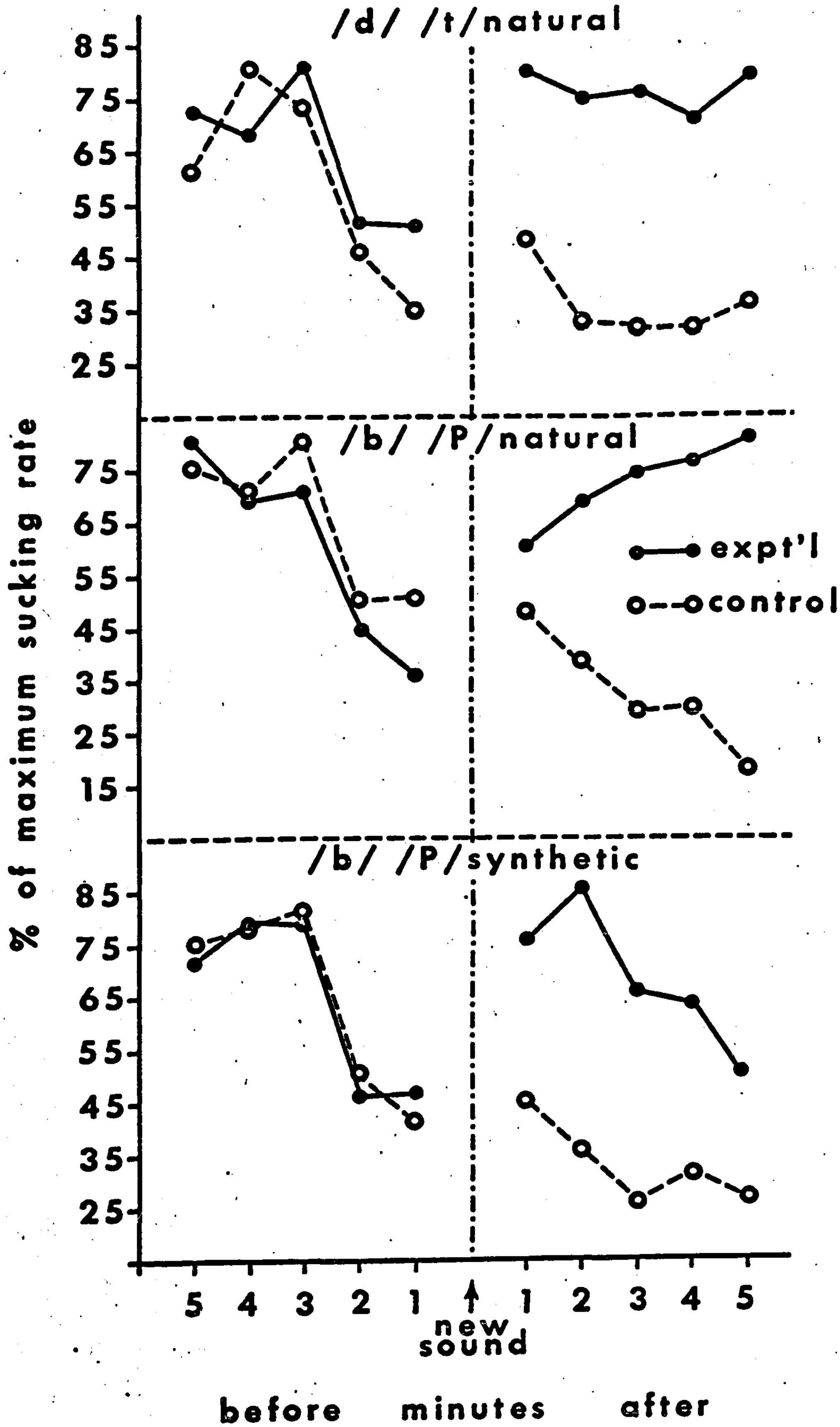

Figure 1. Mean sucking rates, as a percentage of the maximum pre-habituation sucking level, for 5 minutes pre- and post-habituation criterion.

post-habituation minutes (see Appendix for complete analysis of variance). The differences between experimental subjects receiving two sounds and control subjects receiving a single sound throughout were highly significant for infants receiving synthetic /b/ /p/ (F=9.8531, df=1/18, $p < .01$), natural /b/ /p/ (F=12.5381, df=1/18, $p < .005$) and natural /d/ /t/ (F=35.2287, df=1/18, $p < .001$). In the second experiment there was, in addition, a significant group by trials interaction (F=3.1606, df=4/72, $p < .025$) reflecting trend differences in experimental and control subjects. However, if a more stringent test (negatively biased) which avoids assumptions about equal covariance is applied (with df=1/18) this latter difference is no longer significant (Winer, 1962, p. 305).

DISCUSSION

The results clearly indicate that infants four to seventeen weeks of age can readily detect small differences in certain speech signals, specifically, the difference between synthesized and natural speech samples of /b/ and /p/ as well as natural samples of /d/ and /t/.

One implication of Jakobson's (1968) theoretical formulation, namely, that young infants would not hear phonemic differences (Ervin-Tripp, 1967), is clearly negated by the present results. Can one, then, conclude that from the receptive point of view, phonemic development is accomplished in early infancy? One alternative to such a conclusion is that infants, rather than making a phonemic discrimination or one that relates to the perceptual categories of language, are merely making a phonetic or acoustic discrimination. If this is the case, then, these auditory or non-linguistic abilities would not preclude phonemic development from proceeding according to Jakobson's model. There is evidence, however, to suggest that phonemic differentiation per se is being used as the basis for discrimination. Eimas et al. (1971) demonstrated reliably greater discrimination of identical acoustic differences when these were from different phonemic categories (/b/ /p/) as compared to variations within the same phonemic category (allophones). This corresponds to the categorical discrimination of stop consonants typically obtained with adults (Lisker & Abramson, 1967). Additional studies employing other phonemic contrasts compared with allophonic variations would further clarify this issue.

A second possibility arises upon closer examination of the demands of the task performed by the infants. In these studies, as in those of Moffitt (1969), McCaffrey (cited in Friedlander, 1970) and Eimas et al. (1971), infants were detecting differences but not attaching differential responses to distinct perceptual events, as in the typical discrimination learning paradigm or in language usage. It is possible, then, that difference detection does not imply discrimination in the usual sense, so that sensitivity to sound change, while necessary, is not sufficient for language acquisition. If this were the case, then true discrimination might still proceed as outlined by Jakobson. However, work by Papousek (1967) with four-week-old infants, demonstrating differential head turning to bell and buzzer stimuli, increases the likelihood that phonemic contrasts can act as cues for differential responses.

Jakobson had proposed both a temporal and a sequential model of phonemic development. While it appears likely that his specification of time is inappropriate, it remains, nevertheless, to ascertain the precise time schedule of acquisition. The fact that infants of four weeks are capable of these discriminations suggests that these abilities may be present at or soon after birth. The second issue, the order of acquisition, also awaits experimental elaboration. The technique employed in the present investigation appears to provide a simple and direct method for gathering data relevant to both questions.

SUMMARY

Three investigations are reported which indicate that infants between four and seventeen weeks of age are able to detect some differences in sounds upon which phonemic contrasts are based. A habituation-disinhibition procedure was employed where the presentation of sound was contingent on non-nutritive sucking. It was found that the infants were able to detect the difference between /b/ and /p/ and between /d/ and /t/. The implications of these findings for Jakobson's theory of phonemic development are discussed.

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FOOTNOTE

1. Lisker and Abramson (1967) claim that the voiced-voiceless distinction of initial consonant stops is cued acoustically by voice onset time.

APPENDIX

TABLE 1

Analysis of Variance of 5 Post-habituation Minutes:

Synthesized /b/ /p/

Source	df	MS	F
Groups (G)	1	29026.88	9.8531*
Trials (T)	4	1739.642	3.3971**
Ss within groups	18	2945.955	-
G x T	4	494.2285	0.9651
T x Ss within groups	72	512.0967	-

* $p < .01$

** $p < .05$

TABLE 2

Analysis of Variance of 5 Post-habituation Minutes:

Natural /b/ /p/

Source	df	MS	F
Groups (G)	1	38650.72	12.5381*
Trials (T)	4	69.09180	.1185
Ss within groups	18	3082.661	-
G x T	4	1843.417	3.1606**
T x Ss within groups	72	583.2524	-

* $p < .005$

** $p < .025$

TABLE 3

Analysis of Variance of 5 Post-habituation Minutes:

Natural /d/ /t/

Source	df	MS	F
Groups (G)	1	40116.90	35.2287*
Trials (T)	4	503.3557	1.1926
Ss within groups	18	1138.757	-
G x T	4	131.5894	0.3118
T x Ss within groups	72	422.0659	-

* $p < .001$