chol. **18**, 385 (1936); R. Ader, *Ann. N.Y. Acad. Sci.* **159**, 791 (1969)].
17. B. Lindholm, *J. Comp. Physiol. Psychol.* **55**, 597 (1962); S. Levine, in *Roots of Behavior*, E. Bliss, Ed. (Hoeber, New York, 1962), pp. 246–253.
18. R. Bracewell and A. Black, *Learn. Motiv.* **5**, 53 (1974); M. Seligman and G. Beagley, *J. Comp. Physiol. Psychol.* **88**, 534 (1975).
19. J. N. Hingtgen, J. E. Smith, P. A. Shea, M. H. Aprison, T. M. Gaff, *Science* **193**, 332 (1976); H. Anisman and L. Sklar, *J. Comp. Physiol. Psychol.* **93**, 610 (1979).
20. For example, exposure to single or repeated sessions of inescapable shock increases the frequency and severity of ulcers in rats [J. Weiss, *J. Comp. Physiol. Psychol.* **65**, 251 (1968)] or tumors in mice [L. S. Sklar and H. Anisman, *Science* **205**, 513 (1979)] and induces learned helplessness in rats [S. Maier and M. Seligman, *J. Exp. Psychol.* **105**, 3 (1976)]. In humans, exposure to inescapable stress has been linked to depression [M. Seligman, *Helplessness* (Freeman, San Francisco, 1975)], and alterations in MHPG have been associated with subgroups of drug-induced or naturally occurring depressions [R. Watson, E. Hartmann, J. Schildkraut, *Am. J. Psychiatry* **129**, 263 (1972); J. Schildkraut, P. Orsulak, A. Schatzberg, J. Gudeman, J. Cole, W. Rohde, R. LaBrie, *Arch. Gen. Psychiatry* **35**, 1427 (1978)].
21. Supported in part by grants DA-01460 from the National Institute of Drug Abuse and MH-15413 from the National Institute of Mental Health. We thank M. Kling for technical assistance, K. Lyon for preparing the manuscript, and Hoffman-La Roche Inc. for providing the MHPG-SO_4 used in these studies.
* Present address: Ciba-Geigy, Summit, N.J. 07901.

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Contextual Effects in Infant Speech Perception

Abstract. *Infants, aged 2 to 4 months, discriminated synthetic speech patterns that varied in duration of the formant transitions; this variation provides information sufficient to signal the phonetic distinction between a stop consonant and a semivowel in adult listeners. In addition, the discriminability of a given difference in transition duration was a function of both the particular stimulus values and the total duration of the syllable. This contextual effect occurred even though the information for syllable duration came after the transition information. The obtained pattern of discontinuous discriminability was in accord with perception that is relational and categorical.*

In this study of speech perception, we found that young infants discriminated small differences in the duration of formant transitions, acoustic information that is sufficient to signal a distinction between the syllable-initial stop consonant [b] and the semivowel [w] in adult listeners. Of greater importance was the finding that for infants, as for adults, the discriminability of two transitions depended not only on the particular duration values but also on contextual information in the form of syllable duration. This is, to our knowledge, the first demonstration that contextual factors can alter the infants' categorical discriminability function for acoustic information that will soon be relevant for the detection of phonetic distinctions.

Research on the perception of speech in prearticulate infants has shown the presence of sophisticated processing abilities. For example, infants as young as a few months of age are capable of distinguishing small differences in the acoustic dimensions that underlie adult phonetic distinctions based on voicing (*1*, *2*), place of articulation (*3*), and manner of articulation (*4*). In addition, infants discriminate speech patterns much more readily when they signal different adult phonetic categories than when they signal variants of the same adult category (*1*, *5*). This discontinuity in the discriminability function has been interpreted as evidence for categorical perception in infants, a phenomenon that has often, but by no means always, been observed in adult studies of speech perception (*6*). These data suggest that infants have mechanisms for the processing of speech that divide acoustic continua into highly discriminable regions that will form the basis for adult phonetic categories.

Recent studies with adults have demonstrated that perception of phonetic elements involves more than the categorization of information along acoustic dimensions. For instance, there are "top-down" or cognitive influences on speech processing at the phonetic level (*7*). In addition, contextual factors can influence the perception of phonetic segments even when they occur several hundreds of milliseconds before or after the target information (*8*, *9*). In one study of contextual effects, Miller and Liberman (*8*) investigated the influence of an after-occurring contextual factor, syllable duration, on the locus of the phonetic boundary between the stop consonant [b] and the semivowel [w]. The stop-semivowel distinction is signaled by duration of the formant transitions, with shorter transitions identified as a stop and longer transitions as a semivowel. They found that the phonetic boundary along a continuum of transition duration increased systematically as syllable duration was increased by lengthening the vocalic portion of the syllable (*10*). With very short syllables, 80 msec in duration, speech patterns with initial transitions longer than 32 msec were perceived as the semivowel, whereas transitions as long as 47 msec were required for the same percept when the syllable duration was increased to 296 msec. Thus, there are values of transition duration that are ambiguous. Resolution of this ambiguity requires, in the absence of other information, that perception and ultimate classification of transition duration take into account the contextual factor of syllable duration, and thus be relative and not absolute.

We investigated whether the ability to make relative judgments concerning transition duration is within the speech-processing capability of young infants. Our experimental design capitalized on findings that infants are much more likely to discriminate speech patterns if sounds exemplify different phonetic categories than if they are variations of the same category (*1*, *5*). We selected our stimuli from two [ba-wa] continua that differed from each other only in total duration of the individual syllables, being 80 msec in one instance and 296 msec in the other. Within each continuum, syllables differed in duration of the formant transitions. We selected two pairs of syllables from each continuum, the stimuli

Table 1. Mean response rates (number of high-amplitude responses per minute) as function of conditions.

Group	Response measures				
	Preshift			Postshift difference scores*	
	Baseline	Minutes 1 to 7	Minutes 6 and 7	Minutes 1 and 2	Minutes 1 to 4
16-40 short ([b-w])†	25.6	41.1	47.9	+4.0	+4.6
40-64 short ([w-w])	30.4	44.2	48.4	−2.5	−2.2
16-40 long ([b-b])	28.4	40.6	50.3	−3.8	−6.5
40-64 long ([b-w])	27.9	40.1	46.4	+4.3	+3.8
Control	30.6	46.6	50.8	−4.6	−8.5

*Difference scores were obtained by subtracting the average response rate during the 6th and 7th minutes before the shift from the first 2- or entire 4-minute response rate after the shift. †The perceived consonantal quality of the stimuli according to Miller and Liberman (*8*).

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of one pair having transitions 16 and 40 msec long, and the stimuli of the other 40 and 64 msec. According to the results of Miller and Liberman (*8*), whether the two stimuli of a given pair were perceived as having the same or different initial consonants depended on the syllable duration. Specifically, stimuli having transition durations of 16 and 40 msec were perceived as [ba] and [wa], respectively, when the syllables were short but were both perceived as [ba] when the syllables were long. On the other hand, stimuli with transition durations of 40 and 64 msec were both perceived as [wa] when the syllables were short but were heard as [ba] and [wa], respectively, when the syllables were long. Thus, if infants were to perceive the transitions in a relative manner and were also to show greater discriminability for phonetically different stimuli, we would expect the 16-40 pair to be better discriminated when the syllables were short and the 40-64 pair to be better discriminated when the syllables were long.

Our experimental procedure was a modification of the high-amplitude sucking methodology that has frequently been used in studies of infant speech perception. In essence, after obtaining a baseline rate of high-amplitude sucking, the presentation of a synthetic speech pattern was made contingent on the infant's producing a criterial response. Each response yielded a 1-second presentation of the speech pattern plus silence, with the restriction that responses that occurred before the conclusion of one stimulus presentation reset the timer controlling stimulus feedback. This contingency was available for 7 minutes for all subjects, after which time the stimulus was changed by switching channels on the tape deck (*11*). The new stimulus was presented for 4 minutes under the same contingency schedule.

The stimuli [which were prepared on the parallel resonance synthesizer at the Haskins Laboratories (*8*)] were three-formant patterns either 80 or 296 msec long, with transition durations of 16, 40, or 64 msec (*12*). The initial transition period was followed by steady-state formants of various duration, appropriate for the vowel [a].

Eighty infants were assigned randomly to four experimental groups (16-40 short, 40-64 short, 16-40 long, and 40-64 long) and one control group (*13*). The 16 infants assigned to each experimental group received the appropriate stimulus pair, with the order of stimulus presentation counterbalanced across infants. Each of the 16 control infants received a single stimulus, recorded on both tracks of the tape and selected randomly from the six possible stimuli. Evidence of discrimination was inferred from different response rates during the 4-minute postshift period for the experimental and control subjects.

The groups did not differ appreciably before the change in stimulation (Table 1). None of the differences even approached significance at the .05 level. With regard to the postshift data, two questions are of primary concern. (i) Do the postshift scores for the experimental groups differ? and (ii) Which groups show reliable evidence of discrimination? To answer the first question, we performed a two-way analysis of variance, stimulus pair by stimulus duration, on two response measures: the average response rate for the initial two postshift minutes minus the average response rate for the 6th and 7th minutes of the preshift period and the average response rate for the entire 4-minute postshift period minus the same preshift score. For both measures there were no significant main effects ($P > .10$) but a significant interaction ($P < .025$), because the response rates of groups 16-40 short and 40-64 long were higher than those of groups 40-64 short and 16-40 long. As for which groups showed evidence of discrimination, comparisons with the control subjects revealed reliable differences only for groups 16-40 short and 40-64 long ($P < .05$, one-tailed tests), that is, for the two groups that received exemplars from different adult categories. In summary, not only can infants discriminate differences in duration of formant transitions, but they do so in a relational and categorical manner (*14*).

The categorical perception indicates that the mechanisms for the analysis of transition duration in infants are similar in their manner of operation to mechanisms for the analysis of other acoustic cues for speech, for example, voice onset time (*1, 5*). In addition, the evidence for relational processing, showing that perception is influenced by later events, indicates that the infant, like the adult, processes speech in other than a temporally determined, linear fashion. This ability should be especially beneficial for the infant who must come to know the acoustic cues for speech in a relatively brief period of time, despite the fact that the cues for any particular segment are often smeared across units as large or larger than a syllable. That the mechanisms of speech perception are as highly developed in the young infant as these and other data indicate is perhaps not surprising when the importance of speech and language for human development is considered.

PETER D. EIMAS
W. S. Hunter Laboratory of Psychology, Brown University, Providence, Rhode Island 02912
JOANNE L. MILLER
Department of Psychology, Northeastern University, Boston, Massachusetts 02115

References and Notes

1. P. D. Eimas, E. R. Siqueland, P. Jusczyk, J. Vigorito, *Science* **171**, 303 (1971); R. E. Lasky *et al.*, *J. Exp. Child Psychol.* **20**, 215 (1975).
2. L. A. Streeter, *Nature (London)* **259**, 38 (1976).
3. A. R. Moffitt, *Child Dev.* **42**, 717 (1971); P. A. Morse, *J. Exp. Child Psychol.* **14**, 477 (1972).
4. P. D. Eimas and J. L. Miller, *Infant Behav. Child Dev.*, in press; J. Hillenbrand, F. D. Minifie, T. J. Edwards, paper presented at the biennial meeting of the Society for Research in Child Development, New Orleans, March 1977.
5. P. D. Eimas, *Percept. Psychophys.* **16**, 513 (1974); *ibid.* **18**, 341 (1975). For a recent review see P. W. Jusczyk, in *Perspectives on the Study of Speech*, P. D. Eimas, and J. L. Miller, Eds. (Erlbaum, Hillsdale, N.J., in press).
6. A. M. Liberman, F. S. Cooper, D. S. Shankweiler, M. Studdert-Kennedy, *Psychol. Rev.* **74**, 431 (1967); I. G. Mattingly, A. M. Liberman, A. K. Syrdal, T. Halwes, *Cognit. Psychol.* **2**, 131 (1971). But see J. R. Barclay [*Percept. Psychophys.* **11**, 269 (1972)] and A. E. Carney, G. P. Widin, and N. F. Viemeister [*J. Acoust. Soc. Am.* **62**, 961 (1977)] for evidence that categorical perception of consonants does not always occur and Liberman *et al.* and N. A. Macmillan, H. L. Kaplan, and C. D. Creelman [*Psychol. Rev.* **84**, 452 (1977)] for different explanations of categorical perception.
7. W. F. Ganong III, *J. Exp. Psychol. Hum. Percept. Perform.* **6**, 110 (1980).
8. J. L. Miller and A. M. Liberman, *Percept. Psychophys.* **25**, 457 (1979).
9. B. H. Repp, A. M. Liberman, T. Eccardt, D. Pesetsky, *J. Exp. Psychol. Hum. Percept. Perform.* **4**, 621 (1978).
10. J. L. Miller (*Percept. Psychophys.*, in press) has also shown that the peak in the discriminability function at the region of the phonetic boundary between [b] and [w] shifts with changes in syllable duration.
11. We used a fixed period of familiarization rather than the usual procedure of familiarizing the infant with a sound until he attained a performance criterion of familiarization because pilot testing revealed a lower rate of subject attrition without loss of sensitivity with the new procedure.
12. The stimuli were synthesized so that there was a fixed increase in the overall amplitude of the syllable over the course of the entire transition segment. Thus, the variation in transition duration was correlated with a change in the abruptness of the amplitude onset.
13. Of the 80 infants who completed the experiment, approximately half were males and half were females. Approximately one-third of the infants were selected from each of three age levels—2, 3, and 4 months. A total of 143 infants were tested. Of the 63 infants who failed to complete the experiment, 42 infants cried, 11 fell asleep, 9 rejected the nipple, and 1 infant was rejected because of experimenter error. There were no reliable differences in the rate of attrition as a function of stimulus pair.
14. Exactly the same pattern of results was obtained when the average of the entire preshift period was used to compute the difference score in place of the final 2 minutes of the preshift period.
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