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Classification of Bimodal English and Spanish Language Passages by Infants

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This research was undertaken to assess whether 5-month-old infants could discriminate and classify audible and visible, English and Spanish speech passages on the basis of language membership. Forty-eight infants were tested in an infant-control visual habituation procedure. They were habituated to a video display of a woman reciting one of two passages in either English or Spanish. Variables such as speaker identity, meter, number of syllables, affect, facial motion, and speed and intensity of speech were controlled across the English and Spanish versions of each passage. Subjects were randomly assigned to one of three discrimination test conditions: (a) a no-change control, (b) a new passage presented in the old language, or (c) a new passage presented in the new language. It was expected that if infants were capable of classifying passages on the basis of language membership, they would show significant recovery to the new passage when it was presented in the new language, relative to the performance of control subjects, but would generalize habituation across passages of the old language. Results confirmed these expectations. A second experiment identical to the first except for the presentation of silent visual displays demonstrated that classification of languages was not based on visual information for speech. Rather, the auditory information was necessary for classification. These findings are discussed in the context of an invariant-detection view of perceptual development.

infant classification speech language auditory perception habituation

It is now well established that young infants are adept at discriminating a wide variety of speech sounds including consonants, vowels, single syllables, and disyllables on the basis of a diverse set of attributes such as voice onset time (e.g., Eilers, Gavin, & Wilson, 1979; Eimas, Siqueland, Jusczyk, & Vigorito, 1971), formant frequency (Kuhl, 1976, 1977; Kuhl & Miller, 1975; Swoboda, Morse, & Leavitt, 1976; Trehub, 1973), place and manner of articulation (Eimas, 1974; Eimas & Miller, 1980; Hillenbrand, Minifie, & Edwards, 1979;

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Miller, Morse, & Dorman, 1977; Moffit, 1971; Morse, 1972; Trehub, 1976), stress (Jusczyk & Thompson, 1978; Spring & Dale, 1977), and intonation contour (Kuhl & Miller, 1975; Morse, 1972). (See Aslin, Pisoni, & Jusczyk, 1983, or Jusczyk, 1982, for thorough reviews.) Infants are also capable of categorizing speech sounds on the basis of phonetic similarity while ignoring variability along a variety of dimensions (see Kuhl, 1985, or Miller & Eimas, 1983, for recent reviews). They are able to abstract and categorize examples of a specific phoneme across changes in speaker and intonation contour (Kuhl, 1976, 1979, 1983). Hillenbrand (1983) reported that infants are able to categorize a set of different phonemes on the basis of the nasal-plosive distinction. More recently, it has been found that infants are sensitive to cues in the speech stream that mark boundaries between major phrasal units (Hirsh-Pasek et al., 1987), and that even neonates can differentiate novel and familiar speech passages on the basis of extensive prenatal exposure (DeCasper & Spence, 1986). Clearly, infants are adept perceivers of the acoustic information in speech.

Researchers have also investigated the infant's sensitivity to bimodal information in speech. Kuhl and Meltzoff (1982, 1984) found that 4½-month-olds detected invariant relations uniting the spectral information contained in a vowel sound with the articulatory movements of the mouth when voice-lip synchrony was controlled. They suggested that speech is intermodally represented by infants. MacKain, Studdert-Kennedy, Spieker, and Stern (1983) also found evidence for this ability in 5- to 6-month-olds. Furthermore, it has been found that infants detect the voice-lip synchrony in speech streams (Dodd, 1979; Spelke & Cortelyou, 1980; Walker, 1982) and are able to match the sight of a parent's face with the sound of his or her voice (Spelke & Owsley, 1979). Infants are apparently sensitive to several types of optic and acoustic relations in speech.

Most researchers to date who have focused on the infant's perception of acoustic information in speech (with exceptions such as Hirsh-Pasek et al., 1987, and DeCasper & Spence, 1986) have restricted investigation to that of the infant's response to isolated speech sounds. That is, their perception and classification of units, such as vowel sounds, consonants, single syllables, and even two- or three-syllable strings, has been explored with the benefits of a well-controlled laboratory setting, but outside the context of natural, extended speech. Little is known about how these requisite capabilities translate to perception of the diverse and complex stimulation available in ecological speech streams. To date, only a few studies have explored the infant's cognitive and perceptual capabilities in the context of natural, extended speech. One exception has been the research focusing on infants' preference for "motherese" (infant-directed speech) over adult-directed speech (Fernald, 1985). Motherese differs from adult-directed speech in a number of ways including exaggerated intonation, longer pauses, shorter utterances, and the repetition of specific words. Fernald and Kuhl (1987) investigated infants' sensitivity to three aspects

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of the intonation patterns characterizing motherese. They found that 4-month-olds showed a preference for the fundamental frequency patterns of motherese over those of adult-directed speech, but they showed no preference on the basis of amplitude or duration patterns. Thus, by 4 months, infants may be sensitive to the patterns of pitch change in extended speech, at least when motherese and adult-directed speech are contrasted.

The present research focused on a different aspect of infants' perception of natural, extended speech—their ability to discriminate and classify bimodal speech passages on the basis of language membership. Adult perceivers have little trouble recognizing the "sound" of a foreign language or discriminating between the speech of their native language and a foreign language. How and when do infants develop these capabilities? Would infants demonstrate an ability to distinguish between passages of different languages, and further, would they classify speech streams on the basis of language membership? The capability for grouping the great phonetic and prosodic variability from the natural speech of a single language together while distinguishing it from that of another language seems fundamental to the development of speech perception and production. To begin to organize linguistic information in a meaningful way, the infant must abstract regularities in speech across changes along a variety of visual and acoustic dimensions. One of the most fundamental levels of organization is language identity. Infants, especially those growing up in bilingual environments, must differentiate the relevant set of visual and acoustic stimulation from which to abstract these regularities.

If, on the basis of a brief exposure to speech passages, young infants were able to group together the diverse set of sounds and prosodic variation when they belonged to the same language, but not when they belonged to different languages, this would constitute evidence for classification on the basis of language identity. To this end, 5-month-old infants were tested using an habituation method where they were exposed to one of two bimodal passages presented in either English of Spanish. For discrimination, they received either (a) a new passage presented in the new language, (b) a new passage presented in the old language, or (c) no change. It was expected that if infants were capable of classifying passages on the basis of language membership, they would generalize habituation to the new passage presented in the old language and show significant visual recovery only to the new passage presented in the new language relative to the performance of control subjects. Generalized habituation across passages of the same language would suggest that infants are capable of grouping the phonetic variability from the natural speech of a single language together—a prerequisite to the formation of concepts such as "native language," "foreign language," "English," or "Spanish." This research, as well as having potential implications for theories of perception and cognition, may ultimately have practical implications for language learning, especially as it relates to learning in infants brought up in bilingual environments.

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EXPERIMENT 1

Method

Subjects. Forty-eight 5-month-old infants whose mean age was 163.6 days ($SD = 4.3$ days) participated in the experiment. Twenty-nine additional infants began the testing procedure but their data were rejected from the study due to excessive fussiness ($n = 12$), experimenter error and equipment failure ($n = 4$), failure to habituate ($n = 3$), and fatigue ($n = 10$). (See procedure section for complete explanation of rejection criteria.) Subjects were recruited through the use of the local birth records, and all were healthy, with no complications upon delivery. According to results of a questionnaire completed by the subjects' parents, 26 of the infants came from monolingual, English homes where English was spoken to the infant 100% of the time, and 22 came from bilingual, English-Spanish homes where English was spoken to the infant an average of 58% of the time.

Stimulus Events. Videotaped displays were made of a woman reciting two different passages in English and in Spanish. The displays portrayed a close-up color image of the woman's face as she continuously recited the passage. The two passages selected for this purpose were words from popular children's songs (''Jingle Bells'' and ''Brother John''), and each had well known English and Spanish translations. Because of the nature of these materials, differences in variables such as meter, number of syllables, complexity, and intonation pattern were minimized across the English and Spanish versions of each passage. For example, the two translations of each passage had the same meter and number of syllables. ''Jingle Bells'' had 36 syllables that were arranged into six lines with groupings of 6,5,7,7,6, and 5 syllables, respectively, and ''Brother John'' had 32 syllables that were arranged into four lines with groupings of 8,6,12, and 6 syllables, respectively. Furthermore, with practice, utilizing visual and acoustic feedback, the actress was able to approximately equate affective expression, speed and intensity of speech, and amount of facial motion across the English and Spanish translations of each passage. In fact, the average rate of speech differed more between passages than between languages. ''Jingle Bells,'' in both English and Spanish, was spoken at a rate of 2.43 and 2.75 syllables per second (total passage length was 14.8 and 13.1 s, respectively). ''Brother John,'' in both English and Spanish, was spoken at a rate of 1.89 and 1.84 syllables per second (total passage length was 16.9 and 17.4 s, respectively). The videotapes were edited such that continuous, successive presentations of the same passage were presented in a manner similar to the stimulation produced by a tape-loop. The actress was a balanced bilingual, English-Spanish speaker, and five American and five Cuban judges agreed that she had an authentic native accent in their respective language.

In addition to the primary stimulus displays, a videotaped display was also made to serve as the control stimulus. This event depicted a red plastic apple,

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held by its stem, banging in an erratic pattern against a grey table top. It emitted its own characteristic impact sounds.

Apparatus. The subject was seated in an infant seat surrounded on three sides by black curtains and faced a standard 19-in (Panasonic BT-S1900N) video monitor, approximately 55 cm away. The video monitor was surrounded by black posterboard. Two apertures (one toward the upper right- and the other toward the upper left-hand corners of the screen) were cut into the posterboard from which the observers could monitor the subject's visual fixations. A set of colored Christmas tree lights and a mechanical toy dog were positioned above and just to the right of the video display.

All stimulus displays were videotaped with a Panasonic WV 3170 color video camera and a Sony EMC-150T miniature remote microphone. They were then edited and presented with a Panasonic VHS NV-A500 edit controller connected to two Panasonic video decks (NV-8500 and AG-6300). The use of two video decks in all conditions allowed us to switch from one video display to another on the same monitor without extra time resulting from changing cassettes. All soundtracks were presented through a speaker positioned just beneath the video monitor.

Observers wore Tandy 12-198 radio headphones which produced white noise at approximately 79 db. This served to mask the stimulus sounds (which averaged 65–70 db) during the dishabituation sequence and ensured that the observer was blind to the condition presented. The observer(s) recorded infant visual fixations during the entire session by depressing a button as long as the infant was fixating the video image. The button boxes were connected to an Apple IIe personal computer which was programmed to record fixation on line, signal when the infant had looked away for a given amount of time, and signal when the infant had reached a preset habituation criterion. The signal was transmitted through a small speaker and headphone to the experimenter who operated the video equipment from a table behind the infant seat. A permanent record of the infant's visual fixation pattern was printed throughout the experiment using a Qume Letterpro 20-S printer. Only the observations of the primary observer controlled the stimulus presentation, while the observations of the secondary observer were simply recorded by the computer and used for later calculation of interobserver reliability.

Procedure. Prior to testing, the subject's parent was interviewed by the experimenter to assess the degree of exposure the child had to the English and Spanish language. Data were obtained for a number of specific questions including an estimate of the percentage of time the infant heard English versus Spanish spoken to him/her. This served as our measure of linguistic background.

Subjects were tested using an infant-control habituation procedure (Horowitz, Paden, Bhana, & Self, 1972). Prior to presenting the habituation se-

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quence, a control display was presented to assess the subject's natural level of visual fixation to moving stimuli and to provide a warm-up period during which the subject could become accustomed to the experimental setting. The observer's recording of this trial and all habituation and test trials was initiated as soon as the infant fixated the visual display and was terminated once the infant had looked away for 1.5 s. In addition, a ceiling of 120 s was set as the maximum trial length, and the trial was automatically terminated once it exceeded this length. The intertrial intervals were approximately 6 s long, and the colored lights were always illuminated during this period.

Infants were habituated to a display of the woman reciting one of two passages in either English or Spanish. The habituation sequence consisted of four mandatory trials and was then terminated as soon as the infant reached a preset habituation criterion. The criterion was defined as a fixation decrement of 50% or greater on two consecutive trials, relative to the infant's initial fixation level (the average number of seconds fixation during the first two habituation trials). Following the two criterion trials, two (no-change) posthabituation trials were presented. The addition of these two trials established a more conservative habituation criterion, serving to reduce chance habituation and taking into account spontaneous regression effects (see Bertenthal, Haith, & Campos, 1983, for a discussion of these effects). Following the habituation sequence, subjects received two identical test trials to assess discrimination and then a single trial during which the control display was again presented. The 48 subjects were randomly assigned to one of three discrimination test conditions. They received test displays depicting the woman reciting (a), the new passage in the new language, (b) the new passage in the old, habituated language, or (c) a no-change control, the old passage in the old language. Passage presented for habituation ("Jingle Bells" vs. "Brother John") and language of habituation passage (English vs. Spanish) were counterbalanced across subjects such that four subjects in each condition received each of the four language-passage combinations.

The subject's data were examined to determine whether two minimum criteria for habituation and attentiveness had been met. To ensure that subjects in the sample had in fact habituated to the stimulus event, data from subjects whose mean posthabituation fixation level exceeded that of their mean initial fixation level (baseline) were excluded from the study ($n = 3$). Second, to ensure that infants in the sample were not overly fatigued, and thus unable to show visual recovery, their length of fixation during the final control trial was compared with that of the initial control trial. If the final control fixation was less than 20% of their initial level, the subjects' data were also omitted from the study ($n = 10$). The remaining 48 subjects in the sample showed substantial recovery on the final control trial (median = 86% of initial fixation level).

A secondary observer monitored visual fixations for 21% of the infants in the sample for the purpose of assessing interobserver reliability. Total fixation time on each trial was calculated independently from the records of the primary

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and secondary observers for each infant. Interobserver reliability, expressed as a Pearson product-moment correlation between these observations, was .98.

Results and Discussion

Primary Analyses: Discrimination Test Scores. As a measure of recovery to the discrimination test display, a difference score was calculated for each infant. Fixation times for the two posthabituation trials were averaged and subtracted from the mean fixation time infants devoted to the two test trials. This difference, referred to here as the "recovery" score, reflects an infant's change in fixation level to the discrimination test stimulus relative to his/her own habituation level.[1] Figure 1 displays the amount of visual recovery to the discrimination stimulus as a function of the test condition. As can be seen from the figure, recovery was much greater to the new passage presented in the new language than to the new passage presented in the old language or to the no-change control stimulus. In fact, recovery was near zero in these latter two conditions. Results of a one-way analysis of variance on recovery scores revealed a significant main effect of Condition, $F(2,45) = 4.41$, $p < .02$. Planned t tests were conducted to examine the nature of these differences. Results confirmed the above observation; recovery in the new passage-new language condition was significantly greater than that of the no-change control condition, $t(30) = 2.32$, $p < .02$, one-tailed. Recovery in the new passage-old language condition did not differ significantly from that of the control condition, $t(30) = 1.40$, $p > .05$, despite the fact that subjects heard on average approximately 10.5 repetitions of the habituation passage before receiving a change in passage. Subjects apparently generalized habituation across passages of the same language but showed no visual recovery to a new language. Furthermore, recovery in the new passage-new language condition was also greater than that of the new passage-old language condition, $t(30) = 1.91$, $p < .05$, one-tailed. Infants showed significantly greater recovery to a new passage when it was presented in a new, rather than an old, language. None of the above differences were accountable for on the basis of a priori differences across the three conditions in habituation behavior (as described in the next section). These findings are consistent with our main expectations. Five-month-old infants showed evidence of discriminating a change in language across varying passages but showed no evidence of discriminating a change in passage within a single language. These results support an interpretation of classification on the basis of language membership.

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[1] Results of a Levene Test for unequal cell variance revealed a significant effect for recovery scores, $F(5,42) = 5.59$, $p < .0005$. Thus, all analyses involving these scores were conducted with both parametric and nonparametric tests. Because results of the two types of analyses were completely comparable, and the analysis of variance is fairly robust in this respect, only results of the parametric tests will be reported here.

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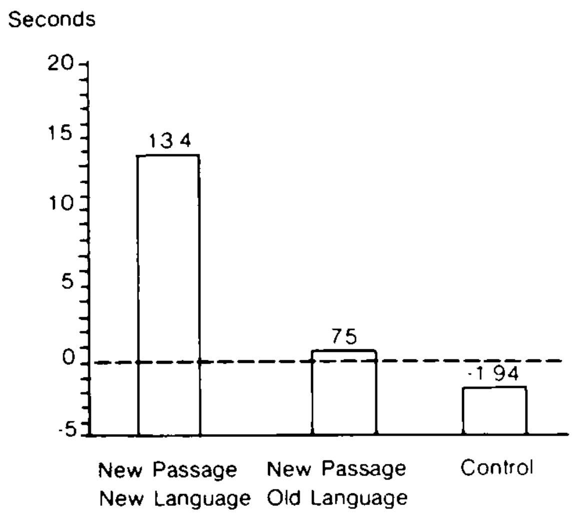

Figure 1. Experiment 1: Mean visual recovery to the test display as a function of the discrimination test condition.

Further analyses were performed to determine whether the visual recovery scores of subjects in the new passage–new language condition were influenced by the language or the passage used during discrimination. Although subjects tended to show more visual recovery to the new language when it was English than when it was Spanish ($M = 17.3$ s vs. 9.5 s), this difference did not reach significance. A two-way analysis of variance with Language and Passage as main factors indicated no significant main effects or interaction, $p > .50$ for all effects. Thus, subjects in this small sample showed no reliable differences in levels of recovery as a function of the language or passage presented for habituation.

In addition, for the new passage–new language condition, the effects of subjects' linguistic background on visual recovery scores to Spanish versus English passages were assessed. Subjects were classified into two groups (monolingual English, $n = 8$, $M = 100\%$ English; and bilingual English/Spanish, $n = 8$, $M = 42\%$ English) according to parental reports of the percentage of time the infant was spoken to in English versus Spanish. A two-way analysis of variance with Linguistic Background (monolingual vs. bilingual) and Language of Discrimination Passage (English vs. Spanish) as main factors indicated no significant main effects or interactions, $p > .1$ for all effects. Thus, subjects from monolingual, English backgrounds showed no evidence of greater visual recovery to new English passages than to new Spanish passages, nor did they show greater recovery to English passages than did subjects from bilingual backgrounds. Thus, in this small sample, differential familiarity with the two languages had no effects on visual recovery scores.

Secondary Analyses: Habituation Performance. The performance of subjects during the habituation phase is summarized in Table 1. Presented in this table, as a function of condition, are (1) baseline, defined as the average length

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TABLE 1
Experiment 1: Habituation Performance Along Five Variables as a Function of Discrimination Test Condition

		Habituation Performance Variables				
Test Condition		1 Baseline	2 *N* of Trials	3 *N* of Seconds	4 Criterion	5 Posthabituation
New passage–new language	*M*	42.9	7.9	186.6	6.8	6.9
	SD	42.8	2.6	131.9	7.4	8.0
New passage–old language	*M*	50.5	7.1	173.9	6.3	9.5
	SD	41.2	1.3	106.1	3.6	12.0
No-change control	*M*	40.8	7.5	164.0	5.7	6.0
	SD	35.0	1.9	111.4	4.8	4.6

Note. Habituation performance variables represent (1) number of seconds fixation averaged over the first two habituation trials, (2) number of trials to habituation, (3) cumulative number of seconds fixation to habituation, (4) number of seconds fixation averaged across the two criterion trials, and (5) number of seconds fixation averaged over the two posthabituation trials.

of fixation on the first two habituation trials; (2) mean number of trials to habituation; (3) mean number of seconds to habituation, summed across trials, (4) average length of fixation on the two criterion trials; and (5) average length of fixation on the two (no-change) posthabituation trials. Analyses of variance assessing the main effect of Condition (new passage–new language, new passage–old language, and control) were performed separately on each of the five habituation measures listed above. These analyses were conducted to examine whether initial interest level (baseline), final interest level (posthabituation), or pattern of habituation (all other measures) differed across the three conditions prior to introducing the differential treatment. Results of all five analyses indicated no significant main effects, $p > .1$ for all tests, suggesting that the subjects' initial and final levels of interest in the stimulus displays and their patterns of habituation were comparable across the three conditions.

As suggested by Bertenthal et al. (1983), the two final habituation trials (criterion trials) provide an artificially low estimate of the subject's habituated level of fixation to the stimuli due to the imposition of the habituation criterion. Note that means for the posthabituation trials are consistently higher than those of the criterion trials because they reflect regression effects. For this reason, mean fixation during the two posthabituation trials (taken after the criterion had been met) was used here as the estimate of the subject's final interest level in the habituated event (and was used for calculating recovery scores, our primary dependent variable discussed in the prior section).

Results of the habituation sequence were subjected to a two-way repeated-measures analysis of variance to confirm that habituation to the language passages had in fact occurred for all three groups. Main effects of Stimulus Condition and Habituation Trial (baseline fixation vs. posthabituation fixa-

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tion levels) were assessed. Results indicated only a significant main effect of Trial, $F(1,45) = 47.6$, $p < .0001$, confirming our expectation that subjects habituated to the stimuli.

In order to assess any effects of the language of habituation passage (English vs. Spanish) or the passage presented ("Jingle Bells" vs. "Brother John") on subjects' initial and final interest level and rate of habituation across the three conditions, three-way analyses of variance were performed separately for each of the five measures depicted in Table 1. Results indicated no significant main effects or interactions, $p > .05$, for any of the analyses. Subjects did not perform differently during habituation as a result of receiving English versus Spanish passages or "Jingle Bells" versus "Brother John." Taken together, the above analyses indicate that there were no important a priori differences across the three conditions in either patterns of habituation or preferences for particular passages or languages. Thus, the recovery scores used for the primary analyses were not biased by any such differences.

Further analyses were conducted to determine whether the linguistic background of the subject influenced habituation performance as a function of the language of the habituation passage. Parental reports of the percentage of time the infant was spoken to in English and/or Spanish were used. Infants were classified into one of two groups, monolingual English ($M = 100\%$ English) and bilingual English-Spanish ($M = 62\%$ English), on the basis of a median split. (Two monolingual subjects were randomly assigned to the bilingual group to accomplish the median split.) Two-way analyses of variance, with Language of Habituation Passage and Linguistic Background of the subject as main factors, were performed separately for each of the five habituation measures depicted in Table 1. Across the five analyses only one significant interaction was obtained, and no significant main effects were observed. Monolingual, English subjects attended more to the English than to the Spanish passages and bilingual subjects attended more to the Spanish than to the English passages during the posthabituation trials, $F(1,44) = 4.67$, $p = .04$. This interaction is consistent with a familiarity effect based on linguistic background where subjects familiar with Spanish attended more to the Spanish passages than those not familiar with Spanish, and those most familiar with English attended most to the English passages. This finding leads one to speculate that more robust effects of linguistic background may be obtained in future research where linguistic background is systematically manipulated as an independent subject variable. In the present study, these effects were not of primary concern and would be minimized because no monolingual, Spanish subjects were included in the sample.

EXPERIMENT 2

The major findings of Experiment 1 suggested that infants classified bimodal speech passages on the basis of language membership while ignoring changes in passage. However, because the language presentations were bimodal, it

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could not be determined from this study whether this classification ability was primarily based on auditory information, or whether the accompanying visual information was necessary for classification. This distinction, however, seems crucial for directing future research on the specific bases of infants' classification of languages. Although the actress in our films was careful to equate visual information such as facial movement and affect across passages of the two languages, it remains possible that there were subtle differences in the visual information for speech that distinguished the languages but not the passages. Such differences may be inherent in the speech patterns of different languages. If so, and if infants detect these differences, then under conditions where only visual information for speech is available, they should demonstrate significant discrimination of a new passage presented in a new language relative to control performance. Thus, this study was conducted as a visual control for Experiment 1 to determine whether visual information alone was sufficient to account for the observed classification abilities.

Method

Subjects. Twenty-four 5-month-old infants whose mean age was 164.0 days ($SD = 7.9$ days) participated in the study. Data from 16 additional subjects were collected but rejected from the study due to excessive fussiness ($n = 5$), experimenter error and equipment failure ($n = 2$), failure to habituate ($n = 2$), and fatigue ($n = 7$). According to results of the questionnaire completed by the parents, 8 of the infants came from monolingual homes where English was spoken to the infant 100% of the time, 6 heard English 99% of the time, and the remaining 10 came from bilingual, English-Spanish homes where English was spoken to the infant an average of 53% of the time.

Procedure. The stimulus events, apparatus, and procedures were identical to those of Experiment 1 with only a few exceptions. The same stimulus displays were used in this study only without their audio accompaniment. Thus, infants viewed silent films of the woman speaking during habituation and test sequences as well as silent initial and final control displays. The 24 infants were randomly assigned to one of three discrimination test conditions, with 8 subjects in each condition: new passage-new language, new passage-old language, and the no-change control. All counterbalancing was identical to that of Experiment 1. The same criteria for ensuring that subjects had in fact habituated to the displays were maintained for this study. However, the criterion for ensuring that subjects were not overly fatigued was relaxed somewhat because by the end of the test sequence subjects were generally less attentive to the silent control display than they had been to the sounding control display of Experiment 1. Thus, the criterion was reduced from 20% to 10% so that if the final control trial fixation was less than 10% of the initial control trial fixation, the subject's data were omitted from the study ($n = 7$). The remaining 24 subjects

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in the sample showed substantial recovery on the final control trial (median = 54.8% of initial control trial fixation).

A second observer monitored visual fixations for 46% of the subjects. Interobserver reliability, expressed as a Pearson product-moment correlation between observations of the primary and secondary observers, was .99.

Results and Discussion

Primary Analyses: Discrimination Test Scores. Recovery scores to the Discrimination test stimuli were calculated as before and are depicted as a function of test condition in the final column of Table 2. As can be seen from the table, all scores are near zero. A one-way analysis of variance indicated no significant main effect of Condition, $F(2,21)=0.11$, $p>.1$. In contrast with the results of Experiment 1, subjects did not show differential visual recovery as a function of test condition. Recovery to the new passage presented in the new language did not differ from recovery in the no-change control condition, $t(14)=0.12, p>.1$. Thus, subjects in this study showed no evidence of discriminating a change in language as they had in Experiment 1 where auditory information for speech was available. These findings suggest that the auditory information available in Experiment 1 was a necessary condition for infants' classification of passages on the basis of language membership. Visual information alone was an insufficient basis for classification. Furthermore, a t test was conducted to compare the recovery scores of subjects in the new passage–new language conditions of Experiment 1 versus Experiment 2. Results indicated that infants showed significantly greater recovery to the new passage

TABLE 2
Experiment 2: Habituation Performance Along Five Variables and Recovery as a Function of Discrimination Test Condition

		Habituation Performance Variables					
Test Condition		1 Baseline	2 *N* of Trials	3 *N* of Seconds	4 Criterion	5 Post-habituation	Recovery
New passage–new language	*M*	38.7	7.4	140.9	7.0	9.6	−0.1
	SD	24.1	2.5	57.1	5.7	16.3	9.6
New passage–old language	*M*	38.1	7.0	121.0	8.0	6.0	−1.1
	SD	35.6	1.4	90.4	8.8	3.6	4.6
No-change control	*M*	49.4	6.1	181.4	8.5	7.2	0.4
	SD	29.2	0.4	121.7	9.6	7.7	4.2

Note. Habituation performance variables represent (1) number of seconds fixation averaged over the first two habituation trials, (2) number of trials to habituation, (3) cumulative number of seconds fixation to habituation, (4) number of seconds fixation averaged across the two criterion trials, and (5) number of seconds fixation averaged over the two posthabituation trials. Recovery scores reflect the difference between the average test trial and posthabituation fixation levels.

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presented in the new language in Experiment 1 ($M = 13.4$) as compared with Experiment 2 ($M = -0.1$), $t(22) = 1.84$, $p < .05$, one-tailed.

A two-way analysis of variance indicated that the recovery scores of subjects in Experiment 2 were uninfluenced by the language or the passage presented during habituation, $p > .05$ for all effects.

Because no recovery to test trials was observed in any of the groups and because the fatigue criterion had been relaxed from 20% to 10% for subjects in this study, it was important to determine whether, in fact, subjects in this study were capable of showing significant recovery to a new visual display and were not overly fatigued. To address this question, a two-way repeated-measures analysis of variance was performed with Condition (new passage–new language, new passage–old language, and control) as one factor and Trials (posthabituation fixation vs. final control trial fixation) as the repeated-measures factor. Results indicated a significant main effect of Trials, $F(1,21) = 16.50$, $p < .001$, and no other significant effects. Subjects showed significantly greater fixation on the final control trial ($M = 29.6$) than on the posthabituation trials ($M = 7.6$), demonstrating significant recovery of attention to the final control stimulus. Thus, subjects in this study were indeed capable of showing visual recovery to a change in visual stimulation, and their lack of recovery to the new passage presented in the new language cannot be accounted for on the basis of fatigue.

Secondary Analyses: Habituation Performance. The performance of subjects during the habituation phase on the five measures of habituation performance (identical to those assessed for Experiment 1) is summarized in Table 2. As in Experiment 1, analyses of variance assessing the main effect of Condition (new passage–new language, new passage–old language, and control) were performed separately for each of the five measures of habituation. Results of all five analyses indicated no significant effects, $p > .1$ for all tests, suggesting that subjects' initial and final levels of interest and their patterns of habituation were comparable across the three conditions.

In order to determine whether habituation to the visual passages had in fact occurred, a two-way repeated-measures analysis of variance was performed with Condition and Trials (baseline fixation vs. posthabituation fixation) as factors. Results indicated a significant main effect of Trials, $F(1,21) = 37.69$, $p < .0001$, confirming that subjects did habituate to the visual displays.

Further analyses assessed the effects of language and passage on subjects' performance during the habituation sequence as a function of Condition. Three-way analyses of variance were performed separately for each of the five measures of habituation and yielded no significant effects for any of the measures, $p > .1$, all measures.

Taken together, findings from the above analyses indicate that there were no important a priori differences across the three conditions in habituation performance and that subjects did show visual habituation to the silent displays.

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The performance of subjects during the habituation phases of Experiments 1 and 2 was also compared. Analyses of variance with Experiment (1 vs. 2) and Condition as factors were performed separately on each of the five habituation measures and revealed no significant main effects or interactions, $p > .1$, all measures. Subjects showed no differences in initial or final interest levels or in their patterns of habituation across the two experiments.

CONCLUSIONS

The question addressed by this research concerned whether infants could discriminate and classify bimodal speech passages on the basis of language membership. Five-month-old infants demonstrated this ability in Experiment 1 by showing renewed interest (relative to no-change control performance) when a new passage was introduced in a new language, but not when it was introduced in the old, familiarized language. They showed no evidence of recovery to a change in passage alone at this age. Infants even showed significantly greater recovery to the new passage when it was presented in the new language than when it was presented in the old language. These results support the conclusion that infants, by 5 months, can discriminate and classify naturalistic, audible, and visible speech on the basis of language membership. Furthermore, the results of Experiment 2 (where silent visual displays were presented) demonstrated that this ability is not based primarily on visual information for speech. Rather, the auditory speech information available in Experiment 1 was necessary for the classification of languages.

On what basis might infants have performed as they did, grouping bimodal speech passages according to language membership? A variety of potential explanations exist, some more plausible than others. Several theoretically less interesting differences that typically differentiate English and Spanish speech were minimized by our choice of passage or were controlled by the actress. For example, the actress was able to roughly equate amount and type of affect, speed and intensity of speech, and amount of facial motion across the English and Spanish translations of each passage, and, as demonstrated by Experiment 2, visual information alone was not a sufficient basis for classification. In addition, our method of stimulus presentation, in which new trials began where old trials left off, eliminated the possibility of discrimination on the basis of initial or final phoneme, because this varied from one trial to the next. Furthermore, the translations of each passage had the same number of syllables, and, though theoretically more interesting, they also had the same meter.

One potential basis of speech classification is the linguistic background of the infant. That is, the infant's familiarity with one of the languages, and relative lack of familiarity with the other, may have served as the basis for discrimination and categorization. However, two observations make this explanation less tenable. First, our sample was composed of infants who live in the multicultural community of Miami, Florida, where only 54% were from

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monolingual, English-speaking homes, and the remainder were from bilingual, English-Spanish homes. Thus, in this study the infants' differential familiarity with the two languages was minimized, making it more difficult to obtain an effect on this basis even if it were an important factor. Second, if results were based primarily on differential familiarity with the two languages, one would expect differential patterns and rates of habituation as a function of whether the habituated passage was in the familiar or unfamiliar language. Analyses revealed only weak effects of linguistic background on habituation performance. Differential familiarity with the two languages was not necessary for classification on the basis of language membership. These observations certainly do not rule out the role of experience as an important basis for classification of languages. They simply suggest that the effects of differential experience were minimized in this study. Because all subjects were familiar with at least one of the languages used in this study, it remains possible that some experience with one of the languages is necessary for classification of languages at this age.

What might be the nature of the speech information infants used as a basis of discriminating between languages? Three potential explanations are entertained here. First, infants might have differentiated and categorized the passages on the basis of a single phoneme or a small set of distinctive phonemes. For example, the Spanish language contains several sounds not found in English (e.g., trilled *r*, dental *t* and *d*, and the voiced, bilabial, fricative β), and the English language contains many sounds not found in the Spanish language (e.g., the *v* as in *vest*, the *th* as in *thin*, and the *r* as in *run*). (See Politzer & Politzer, 1972, for further examples.) It is possible that infants in the new passage–new language condition noticed the occurrence of one or several new sounds, or the lack of occurrence of one or several old sounds in the discrimination passage, and discriminated on this basis, whereas infants in the new passage–old language condition generalized habituation across passages because of the continued presence of these distinctive phonemes across two passages of the same language. However, this explanation may be limited in that many "new" sounds also occurred in the new passage of the old language and many "old" sounds occurred in the new passage of the new language. How would infants select a set of phonemes that was distinctive to one of the languages rather than shared by both, and how would they select a set of phonemes that was not distinctive to one of the passages within a language but was shared by both of the same language? Finally, the "distinctive phoneme" explanation is further complicated by the fact that the infant must "decide," after an average of 4 s exposure (i.e., mean test trial fixation for no-change control subjects) to the discrimination test stimulus, whether or not to stop looking (if it is the same language) or to continue looking (if it is a new language). This brief period may not be a long enough sample to include the specific phonemes selected, even if they were ones that correctly distinguished the two languages. Nevertheless, the distinctive phoneme explanation cannot be ruled out as a basis for classification of languages.

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A second explanation is that infants may have classified speech passages on the basis of phoneme-order differences across the English and Spanish languages. As in the case of distinctive phonemes, English and Spanish share many phoneme sequences, but there are also sequences that are language-specific. For example, Spanish uses a much smaller number of initial *CC* or *CCC* combinations before vowels than does English; Spanish has no initial *s* before a consonant as does English; it has the three nasals as in English, but, unlike English, when they occur before a consonant, *m* is only used before a labial, *n* before a dental, and *ɲ* before a velar; and Spanish has no initial *w* as in *way,* unless preceded by a vowel sound (see Politzer & Politzer, 1972, for further examples). The phoneme-order hypothesis, however, is subject to the same criticisms as the distinctive phoneme hypothesis above. How would infants selectively attend to phoneme sequences that were language-specific rather than shared by the two languages and to sequences that were not passage-specific? Furthermore, even if the selected sequences were language-specific, they may or may not occur in the first 4 s of the discrimination test trial. Though problematic, the phoneme-order explanation also cannot be ruled out as a basis of classification.

A third explanation for infants' classification of speech on the basis of language membership is a sensitivity to suprasegmental or prosodic aspects of speech that typically differentiate the two languages. Infants may have abstracted invariant relations specifying the overall "sound" or rhythm of one language and differentiated this from the overall "sound" or rhythm of the other language. Consistent with Gibson's (1969) invariant-detection view of perceptual development, there may be higher-order invariant relations characterizing the visually and acoustically presented speech of different languages. The English and Spanish languages are characterized by different rhythmic structures and intonation patterns. English is more variable than Spanish in stress, rhythm, and intonation (see Stockwell & Bowen, 1965, for a detailed discussion). For example, English has four significant pitch levels, whereas Spanish has only three, and they are spaced more closely together than those of English. English has three degrees of stress, whereas Spanish has only two; and Spanish has longer syllable sequences with weak stress, whereas English has a more regular alternation of weak and more strongly stressed syllables. Finally, English is a stress-timed language, where stressed syllables are lengthened at the expense of unstressed syllables, and Spanish is a syllable-timed language, where most syllables take approximately the same time to pronounce. These are all examples of higher-order temporal or intensity relations that are invariant across speech samples of a particular language and could serve to distinguish between the naturalistic speech of the two languages. Furthermore, these relations are inherent in the flow of speech and would be apparent even within the relatively brief speech sample subjects received before "deciding" whether or not to look away from the test displays. According to Gibson's view of perceptual development, infants are capable of detecting higher-order invariant

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relations from the beginning. Thus, no specific linguistic experience would necessarily be required in order for infants to differentiate languages on the basis of suprasegmental invariant relations. Because young infants are capable of detecting similar temporal invariants in other types of audio and/or visual events (Allen, Walker, Symonds, & Marcell, 1977; Bahrick, 1983; 1987, 1988; Chang & Trehub, 1977; Demany, McKenzie, & Vurpillot, 1977; Mendelson & Ferland, 1982; Spelke, 1979), it seems reasonable to expect that they could detect temporal invariants in the domain of speech as well by 5 months of age. Thus, infants may have generalized across passages of the same language, and discriminated to a change in language, on the basis of these global, "suprasegmental invariants." This seems to us the most compelling account of the observed effects.

However, another alternative explanation should also be noted. Rather than detecting suprasegmental invariants, infants may simply have responded to general differences in stimulus variability by a change in arousal level. Because English has more suprasegmental variability than Spanish, infants may have recovered to the new language because of a change in arousal level resulting from a change in stimulus variability. Current findings that have recently come from another lab are consistent with both of the above interpretations. Jusczyk (1986) and Mehler, Lambertz, Jusczyk, and Amiel-Tison (1986) found that 2-month-old American subjects could discriminate between English and Italian passages, and 4-day-old French infants could distinguish between French and Russian passages. When speech samples were low-pass filtered, disrupting phonetic information but preserving variations in fundamental frequency and rhythmic structure, discrimination of languages by the 2-month-olds was still evident.

The present findings also speak to the issue of the young infant's ability to discriminate passages within a language. Under the present relatively brief exposure conditions, 5-month-olds showed no evidence of discriminating a passage (of 32 or 36 syllables), which was repeated an average of 10.5 times, from a novel passage of the same language. However, when the same novel passage was presented in a novel language, discrimination was evident. This suggests that under these exposure conditions, language identity is more salient than passage identity to infants of 5 months. On the other hand, as results of the DeCasper and Spence (1986) study point out, even neonates can discriminate between a novel and familiar passage given extended prenatal familiarization of approximately 6 min per day across a 6-week period. Presumably, with longer familiarization, 5-month-olds would also discriminate between passages within a language. Furthermore, in the context of the present results, one might speculate that neonates, under extended exposure conditions, would be capable of discriminating between passages of different languages more readily than between passages of the same language.

This research has extended the investigation of speech perception to a more ecological context, that of bimodal (audible and visible) extended speech pass-

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ages. Infants were found to be capable of differentiating and classifying naturalistic, English and Spanish speech on the basis of language membership. Whether this capability is based on the detection of distinctive phonemes, phoneme-order information, suprasegmental invariants, and/or stimulus variability was not conclusively determined. Regardless of the ultimate explanation, results of this effort suggest that infants classify the naturalistic, bimodal speech encountered in everyday life on the basis of meaningful dimensions quite early in infancy.

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