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The Discrimination of Foreign Speech Contrasts by Infants and Adults

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TREHUB, SANDRA E. The Discrimination of Foreign Speech Contrasts by Infants and Adults. CHILD DEVELOPMENT, 1976, 47, 466-472. Infants 5-17 weeks of age were presented with foreign speech sounds which were contingent upon their nonnutritive sucking. When the infants met a specified criterion of sucking decrement, a contrasting sound was substituted. Significant differences in response recovery for experimental versus control (no sound change) subjects were found for the contrast pairs [pa]-[p-a] and [za]-[ťa]. Adults were presented with a comparable discrimination task for the foreign contrasts [za]-[ťa] and the English contrasts [li]-[ri]. It was found that adults achieved perfect accuracy with English contrasts but readily confused the foreign contrasts. The implications of these results for theories of perceptual development are discussed.

Experiments I and II

It has become clear that infants can discriminate both consonant (Eimas, Siqueland, Jusczyk, & Vigorito 1971; Moffitt 1971; Morse 1972; Trehub & Rabinovitch 1972) and vowel (Trehub 1973) contrasts which are distinctive in the English language. Furthermore, this ability does not appear to improve between the ages of 1 and 4 months (Eimas et al. 1971; Trehub 1973). The age of 1 month does not necessarily represent a temporal minimum for these discriminations; it represents, instead, what several investigators have found to be the youngest age for practical subject recruitment. It is possible, then, that evidence for these discriminations can be obtained considerably earlier in infancy. Eimas et al. (1971) and Moffitt (Note 1) have speculated that these abilities are present at birth. Although this notion appears plausible, one cannot rule out the possibility that prior exposure to speech containing such contrasts can account for the observed differentiations in the research to date. One definitive means of excluding this experiential interpretation would involve examination of discriminative performance on contrasts which would not occur in the realm of experience of the infant, that is, foreign language contrasts. In the present series of experiments, two such contrasts were employed. The stimuli of Experiment I, [pa] and [p-a], highlight the oral/nasal vowel distinction which occurs only in the French and Polish languages (Jakobson 1968). The stimuli of Experiment II, [za] and [ťa], exemplify the distinctive feature of stridency, with the consonant [ť] used by Czech speakers (Chomsky & Halle 1968, p. 329).

Method

Apparatus. —Two testing rooms separated by one-way glass were used, one for equipment, operator, and observers, the second for subject and assistant. The apparatus has been described in detail by Trehub and Rabinovitch (1972). Briefly, it consists of a blind nipple (Evenflow) attached to a pressure transducer (Statham P23AA) which yields a polygraphic recording of sucking. Pen deflections beyond a mechanically set criterion level activate a Uher Royal Deluxe stereo tape recorder wired to a speaker (Knight 15 watt/8 ohm) directly behind the semireclining infant. The tape recorder stops silently and automatically after a single sound stimulus, ready to be reactivated by further criterion-level pressure on the nipple. Criterion sucks per minute are recorded by counters. Ambient noise level at the site of the infant’s head was 38 decibels as measured by a General Radio Company sound level meter (Type 1551-C) weighted at A.

Procedure. —Infants were always awake at the beginning of the testing session. The experiment then proceeded without interruption despite occasional apparent alterations in the infant’s state (Trehub 1975). Thus infants who fussed somewhat or fell asleep were retained provided they continued to suck. An assistant wearing earphones connected to a radio inserted and held the nipple in the infant’s mouth, replacing it immediately when ejected. After approximately 30 seconds of sucking, the criterion level for each infant was adjusted so that most of the infant’s sucks would be of sufficient pressure to activate the sound. Following a 1-minute period of baseline sucking, the

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sound stimuli, in counterbalanced order, were delivered contingent upon criterion sucking. Thus one stimulus was presented to half of the experimental and control subjects, the contrasting stimulus to the other half. A decrement criterion was defined as a decreased sucking rate at least $33\frac{1}{3}$% below the infant's highest rate, maintained for 2 consecutive minutes. The high reference minute was excluded from occurring in the first 2 minutes of sound presentation. When the decrement criterion was reached the contrast stimulus was substituted for infants in the experimental condition. (Channels were always changed during the silent intervals.) An equal number of control subjects received no change in stimulation. Sensitivity to the change in sound was inferred from significant differences between experimental and control subjects in the postdecrement period.

**Subjects.**—All subjects were residents of Montreal, Canada. Infants were excluded from the study on the following bases: failure to meet an a priori criterion of at least 20 sucks in the baseline minute (10), failure to emit any sucks in the minute following the decrement criterion (5), persistent fussing or crying (8), technical difficulties (9), or a request by the guardian for early termination (6). An equal number of control groups was also eliminated for infants in the experimental group who failed to emit any sucks in the 2 minutes following the decrement criterion (5), persistent fussing or crying (8), technical difficulties (9), or a request by the guardian for early termination (6). The final sample of 40 full-term, healthy infants was divided equally between Experiments I and II.

In the case of Experiment I all infants from French-speaking homes were excluded. In Experiment II infants from families where Czech or other eastern European languages were spoken were similarly excluded. The age range and median age were 6–17 weeks and 10.5 weeks, 5–15 weeks and 9.5 weeks for Experiments I and II, respectively.

**Stimuli.**—The stimuli of Experiment I, [pa] and [pâ], were produced by a French-speaking male and were approximately 500 milliseconds in duration. The stimuli were matched visually on intensity contour and duration by means of spectrographic and mingographic records. Six native speakers of French agreed that the stimulus tape comprised four different exemplars of [pa] on one channel and four varying instances of [pâ] on the other channel of the same tape face. The resultant tape thus included audible but minor variations in intensity, intonation, duration, and stress. Stimulus durations were $500 \pm 100$ milliseconds with silent intervals equivalent to 1 second minus stimulus duration. The stimuli were presented at 62 db (A scale).

**Results**

Data for each infant consisted of criterion sucks per minute over successive minutes. To eliminate the positive bias of subjects with atypical (generally high) sucking rates, each subject's scores were converted to percentages of that individual's maximum predecrement sucking rate. Percentage pre- and postdecrement scores for Experiments I and II are shown in figure 1. Analyses of variance (groups x minutes with 5 repeated measures on the latter factor) on these scores yielded no differences between experimental and control groups in the predecrement period and significant differences in the postdecrement period between experimental and control groups receiving the contrast pairs [pa] [pâ], $F(1, 18) = 5.25$, $p < .05$, and [za] [Fa], $F(1, 18) = 5.14$, $p < .05$.

**Discussion**

Infants can differentiate two pairs of foreign language contrasts which they, in all likelihood, have never heard before. While it is conceivable that these infants may have previously heard the contrasts [pa] and [pâ] because of their residence in French Canada, the chances of this are slim, given the substantial physical and social separation of English and French linguistic communities in Montreal. In any case, it must be conceded that their chances of having heard the Czech contrasts must be infinitesimal.

Butterfield and Cairns (1974) have suggested that prior relevant experience is necessary to trig-
ger infants' discriminative capacities. On the basis of the present findings, it would appear that if any experience is necessary it must take some very general form which does not necessitate exposure to the contrasts in question. The role played by such general experience could be ascertained through systematic comparisons of performance of older infants with newborns or, alternatively, with institutionalized infants who presumably experience a contrasting history of auditory as well as nonauditory stimulation.

Furthermore, if infants can, without prior exposure, discriminate contrasts relevant to any particular language, it is reasonable to expect that they will be capable of discriminating contrasts relevant to all languages. The historical origin of the phonetic content of various languages is probably related to the exploitation of these biological capacities of discrimination. This is not meant to suggest that there are no limits to infants' capacity to discriminate segmental features. In fact, Eilers and Minifie (1975), on the basis of their failure to obtain evidence for infants' discrimination of the fricative contrasts [s] and [z], have challenged the claim by Eimas et al. (1971) that infants can differentiate among phonetic units which differ only in voice onset time.

Infants' ability to discriminate the foreign contrasts of the present study highlights the divergent developmental processes which characterize

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**FIG. 1.**—Mean number of sucks per minute, as a percentage of the maximum prededrement sucking rate, for 5 minutes before and after the decrement criterion.
speech perception and production, for the nasal vowel [ə] and strident consonant [?] are among the latest productive acquisitions for speakers of the relevant languages (Jakobson 1968). McCaffrey (Note 2) has proposed a possible basis for this asymmetry. He argues that phonemes, regarded as bundles of distinctive features, can be discriminated with reference to any single contrastive feature but can be produced only by mastery of their constituent complex of features or properties. It follows, then, that the processes of perception and production, one analytic, the other constructive, would manifest divergent patterns of development.

The present suggestion that infants can perceive contrasts which they have never heard before would be of particular theoretical import if adults could not readily make such differentiations. It has been claimed that adults experience considerable difficulty discriminating certain contrasts which are not distinctive in their language community (Goto 1971; Singh & Black 1966). However, neither the French/Polish nor the Czech contrasts of the present study have been formally tested with adults.

Experiment III

The purpose of the present experiment was to examine adults’ discrimination of foreign and native language contrasts in a paradigm which simulated some aspects of Experiments I and II. It should be emphasized that a direct comparison of infant and adult skills was not being attempted. In fact, it is questionable whether such a comparison is even possible, given inevitable differences in the functional significance of any task for infant and adult populations. The more limited goal of the present effort was simply to ascertain the ease or difficulty of certain foreign differentiations for adults.

Pilot testing for Experiment II had revealed that adults were experiencing difficulty with some different tasks involving the Czech contrasts. However, it was possible that such difficulties would disappear if the stimulus contrasts would be presented in a series which embodied repeated presentations of each stimulus. Since French contrasts cannot be considered foreign in a country where French is the second official language, consideration was limited to the Czech contrasts.

Method

Subjects.—The subjects were 10 advanced students of psychology at the University of Toronto, all of whom had English as their first language. Four subjects spoke a second language, and two additional subjects understood a foreign language. However, none of the participants spoke or understood Czech.

Materials.—Sixteen trial series were prepared, eight of these comprising English syllables and the remaining eight Czech syllables. Each trial series comprised 10 sounds separated by interstimulus intervals of 1, 2, 3, 4, or 5 seconds which were assigned randomly. There were four change and four no-change trials for the English and Czech series. On change trials both members of the contrast pair were presented; on no-change trials only one member of the contrast pair occurred. Change trials involved only one instance of a phonetic change, from [za] to [fa] or [r?u] to [za] in the case of the Czech sounds, and from [li] to [ri] or [r?i] to [li] in the case of the English sounds. The latter consonant pair was selected as comparison stimuli because of the reported difficulty experienced by Orientals with these sounds (Goto 1971). The position of the sound change in the change trials was assigned randomly with the constraint that such a change could not occur earlier than the third position. The series were thus of the following type: AAAAAABBBB (change), BBBBBBBBBB (no change), BBBAAAAAAA (change), BBBBBBBAAA (change), AAAAAAAAA (no change), etc. The intertrial interval was 10 seconds. Stimuli for the Czech series were obtained from the master tape from which the tape loop of Experiment II had been prepared. Stimuli for the English series were prepared by a native speaker of English. Both tapes were verified by several native speakers. During testing sessions the stimuli were presented at approximately 62 db against an ambient noise level of 38 db (A scale).

Procedure.—Subjects were tested individually. They were each given a page of printed instructions with the following information. They were told that they were participating in an experiment on speech sound discrimination, that each trial would consist of a series of sounds, and that their task was to decide whether a change of sound had occurred within each series of sounds. They were also told that on change trials sound A would be presented a number of times, followed by sound B which would continue for the remainder of the series; on no-change trials the same sound would occur throughout the series. They were given several written examples of possible series.

They were told as well that they would hear three sample trials prior to the test trials. The first sample trial illustrated a Czech no-change trial, while the second and third illustrated English and Czech change trials, respectively. Subjects were
instructed to indicate their judgment as to the change or no-change status of each test trial by circling yes to indicate a change and no to indicate no-change. Furthermore, they were requested to estimate the confidence of their judgment by checking the appropriate rating from 4 (very sure) to 1 (guessing). Subjects were instructed to record their answers only at the conclusion of each trial.

When the subject indicated that he had understood the instructions and was ready to proceed, the experimenter turned on the tape recorder and left the room. The experimenter returned at the conclusion of the 16 trial series.

Results

The combined yes and no responses for all subjects on English and Czech change and no-change trials are presented in figure 2. It is readily apparent that subjects discriminated the English contrasts [li] and [ri] with perfect accuracy. Pearson's $\chi^2$ test was used to determine the existence of an association between subjects' yes (change) and no (no-change) responses and the actual occurrence or nonoccurrence of such change in the Czech series. A significant association was found, $\chi^2 = 8.49, p < .01$, indicating that performance exceeded the level which would be expected by chance. Since the magnitude of this association is not revealed by the $\chi^2$ test, a signal detection analysis was performed. On the assumption that the Czech contrasts differ on at least one physical parameter which is present in only one member of the pair, a signal detection analysis can yield information about the distinguishability of the contrasts. This analysis yielded a $d'$ value of .83, a relatively small value which implies substantial confusion of the two Czech sounds by English speakers. This compared with an obtained value of $\infty$ for English contrasts. Furthermore, subjects' uncertainty regarding the change or no-change status of the Czech series was also reflected in comparatively depressed confidence ratings. Mean confidence ratings on Czech change and no-change trials were 2.58 and 2.50, respectively, compared to ratings on English change and no-change trials of 4 and 3.92, respectively (the maximum rating being 4).

Discussion

It appears that the contrasts [za] and [fa], although distinguishable beyond chance levels, are nevertheless readily confused by English-speaking adults. Moreover, the discriminative performance on these foreign contrasts differs markedly from the performance of these same adults with respect to the English contrasts [ri] and [li]. Although the results of Experiment II indicate that infants can discriminate between [za] and [fa], it is possible that their performance on these Czech contrasts also differs substantially from their performance on English contrasts.

According to Jakobson's (1968) theory of phonemic development, the contrasts [za] and [fa], which are rare among languages of the world, should be late acquisitions, while the contrasts [ba] and [pa], which occur with considerably greater frequency in the languages of the world, should appear earlier in ontogeny. Phonemes per se are not an issue in the early months of life when speech contrasts do not signal differences in meaning. Nevertheless, it is conceivable that such factors as degree of universality and order of acquisition of phonemes could be related to perceptual difficulty. Although there is no direct means for assessing the relative perceptual difficulty of various discriminable contrasts for infant subjects, it is possible that with the nonnutritive sucking measure of the present study difficulty would be revealed by the magnitude of differences between experimental (change) and control (no-change) subjects. To evaluate this possibility, data from Experiment II were compared with infant discrimination data on the contrasts [ba]-[pa] which had been collected earlier by Trehub and Rabino-vitch (1972) in the same laboratory, with the same procedure, and under identical conditions. A three-way analysis of variance (groups x minutes x language) was performed on [za]-[fa] data from the 5 postdecrement minutes of the present report
and natural [ba]-[pa] data from the Trehub and Rabinovitch report. No significant interactions between groups (experimental vs. control) and language (Czech vs. English) were obtained, indicating that there was no basis for inferring greater discriminability by infants of the English contrasts [ba]-[pa] compared to the Czech contrasts [za]-[za].

If perceptual confusion is the case for adults but not for infants, then either or both of two factors may be relevant. First, it may be that these perceptual discriminations are accomplished with reference to distinctly different systems in semantic and a-semantic contexts. In the case of productive abilities, a distinct qualitative and quantitative discontinuity has been observed to coincide with the transition from babbling to meaningful utterances (Jakobson 1968; McNeill 1970). Shvachkin (1973) has proposed a comparable perceptual discontinuity which separates random a-semantic perceptions of the first year from an orderly period of semantically based perceptions which begins early in the second year. McCaffrey (Note 2) concurs with the idea of perceptual discontinuity but locates the point of transition at approximately 3 months of age. In any case, the notion of perceptual discontinuity, while provocative, has, as yet, no empirical support.

Second, it is possible that language-specific experience might provoke the ultimate loss of discriminative capacity with respect to nonfunctional phonetic distinctions. This may account for the fact that Oriental adults, for example, fail to distinguish [r] from [l] (Goto 1971). It is possible, then, that development might proceed in the direction of fine to gross distinctions, at least with respect to features which are irrelevant to one's own language. This position contradicts traditional theories of perception which describe development as a process of successive differentiation and refinement (Gibson 1969) or, alternatively, as a response-oriented process by which distinctiveness is acquired (Miller & Dollard 1941).

McCaffrey (1974) has recently attempted to organize the data on infant speech perception in a "preliminary model" which embodies the ontogenetic acquisition of successive levels of linguistic coding over the first few months of life. He contends that the sequence of development proceeds from the initial acquisition of perceptual aspects of speech involving minimal coding or transformation, through simple, then complex phonetic rules, and, ultimately, language-specific phonemic rules. Thus, development proceeds from "low level auditory perception" (p. 26) to linguistically relevant perception or perception in terms of the complex rules of the speech code (Liberman 1970). In the context of the present report, one could then argue that infants were processing the foreign contrasts in "low level" fashion on the sole basis of acoustic differences contrasted with adults' perception of these contrasts on the basis of linguistically relevant acoustic cues. However, this only translates the problem to another form of the perceptual discontinuity issue. Moreover, if progress from simple to complex coding is being accomplished in the early months of life, then this should be reflected in developmental changes in the context of these infant speech perception tasks. Nevertheless, evidence for such developmental change has, to date, been absent from all investigations of infant speech discrimination. In addition, if the young infant is functioning in terms of "low level auditory perception," theoretically he should be capable of differentiating intraphonemic as well as interphonemic contrasts. Nevertheless, attempts to obtain evidence for intraphonemic discrimination have failed (Eimas 1974), even for infants as young as 1 month of age (Eimas et al. 1971).

Similarly, Eimas's (1974) efforts to account for the data of infant and adult speech perception in terms of innate feature detectors or speech-processing analyzers are irrelevant to the interpretive questions of the present report.

Thus, traditional approaches to perceptual development in general, as well as contemporary approaches to infant speech perception in particular, cannot effectively incorporate the data of the present investigation, for these approaches typically embrace the notion of improvement, either with reference to experience (Gibson 1969; Miller & Dollard 1941; Morse 1974) or to the elaboration of linguistic and mental structures (Jakobson 1968; McCaffrey, Note 2). However, if it is the case that discriminative capacity with respect to some speech contrasts does decline with age, then a significant task of future research will be first to ascertain and then to explain the precise course of this process.

Reference Notes


References

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