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Do Words Facilitate Object Categorization in 9-Month-Old Infants?

MARIE T. BALABAN

The Johns Hopkins University

AND

SANDRA R. WAXMAN

Northwestern University

Previous research reveals that novel words highlight object categories for preschoolers and infants as young as 12 months. Three experiments extend these findings to 9-month-olds. Infants were familiarized to slides of animals (e.g., rabbits). Infants in the *Word* condition heard infant-directed word phrases (''a rabbit'') and infants in the *Tone* condition heard tones. During familiarization, infants' visual fixation was enhanced on trials with sounds (either words or tones), relative to silent trials. On test trials, a new exemplar from the familiar category (e.g., rabbit) was paired with a novel animal (e.g., pig). Infants in the *Word* condition showed greater attention to novelty than those in the *Tone* condition. A third group of infants who heard content-filtered words responded similarly to infants in the *Word* condition. Implications of the facilitative effects of words and content-filtered words on object categorization are discussed within a framework describing infants' emerging appreciation of language over the first year of life.

Recent research has documented that labelling objects with novel nouns highlights object categories for infants as young as 12 months (Waxman &

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Markow, 1995). In these studies, infants were familiarized to a series of objects from the same category (e.g., animals). In the *Noun* condition, the experimenter labeled the objects with a novel noun phrase (e.g., ''See the fauna?''). In the *No Word* condition, the experimenter used a more general phrase (e.g., ''See here?''). On the final test trials, the experimenter presented two objects: a new exemplar from the familiar category (e.g., an animal) and an exemplar from a novel category (e.g., a vehicle). Infants in the *Noun* condition showed a greater preference for the novel (out-of-category) stimulus than did infants in the *No Word* condition. These results suggest that the noun phrases facilitated the extraction of category information during familiarization and enhanced attention to the novel, out-of-category object during the test phase. At 12 months, noun phrases influenced categorization for infants who were tested with superordinate-level object categories (e.g., animal vs vehicle). Waxman and Markow suggested that presentation of the same label with various objects invites infants to search for coherence among the different objects and to form object categories.

This recent finding is important because it suggests that even before infants have accumulated much productive language, they take advantage of a relation between linguistic and conceptual organization. The three studies in this report extend this finding in two ways. First, the experiments examine whether this facilitative effect of novel words on object categorization is evident even earlier, at 9 months of age. Second, the experiments are designed to reveal whether the facilitative effect of novel words is related to the functional significance of language, per se, (c.f. Waxman & Markow, 1995) or to an alerting or attention-engaging function of auditory stimulation in general (Roberts & Jacob, 1991).

Throughout the first year of life, infants make considerable advances in both language and conceptual development. With regard to language, they are attuned to various aspects of speech and language from birth. Young infants distinguish speech from non-speech stimuli and perceive speech sounds categorically (Aslin, Pisoni, & Jusczyk, 1983; Kuhl, 1985). Moreover, the pitch, intonational contours, and other prosodic cues associated with infant-directed speech are particularly attractive to infants (Cooper & Aslin, 1990; Fernald, 1992). By the age of 8 or 9 months, infants may begin to take advantage of these cues inherent in infant-directed speech in their initial attempts to map sounds to their meanings. For example, they begin to identify phrases as they listen to the stream of speech, and they also begin to distinguish familiar words from novel words (Jusczyk et al., 1992; Jusczyk & Aslin, 1995; Kemler Nelson, Hirsh-Pasek, Jusczyk, & Cassidy, 1989; Newsome & Jusczyk, 1994). These accomplishments, which emerge during the latter half of the first year, appear to function as ''perceptual scaffolding on which language-learning strategies can build'' (Hirsh-Pasek et al., 1987, p. 282). Studies of infants' language comprehension reveal that, at 9 months, infants typically have begun to map familiar words to their meanings, in at least a rudimentary fashion (Fenson et al., 1994).

In addition to these advances in language acquisition, infants also make advances in conceptual development during the first year of life. Even young infants demonstrate the ability to categorize geometric shapes and other forms (e.g., Bomba & Siqueland, 1983; Colombo, McCollam, Coldren, Mitchell, & Rash, 1990). Infants also treat prototypic exemplars of basic level animal categories as equivalent by 9 months of age, and perhaps earlier (Eimas & Quinn, 1994; Roberts & Horowitz, 1986; Younger and Cohen, 1986; Kemler Nelson, 1984). Although infants' early object categories may be primarily perceptual in nature (but see Mandler, 1988), their extension overlaps largely with what will subsequently become basic-level categories (Rosch, 1978).

Thus there is ample evidence that, by the age of 9 months, infants attend to various features of language, and they demonstrate categorization of forms and natural objects. In the three studies reported here, we investigate the emerging relation between linguistic and conceptual knowledge by asking whether novel words facilitate the formation of object categories in 9-month-old infants.

If a facilitative effect occurs, it is important to consider whether it stems from the salience of language or from the alerting and attention-engaging functions of auditory stimulation in general. On the one hand, Jusczyk and Bertoncini (1988) speculated that infants might process speech sounds more thoroughly than other sounds because of the salience of speech. On the other hand, a generalized facilitation of visual attention by auditory stimulation has been documented in young infants (Kaplan, Fox, Scheuneman, & Jenkins, 1991; Mendelson & Haith, 1976). Both of these explanations are plausible. For example, Baldwin and Markman (1989) found that 10- to 14-month-old infants looked longer at toys presented with word labels than at toys presented silently. They noted that this result could reflect either a language-based influence or a more general alerting effect of auditory stimulation.

In these studies, we compared the effect of word phrases and tone sequences on infants' categorization at the basic level. The word phrases were count nouns (e.g., ''a rabbit'') presented in infant-directed speech. The *Tone* condition was included as a control to test for the alerting effects of auditory stimulation on infants' visual attention. In the task, which was adapted from a typical novelty recognition procedure, infants viewed photographic slides of drawings of exemplars of a basic level animal category (e.g., rabbit) presented sequentially during a familiarization phase. The subsequent test phase included two trials, each of which paired a novel exemplar of the familiar category (e.g., another rabbit) with a member of a novel category (e.g., a pig). These pictures were displayed simultaneously (as paired comparisons) on each test trial, and different exemplars were used for the two trials. The dependent measure was the infant's visual attention, as indexed by the cumulative duration of their visual fixations to each picture. A fixed-trials design was used in order to equate the task across subjects in the *Word* and *Tone* conditions (Colombo, 1993).

The primary question was whether infants who heard a word phrase re-

peated with different exemplars of a category during familiarization would show greater preferences for novel, out-of-category exemplars on subsequent test trials than would infants who heard a tone sequence. A related question was whether infants in the *Word* condition would show greater habituation than infants in the *Tone* condition during the familiarization phase. In addition the design included some familiarization trials with sounds (i.e., a word phrase or a tone sequence) and some silent familiarization trials, allowing within-subjects comparisons of infants' visual attention on familiarization trials with or without auditory stimulation. We predicted a general alerting effect of auditory stimulation, such that infants would look longer at pictures presented with sound than pictures presented in silence. We also examined whether this effect would be more evident during familiarization for those infants hearing word phrases, relative to tone sequences.

The first two studies compared the responses of infants in *Word* and *Tone* conditions in a basic-level categorization task (rabbit vs pig in Experiment 1; bird vs dinosaur in Experiment 2). The third study replicated the findings in Experiment 2, and extended the investigation of language-based influences on categorization to word phrases that had been content-filtered. The process of content-filtering obscures the intelligibility of words, but preserves the lower frequencies, and thus the intonational contours, of the phrase.

EXPERIMENT 1

Method

Subjects. The 24 participants included 12 female and 12 male healthy infants between 37 and 41 weeks of age ($M = 39$ weeks). Parents were recruited from advertisements in a local parents' paper and from letters sent to families identified through Massachusetts birth records. Data from 15 additional subjects were not included because of non-alert state ($n = 2$), insufficient looking time ($n = 11$) or experimenter error ($n = 2$).

Materials. The visual stimuli included color slides of simple drawings of pigs and rabbits. Animals in each set varied in form (Fig. 1). Each animal was a solid color, outlined in black, and presented against a white background. Animal color varied across slides, but on test trials both animals were the same color. The horizontal edge of the slide frame subtended a visual angle of 38 degrees; each animal subtended about 13 degrees of visual angle.

The auditory stimuli consisted of words and tones. For the *Word* condition, the two noun phrases (''a pig'' or ''a rabbit'') were produced by an adult female using characteristics of infant-directed speech. The two spoken phrases, digitized by an Amiga 2000 computer, were each 1.25 s in total duration and were matched to each other in the durations of words and pauses. For the *Tone* condition, a 400 Hz sine wave tone was digitized and edited into a sequence of two tones, matched to the word phrases in duration of each tone and pause. The stimuli were recorded on audiotape for use during the experiment, and presented through a speaker located below the slide

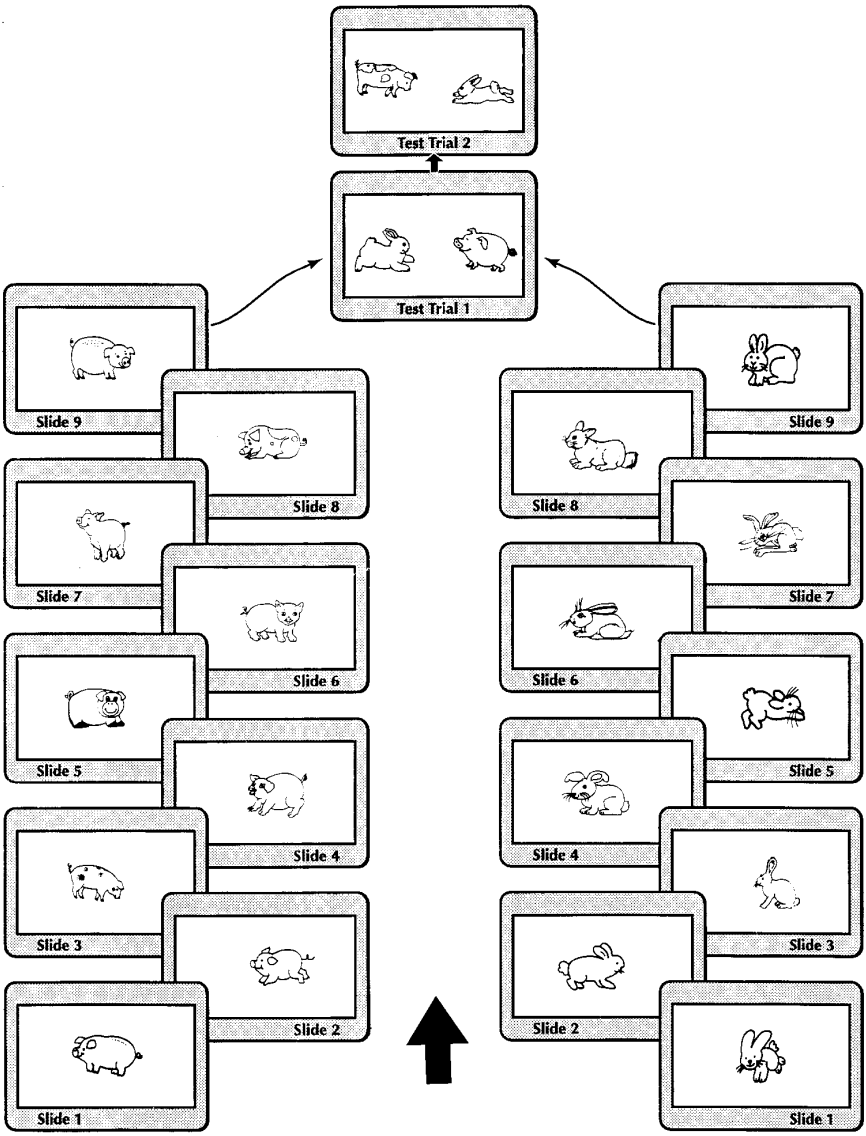

FIG. 1. From bottom to top, the familiarization stimuli (Slides 1–9) for infants assigned to the pig and rabbit familiarization groups followed by the pairs of pigs and rabbits shown during the test trials for all subjects. For half of the subjects, side of presentation of the pigs and rabbits on the test trials was reversed from that shown here.

screen. The words and tones were matched in loudness and were calibrated to 75 dB(A) at the position of the infant's head.

Design. The task consisted of a familiarization phase and a test phase (see Fig. 1). During the *familiarization* phase, infants viewed nine successive

slides, each depicting a different member of a category (e.g., rabbit). Designation of familiar and novel categories (rabbits and pigs) was counterbalanced across subjects. Three of the nine familiarization slides were presented in silence; the remaining six familiarization slides (trials 1, 3, 5, 6, 8, and 9) were presented in conjunction with an auditory stimulus.

Infants were randomly assigned to one of two auditory conditions, *Word* or *Tone,* with approximately equal numbers of males and females assigned to each condition. In the *Word* condition, the six familiarization slides were presented in conjunction with the appropriate spoken noun phrase (i.e., ''a rabbit'' or ''a pig''). In the *Tone* condition, those six slides were presented in conjunction with the tone sequence.

During the *test* phase, infants viewed two slides, each of which depicted both a new member of the familiar category (e.g., another rabbit) and a member of the novel category (e.g., pig). Different pairs of exemplars were presented on each test trial (see Fig. 1). A pilot study revealed no a priori preferences within either of the pairs presented at test. The animals from the novel category were presented at the right side of the slide on one test trial and at the left side on the other test trial; order of right-left presentation was counterbalanced across subjects. For all subjects, the test trials were presented in silence.

Procedure. Upon arrival at the laboratory, the study was described to the parents and their consent obtained. Subjects were tested while sitting on their parent's lap about 80 cm from the rear-projection slide screen ($n = 17$) or while sitting in an infant seat the same distance from the screen ($n = 6$), with the parent standing behind them. One subject who began the session in the infant seat was switched to the parent's lap during the session. The room was dimly lit with a red lamp located behind the infant. Parents were asked to refrain from speaking to the infant or from directing the infant's attention to the screen.

Stimulus presentation was controlled by a computer located in an adjacent room. Each slide was presented for 10 s, and intertrial intervals varied from 3 to 5 s. On the six auditory trials, the onset of the word phrase or tone sequence occurred during the initial 4 s of the slide presentation ($M = 2.6$ s). Times varied due to variations in the relay control of the cassette player.

A trained laboratory assistant observed the infant through a small hole in a curtain next to the screen. The color of a light-emitting diode, located to the side of the infant, signalled the familiarization and test phases. During the familiarization trials, the observer indicated, via a hand-held switch, whether or not the infant was looking at the slide. During the test trials, if the infant was looking at the slide, the observer made continuous forced-choice determinations of whether the infant was looking to the right or left side. The observer was not informed about which side of the screen had the familiar or the novel animals during the test trials. Looking time, as coded by the observer, was computer-digitized and scored. The infant was also videotaped through a small opening in the slide screen.

Parental report. After the experiment, parents were asked a series of ques-

tions in an interview format. We asked the parents whether or not the infant was familiar with each object category (pig and rabbit). This rating was based upon familiarity with the objects (rather than their labels), and could include experience with toys, pictures in books, real exemplars of the category, etc. The parents' responses were coded categorically as ''not familiar'' or ''familiar'' for each object category. Regarding language development, we asked what language(s) were familiar to the infant, and we asked parents to freely recall (a) any words the infant understood and (b) any words the infant reliably produced. In addition, we asked general questions about the infant's health.

Data analysis. For familiarization trials, looking time was measured as the cumulative duration of the infant's visual fixations signaled by the observer during the 10 s slide presentation. For test trials, the computer scored the cumulative durations of left-side and right-side visual fixations, as signaled by the observer.

There were two criteria for including subjects in the final sample. First, they were required to be judged as alert for both test trials. The infant's state was coded from videotape as alert or fussy for each trial. The rating criteria allowed one brief (<2 s) period of fussy behavior or vocalization on ''alert'' trials. State was rated as alert on 98% of familiarization trials for accepted subjects. Reliability of state coding was obtained by comparing ratings of a second observer for one-half of all subjects. For this subset, the two observers demonstrated 98% agreement. The second criterion was that infants' looking times on each of the test trials had to be $\geqslant 3$ s; this was determined from the computer-scored looking times obtained online from the observer.

In order to investigate whether infants in the *Word* and *Tone* conditions showed differences in vocalization in response to the stimuli, we asked a naive observer to code, from videotape, infants' non-fussy vocalizations during the trials. Because vocalizations were infrequent, these data were not analyzed further; the few vocalizations that occurred were not distributed differentially across conditions.

In all analyses with repeated measures, the degrees of freedom were adjusted according to the Geisser-Greenhouse correction (Keppel, 1982). An α criterion of .05 was adopted for all statistical tests. An effect size estimate for F tests, f, is included with reported results. In order to interpret the magnitude of this index, .10 is considered a small effect size, .25 a medium effect size, and .40 a large effect size (Rosenthal & Rosnow, 1991).

Although there were equal numbers of male and female infants in the *Word* and *Tone* conditions in Experiment 1, sex was not counterbalanced with the other variables in the design. A preliminary analysis revealed no significant effects or interactions with sex; therefore sex was not included as a variable in subsequent analyses.

Familiarization phase. The first analysis compares looking times during the familiarization phase in the *Word* vs the *Tone* conditions. The familiarization trials were grouped into three blocks (block 1 = trials 1, 2, 3; block 2 = trials 4, 5, 6; block 3 = trials 7, 8, 9); each block consisted of one silent

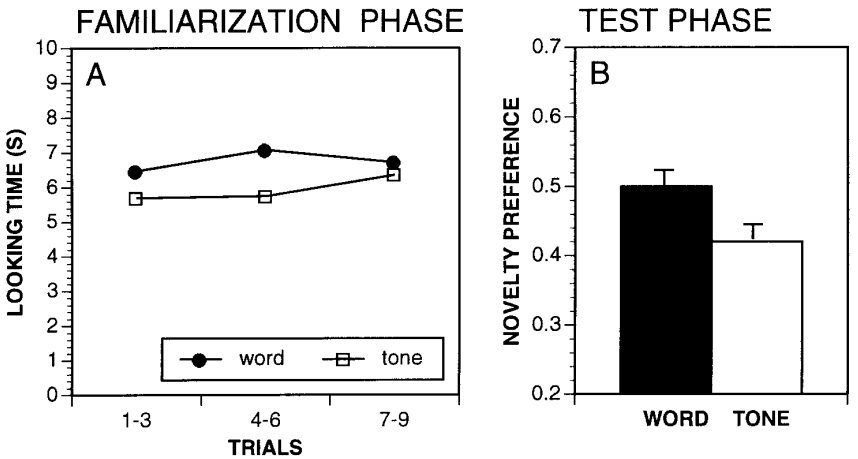

FIG. 2. A. Experiment 1 looking times, averaged over blocks of three trials, during the familiarization phase for infants in the *Word* and *Tone* conditions. Data were averaged across familiarization stimulus type (rabbits or pigs) and trial type (auditory or silent). Standard errors were .33 to .48 s. B. Novelty preferences on the test trials for infants in the *Word* and *Tone* conditions, averaged across familiarization stimulus type. Bars indicate +1 S.E.M.

trial and two auditory trials. The analysis of variance included condition (word vs tone) and familiarization stimulus (rabbit vs pig) as between-subjects variables, and trial block (block 1 vs block 2 vs block 3) and trial type (auditory vs silent) as within-subjects variables. The mean overall amount of looking time accumulated over the nine familiarization trials was about 58 s. There were no significant differences between infants in the *Word* and *Tone* conditions, neither were there differences over blocks. Thus, there was no evidence of habituation during the familiarization phase (Fig. 2A).

The main effect of trial type (Table 1) indicated significant facilitation of infant looking times during the auditory relative to the silent familiarization trials. This supports our hypothesis that auditory stimulation, per se, would facilitate the infants' visual fixation of the slides. There were no other significant effects or interactions.

The observer who coded the infants' visual fixations was present in the test room and could hear the word phrases or tone sequences. In order to rule out the possibility that the differences in fixation time on auditory and silent trials resulted from observer bias, another laboratory assistant later coded the infants' fixations from videotape, without the sound connected, so that they were naive to the condition (*Word* or *Tone*) and to the trial type (auditory or silent). The pattern of results for these data, over the entire set of subjects, also indicated significantly longer looking times during auditory, relative to silent, familiarization trials (Table 1). No other effects or interactions were significant.

Another method of analyzing changes in infants' visual attention during

TABLE 1
Average Looking Times for Auditory and Silent Trials During Familiarization

		Looking time (seconds)		f	
		Auditory trials	Silent trials	(effect size)	F
Experiment 1 (n = 24)					
Coding during experiment	*M*	6.62	5.80	.59	7.09*
	SD	1.41	1.54		
Reliability coding[a]	*M*	6.91	5.75	.73	10.72**
	SD	1.71	2.31		
Experiment 2 (n = 24)	*M*	6.91	6.40	.39	2.92
	SD	1.14	1.32		
Experiment 3 (n = 48)	*M*	7.05	5.79	.90	35.00****
	SD	1.33	1.68		

Note. Effect size estimate described by Rosenthal and Rosnow (1991), $f = \sqrt{\text{eta}^2/(1\text{-eta}^2)}$.
[a] Coded by a different observer off-line from videotape with sound turned off.
* $p < .05$, ** $p < .01$, **** $p < .0001$.

familiarization was employed, in order to characterize the responses of individual infants. For each subject, an individual habituation contrast score (Rosenthal & Rosnow, 1991) was derived by multiplying the average looking time on each familiarization trial block (1, 2, and 3) by the appropriate contrast weights for a linear trend (−1, 0, +1) and summing the resulting products. If a subject did not show a linear change in looking time over familiarization blocks, the contrast score should equal zero. The contrast scores did not differ between *Word* and *Tone* conditions. The average contrast score was 0.46 for the group of 24 subjects, indicating that looking times tended to *increase* from trial block 1 to trial block 3 during familiarization; however, this increase did not differ significantly from zero, $t(23) = 1.55$, $p > .10$.

Test phase. The looking times, averaged for the two test trials, were converted to novelty preference scores by dividing each infant's looking time to the animal in the novel category by their total looking time. A score equal to 0.50 would indicate that the infant spent equal time attending to animals in the familiar and the novel categories across the two test trials. Scores greater than 0.50 indicate relatively greater attention to novelty, and scores lower than 0.50 indicate relatively greater attention to familiarity. These scores were analyzed in an analysis of variance with condition and familiarization stimulus as between-subject variables. There were no significant effects or interactions. However, the difference between *Word* and *Tone* conditions was in the predicted direction (Fig. 2B), $F(1,20) = 4.18$, $p < .06$, effect size $f = .45$.

Follow-up t tests compared whether the preference scores in each condition differed significantly from a score of 0.50. Infants in the *Tone* condition exhibited a significant familiarity preference ($M = .42$, $t(11) = 3.0$, $p < .02$).

The preference scores of infants in the *Word* condition ($M = .50$) did not differ from 0.50. An additional analysis of the direction of preference scores for individual subjects indicated longer fixation of the novel category (i.e., a preference > 0.50) for 7 of the 12 infants in the *Word* condition, but only 2 of the 12 infants in the *Tone* condition. A Fisher exact test indicated that this difference was significant, $p < .04$.

Familiarization and test phases. Supplemental analyses suggested that changes in individual infants' looking times during the familiarization phase were unrelated to novelty preferences in the test phase. The low correlation between familiarization contrast scores and novelty preferences was not reliable ($r = .15$). Also, there were no significant differences in an analysis of familiarization contrast scores based on a median split of the test trial preference data.

Parental report. Parents were asked whether they thought that their infant was, or was not, familiar with each object category. The percentages of infants reported to have familiarity with the animal category were 39% for rabbits and 26% for pigs. Parents were also asked to freely recall any words their infant understood and any words they produced reliably. Reported comprehension ranged from 2 to 7 words ($M = 3.9$) and reported production ranged from 0 to 2 words ($M = .6$). It is possible that asking parents to freely recall words their infant understands results in an underestimation of the child's language comprehension (e.g., as compared to language checklists). For the purposes of this study, we were primarily interested in whether or not the parents would report the stimulus category words among the list of words their infant understood. Among the reported words, only one parent reported that their infant understood a word for one of the stimulus categories (''bunny'').

Discussion

The results indicate both a general influence of auditory stimulation on visual attention as well as a more specific influence of words on categorization performance. These general and specific influences were revealed, respectively, in the familiarization and the test phases.

Familiarization phase. During the familiarization phase, infants devoted more visual attention to the slides on auditory trials than on silent trials, regardless of whether the auditory stimulus was a word phrase or a tone sequence. This alerting influence of auditory stimulation is consistent with past research suggesting that sounds can enhance infants' visual attention (Baldwin & Markman, 1989; Kaplan et al., 1991).

Test phase. During the test phase, the pattern of performance of infants in the *Word* and *Tone* conditions differed. More of the infants in the *Word* than in the *Tone* condition showed greater attention to the novel than the familiar category during the test phase. This result was consistent with the prediction that the word phrases would facilitate category formation. Furthermore, infants in the *Tone* condition demonstrated a significant familiarity preference.

As predicted, the mean proportion of time attending to members of the novel category was greater for infants in the *Word* condition than for infants in the *Tone* condition, but this difference was not significant in statistical analyses.

Relating familiarization and test phases. Changes in individual infants' looking times across blocks during familiarization were unrelated to their preferences for novelty or familiarity in the test phase. This absence of a relation between familiarization and test phases is not surprising because there was no evidence for habituation during the familiarization phase. The lack of habituation was in itself not unexpected. It is possible that several aspects of the procedure influenced the infants' attention during the task and contributed to the absence of habituation across the familiarization phase. For example, the luminance change at slide onset and the auditory stimulus onset on sounded trials may have drawn infants' attention to the slide area more effectively, over trials, as infants grew accustomed to the pattern of events in the study. Also, because infants were not given any baseline or warm-up trials, they might have been more distracted during the early trials, when the situational context was unfamiliar. In addition to these factors that might have inadvertently contributed to increased fixation over trials, there is evidence that infants do not always show habituation in tasks like ours that involve a brief familiarization procedure. For example, McCall (1979) found that 10-month-olds, viewing relatively simple stimuli, rarely showed a linear decrease in looking times over trials.

The critical question is whether infants accrued sufficient familiarity with the category members during the familiarization phase to be able to discriminate between members of the familiar and novel categories at test. Other researchers have noted that a lack of habituation does not necessarily preclude novelty recognition in the test phase. For example, Reznick and Kagan (1983) found that 14-month-old infants showed recovery of attention to a member of a novel category without evidence of habituation to the familiar category. The pattern they describe mirrors that obtained here. Also note that, in our task, members of the familiar category were presented alone during familiarization, whereas a new member of the familiar category and a member of a novel category were presented as paired comparisons during each test trial. Infants' looking times during paired stimulus presentation at test include active comparison and shifts in fixation, and thus represent a different type of behavior than looking times to a single stimulus presented alone.

Implications for categorization. We have interpreted the test phase results as suggestive evidence that word phrases facilitate categorization. This interpretation is based on models of infant selective looking that propose (a) that familiarity preferences may occur with short familiarization times or with a high processing load and (b) that a shift toward a novelty preference occurs with increased familiarization (Colombo & Bundy, 1983; Hunter & Ames, 1988; Uzgiris & Hunt, 1970; Wagner & Sakovits, 1986). The significant familiarity preference (that is, preference for a novel exemplar of a familiar category) demonstrated by infants in the *Tone* condition could imply that, at

test, infants are still at an initial stage of processing in which they are attending preferentially to the objects in the familiar category. If words facilitate this categorization process, then the lack of a significant novelty preference in the *Word* condition might indicate that these subjects are in transition between familiarity and novelty preferences (Colombo, 1993). This is consistent with our prediction that words facilitate categorization.

Hunter and Ames (1988) suggested that age, familiarization time, and stimulus complexity are among the factors that contribute to infants' familiarity or novelty preferences. They predicted and demonstrated greater familiarity preferences with younger infants, shorter familiarization times, or more complex stimulus discriminations. In the current study, the overall lack of novelty preferences may be related to the relatively short familiarization time (90 s) or to the relative complexity of the discrimination at test. In order to assess these possibilities, we could either (a) lengthen the familiarization procedure or (b) simplify the discriminability of the stimulus categories. Increasing the familiarization time did not seem advisable. Our subjective impression was that it would be difficult to sustain infants' attention if the slide task was lengthened. In fact, the criterion for $\geqslant$3 s looking times on test trials led to the exclusion of 11 subjects (6 in the *Word* and 5 in the *Tone* conditions) whose looking times did decline over the session. Also, an advantage of using a relatively short familiarization time is that ceiling effects on categorization are avoided. Therefore, we decided to simplify the discriminability of the stimulus categories and attempt to replicate and bolster the pattern of results suggestive of a facilitative effect of word phrases on categorization. In Experiment 2, we selected basic level stimulus sets that were more disparate perceptually (dinosaurs and birds).

EXPERIMENT 2

In this experiment, we presented infants with slides depicting members of two new categories (dinosaurs vs birds) in a procedure that paralleled that of the first study. The following Methods section describes only the differences from Experiment 1.

Method

Subjects. Subjects included 12 male and 12 female infants between 37 and 41 weeks of age (M = 39 weeks). Eight additional subjects were rejected due to non-alert state (n = 4), insufficient looking time (n = 2), or experimenter error (n = 2).

Materials. The stimuli were slides of simple drawings of dinosaurs and birds. The spoken noun phrases (''a dinosaur'' or ''a bird'') were computer-digitized and matched in duration to the words and tones used in Experiment 1.

Stimulus selection: Sixteen adult subjects were asked to rate the perceptual similarity of pairs of the pig and rabbit pictures (one from each category) from the exemplars paired in the test phase of Experiment 1 and pairs of the

bird and dinosaur exemplars paired for the test phase of this experiment on a 7-point scale from low (1) to high (7) perceptual similarity. They were told that these stimuli were to be used in an infant study, and instructed to try to ignore their knowledge of the animals (and their labels) and to focus on the perceptual form and features of the materials as we presented them. Lower ratings on this scale would indicate that the animal pairs were less similar to each other and, therefore, should be more easily discriminable. Adults rated the paired dinosaur and bird pictures as significantly less similar to one another ($M = 2.8$) than the pig and rabbit pairs ($M = 3.9$), $t(15) = 2.69$, $p < .02$. This implies that the complexity would be reduced for discriminating between the dinosaur and bird categories at test.

Procedure and data analysis. All infants began the study seated in an infant car seat. Three of these infants did not tolerate the seat and, early in the procedure, the trials were interrupted and the infants were switched to their parent's lap. Accepted subjects were rated alert on 97% of familiarization trials. Reliability of state ratings for one-half of all subjects indicated 99% agreement. Preliminary analyses indicated no significant effects of, or interactions with, infants' sex; therefore, sex was not included as a variable in subsequent analyses.

Results

Familiarization phase. The infants accumulated about 59 s of looking time over the nine familiarization trials. The familiarization trials were analyzed as in Experiment 1. The significant effect of trial blocks, $F(2,40_{adj}) = 7.64$, $p < .002$, effect size $f = .62$, indicated an increase in looking time over blocks, thus there was no habituation evident during familiarization (Fig. 3A). The 3-way interaction of condition, familiarization stimulus type, and trial block was also significant, $F(2,40_{adj}) = 3.39$, $p < .05$, effect size $f = .41$. For infants in the *Tone* condition, mean looking times increased across successive trial blocks (block 3 > block 2 > block 1). This was also true for infants in the *Word* condition who were familiarized to birds; however, infants in the *Word* condition who were familiarized to dinosaurs showed an idiosyncratic quadratic pattern of looking time over trial blocks (block 2 > block 3 > block 1).

The overall analysis of the familiarization phase also permitted us to compare fixation times on auditory vs silent trials. The average looking times during trials with auditory stimulation were longer than during silent trials; however, this difference was not significant (Table 1). No other effects or interactions were significant.

The average familiarization contrast score was 1.10 for the group of 24 subjects, indicating a linear increase in looking times from the first to the third trial block during familiarization; this increase was significantly different from zero, $t(23) = 3.53$, $p < .001$.

Test phase. There was a significant effect of *Word* vs *Tone* condition on novelty preferences, $F(1,20) = 6.30$, $p < .03$, effect size $f = .56$. The pattern

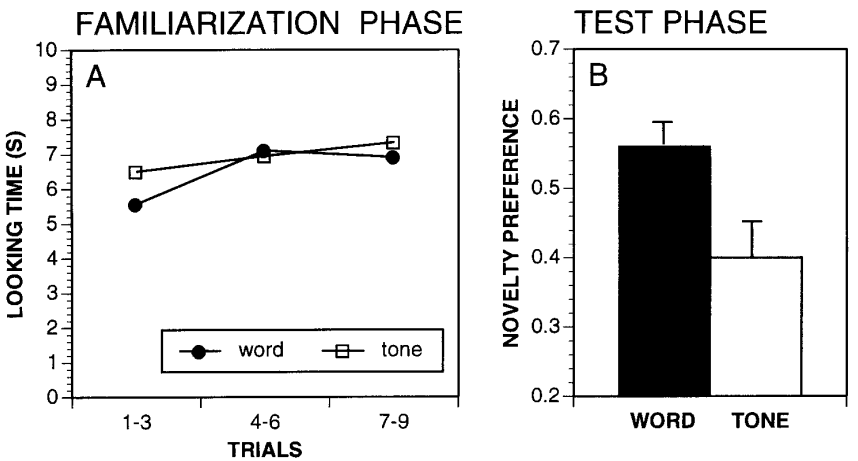

FIG. 3. A. Experiment 2 looking times, averaged over blocks of three trials, during the familiarization phase for infants in the *Word* and *Tone* conditions. Data were averaged across familiarization stimulus type (birds or dinosaurs) and trial type (auditory or silent). Standard errors were .25 to .57 s. B. Novelty preferences on the test trials for infants in the *Word* and *Tone* conditions, averaged across familiarization stimulus type. Bars indicate +1 S.E.M.

of results (Fig. 3B) indicated that infants in the *Word* condition tended to look longer at the animal in the novel category ($M = .56$) whereas infants in the *Tone* condition tended to look longer at the animal in the familiar category ($M = .40$). Although this pattern differed significantly between *Word* and *Tone* conditions, separate *t* tests for each condition ($n = 12$ subjects) indicated that neither condition had a mean preference score that differed significantly from a score of 0.50. Examination of individual performance indicated that 8 of the 12 infants in the *Word* condition attended relatively more to the novel category (i.e., a preference score $> .50$), whereas only one infant in the *Tone* condition showed this pattern. This difference between *Word* and *Tone* conditions was significant, Fisher exact $p < .005$.

There was also a main effect of familiarization stimulus: Infants familiarized to dinosaurs showed greater attention to novelty than the infants familiarized to birds, $F(1,20) = 4.38$, $p < .05$, effect size $f = .47$. Because the familiarization category was counterbalanced across subjects, this preference can not account for the effect of condition. This effect of familiarization stimulus on performance during the test phase did not interact with *Word* vs *Tone* conditions ($F < 1$). Proportion of attention devoted to the novel object was .52 for the *Word* condition and .30 for the *Tone* condition for infants familiarized to birds and .60 for the *Word* condition and .49 for the *Tone* condition for infants familiarized to dinosaurs. This descriptive breakdown reveals that in both of the familiarization stimulus groups, infants in the *Word* conditions showed relatively greater attention to a member of the novel category than did infants in the *Tone* conditions.

Familiarization and test phases. The familiarization contrast scores were not reliably correlated with the infants' preferences for novelty during the test phase ($r = .28$). There was no significant difference between familiarization contrast scores analyzed based on a median split of test-phase preference scores.

Parental report. Parents reported that 46% of the infants were familiar with the object category birds, and 21% were familiar with the object category dinosaurs. Moreover, no parents reported that their infants could produce or comprehend the labels, ''bird'' or ''dinosaur.'' Reported language comprehension ranged from 2 to 10 words ($M = 4.7$) and reported production ranged from 0 to 3 words ($M = 1$).

Discussion

The difference between infants' preferences in the *Word* and *Tone* conditions was consistent with the pattern obtained in Experiment 1 and with the prediction that words facilitate categorization. Infants in the *Word* condition showed significantly greater attention to novelty than infants in the *Tone* condition during the test phase. Note that, across Experiments 1 and 2, infants in both the *Word* and *Tone* conditions accrued the same amounts of familiarization time. In Experiment 1, words and tones, relative to silence, were equally effective at facilitating visual fixation during familiarization. Despite the lack of differences between *Word* and *Tone* conditions during familiarization, differences between *Word* and *Tone* conditions emerged in the test phase. Across both studies, greater attention to novelty during the test phase was demonstrated by more of the infants who heard word phrases during familiarization than infants who heard tones. Experiment 2 also revealed a significant difference in novelty preference between *Word* and *Tone* conditions. Taken together, these two experiments reveal that a facilitative influence on categorization, linked to word phrases rather than to general auditory stimulation, is evident at 9 months.

Our goals in the next experiment were (a) to replicate the facilitative influence of word phrases, relative to tones, on categorization and (b) to determine whether content-filtered presentations of those same word phrases might also have a facilitative influence on categorization. This new manipulation permits us to begin exploring which characteristics of word phrases are responsible for the categorization effect. Content-filtered speech preserves the intonational contours of the word phrases but obscures the intelligibility of the specific words (Rogers, Scherer, & Rosenthal, 1971). Thus, we ask whether word phrases facilitate categorization even when their phonetic information is degraded.

EXPERIMENT 3

This experiment included three conditions that differed only in the auditory stimulus presented during familiarization. The conditions included the same word phrases and tone sequences as in Experiment 2, and also content-filtered

word phrases. The following Methods section describes any changes from Experiment 2.

Method

Subjects. Subjects included 26 male and 22 female infants between 36.7 and 40.8 weeks ($M = 38.5$ weeks). Other subjects were not included in the analyzed sample due to non-alert state ($n = 9$), insufficient looking times on test trials ($n = 17$), infant health ($n = 1$), or parents' behavior ($n = 3$).

Materials. The pictures were the same as in Experiment 2. The auditory stimuli included the word phrases and tone sequence from Experiment 2 as well as content-filtered versions of the same word phrases (''a bird'' and ''a dinosaur''). The content-filtered phrases were obtained by filtering the original, computer-digitized, phrases with an electronic filter system in order to remove high frequencies (frequencies above 650 Hz were filtered out; lower frequencies were bandpass filtered with a peak at about 310 Hz; Rogers et al., 1971). These stimuli were recorded on tape for presentation and were matched in loudness to the other word phrases and tone sequence.

In order to assess the intelligibility of the content-filtered speech stimuli, college undergraduates, tested individually, were asked to discern the phrases. Each recorded content-filtered phrase (''a bird'' and ''a dinosaur'') was presented in a block of seven trials. After each repetition of the content-filtered phrase, the subjects were asked to guess what was said. None of the adult subjects correctly identified the phrase ''a bird.'' Some guesses were ''avoid,'' ''afford,'' ''that's good,'' and ''it's cold.'' Five of the 14 adult subjects correctly guessed the phrase ''a dinosaur.'' Correct identification for these subjects occurred after 2, 3, 3, 5, and 5 repetitions of the phrase. Other guesses included ''phone is clear,'' ''odonosphere,'' ''a blindfold,'' ''going soon,'' and ''we're going ashore.'' These guesses reveal that adults accept these phrases as words but, in general, failed to identify the words correctly.

Design and procedure. Infants were assigned to one of three conditions: *Content-filtered Word* ($N = 9$ males, 7 females), *Word* ($N = 9$ males, 7 females), or *Tone* ($N = 8$ males, 8 females). All infants were tested while seated on their parent's lap. The infants in this study were tested in a smaller room than that used for the first two experiments; however, the configuration of projector and screen and the distance between the screen and the subject were the same. In order to avoid the possibility that parents' reactions might bias the infants' responses, an opaque curtain was suspended above the infant and adjusted to prevent the parent from viewing the slides.

Data analysis. Accepted subjects were rated alert on 99% of familiarization trials. Reliability of state ratings, obtained for one-third of all subjects, indicated 100% agreement. Because this study was designed, in part, as an attempt to replicate the difference between word phrases and tones obtained in the first two studies, a planned comparison between *Word* and *Tone* conditions was included in the analysis of the test phase results. In addition, because this study extended the results of the first two studies by adding a *Content-*

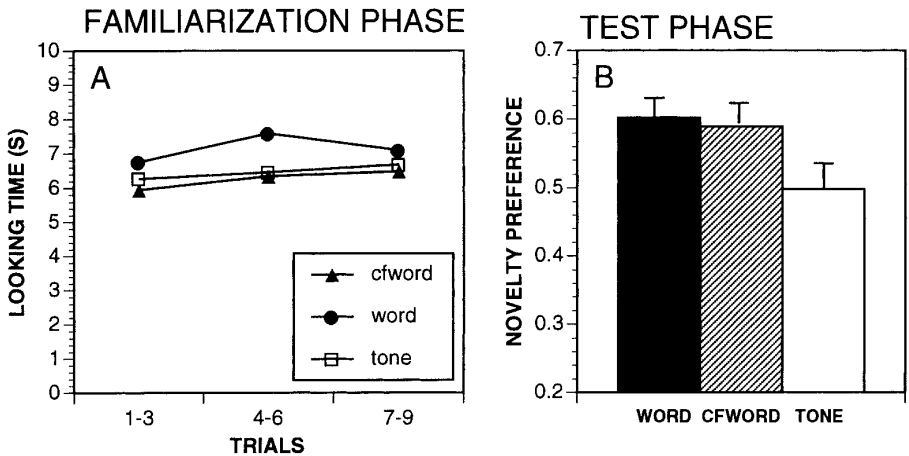

FIG. 4. A. Experiment 3 looking times, averaged over blocks of three trials, during the familiarization phase for infants in the *Word, Content-filtered Word,* and *Tone* conditions. Data were averaged across familiarization stimulus type (birds or dinosaurs) and trial type (auditory or silent). Standard errors were .25 to .44 s. B. Novelty preferences on the test trials for infants in the *Word* and *Tone* conditions, averaged across familiarization stimulus type. Bars indicate +1 S.E.M.

filtered Word condition, planned comparisons between *Content-filtered Word* and *Tone* conditions and between *Content-filtered Word* and *Word* conditions were also included. Preliminary analyses revealed no significant effects of, or interactions with, infants' sex; therefore, sex was not included as a variable in subsequent analyses.

Results

Familiarization phase. The total accumulated looking time during the familiarization trials did not differ among the three conditions. An analysis of variance included condition (*Word* vs *Content-filtered Word* vs *Tone*) and Familiarization stimulus (bird vs dinosaur) as between-subjects variables, and trial type (auditory vs silent) and trial block (block 1 vs block 2 vs block 3) as within-subjects variables. Although infants' looking time tended to increase over the familiarization trials (Fig. 4A), the effect of trial block was not significant, $F(2,84_{adj}) = 2.77$, $p < .08$. The mean linear familiarization contrast score was .43 for the group of 48 subjects, indicating that, on average, looking times increased from trial block 1 to trial block 3 during familiarization; however, this increase was not significant, relative to zero change, $t(47) = 1.97$, $p < .06$.

Analysis of average looking times during auditory and silent trials in the familiarization phase indicated that, across all three conditions, infants' visual attention was significantly facilitated by auditory stimulation (Table 1). There were no other significant effects or interactions.

Test phase. The pattern of average novelty preferences was in the direction of greater attention to novelty for infants in the two language conditions than for infants in the *Tone* condition (Fig. 4B). The first set of analyses of the test phase data included the three planned pair-wise comparisons of the *Word, Content-filtered Word,* and *Tone* conditions. The difference between *Word* and *Tone* conditions was significant, $F(1,42) = 4.74$, $p < .04$, effect size $f = .33$, indicating that infants in the *Word* condition devoted greater attention to the animal in the novel category than did infants in the *Tone* condition. The difference between infants in the *Content-filtered Word* and *Tone* conditions was in the same direction but was not significant, $F(1,42) = 3.67$, $p = .062$, effect size $f = .29$. The comparison between *Content-filtered Word* and *Word* conditions was not significant, $F(1,42) < 1$, and the means indicate comparable results for these two language conditions (Fig. 4B). No other effects or interactions were significant.

The next set of analyses separately compared the preference scores in each condition to a score of 0.50. For infants in the *Word* and *Content-filtered Word* conditions, novelty preferences were reliably higher than 0.50, (*Word* $t(15) = 3.44$, $p < .01$; *Content-filtered Word* $t(15) = 2.86$, $p < .02$). The infants in the *Tone* condition did not show a novelty preference ($M = .50$). Finally, a descriptive analysis of individual performance indicated that the number of subjects showing preferences for novelty (i.e., preferences $> .50$) was 12 of 16 in the *Word* condition, 12 of 16 in the *Content-filtered Word* condition, and 7 of 16 in the *Tone* condition.

Familiarization and test phases. The familiarization contrast scores were not correlated with the infants' preferences for novelty during the test phase ($r = -.03$). There was no significant difference between familiarization contrast scores based on a median split of the test-phase preference data.

Parental reports. Infant familiarity with the stimulus categories was reported for 56% of the sample for birds and 54% for dinosaurs. The parent-generated lists of words that the infants understood (range 1 to 12 words, $M = 4.9$) and produced (range 0 to 6 words, $M = .7$) did not include the stimulus category words ''bird'' and ''dinosaur.''

Discussion

The results of this study replicate the effects found for the *Word* and *Tone* conditions of the earlier experiments and a consistent pattern of results emerges: (a) For both words and tones, attention was enhanced during sounded, relative to silent, trials during the familiarization phase; (b) Infants who heard word phrases during familiarization showed greater attention to objects in the novel category during the test phase than infants in the *Tone* condition; and (c) More infants in the *Word* condition than the *Tone* condition showed these attentional preferences for novelty. The results for the *Content-filtered Word* condition resembled the results for the *Word* condition in that infants in the *Content-filtered Word* condition showed significantly greater attention to objects in the novel category. This suggests that the lower fre-

quency components of the speech signal, preserved in the content-filtered word phrases, contribute to the facilitative effects of the word phrases. The similarity in the pattern of results for the *Word* and *Content-filtered Word* conditions, compared to the *Tone* condition, suggests that the facilitative effects are more closely linked to language, per se, than to more general alerting effects of auditory stimuli.

GENERAL DISCUSSION

The consistent pattern of results across these three studies suggests that word phrases influence object categorization in infants as young as 9 months. This facilitative influence appears to involve more than a general alerting effect. In fact, there was a general enhancement of infant visual attention due to auditory stimulation, as indicated by prolonged looking times on familiarization trials presented with sound (tones, words, or content-filtered words), relative to silent familiarization trials. This effect was statistically significant in two of the three studies. However, at test, attention to members of the novel category, relative to the familiar category, was greater for infants who had heard word phrases during familiarization than for infants who had heard tone sequences. These differences in the influence of words vs tones on categorization were modest in magnitude, but consistent in direction over the three studies.

Roberts and Jacob (1991) reported a different pattern of findings. Like us, they argue for a facilitative effect of words on infants' categorization. But unlike us, they attribute this effect to the general influence of auditory stimulation because they did not find a specific facilitative influence of words, relative to instrumental music. Because of procedural differences between their study and ours, it is difficult to reconcile the discrepant findings. One difference seems particularly important: In Roberts and Jacob's study, the musical segments and word phrases were presented only as long as the infant visually fixated the slide; the sounds were terminated whenever the infant turned away. One consequence of this contingent procedure is that the auditory input could be interrupted abruptly, in the middle of word and/or phrase boundaries. Such interruptions would degrade the prosodic and syntactic integrity of the word phrases, making it difficult for infants (particularly those with short or inconsistent looking times) to recognize the auditory input in the word condition as speech. There were various other differences between Roberts and Jacob's procedure and our own, including the age of subjects (15 months vs 9 months), and hierarchical level of categories presented (superordinate vs basic).

Our results indicating a facilitative effect of words on categorization at the basic level in 9-month-old infants are consistent with other studies that document a facilitative effect of novel words on categorization at the superordinate level in older infants. At 15 months, novel words facilitate superordinate level categorization in a triad task (Waxman & Hall, 1993); at 12 to 14 months, novel words facilitate superordinate level categorization in a manual habituation task (Waxman & Markow, 1995). In both of these studies, all infants

heard infant-directed speech. The only difference among conditions was in the presence (e.g., ''See the fauna?'') or absence (e.g., ''See here?'') of novel words. Thus, the facilitative effect in these studies was tied directly to novel words. It is interesting that in the habituation task with 12- to 14-month-olds, the facilitation of categorization by noun phrases (e.g., ''See the fauna?'') relative to more general phrases (e.g., ''See here?'') was indexed both by greater habituation during familiarization and by greater attention to novelty at test.

In our studies of 9-month-olds, there was no evidence of habituation during the familiarization phase. Neither were there differential changes in visual fixation, during familiarization, for infants in *Word* and *Tone* conditions. Nonetheless, compared to infants who heard tone sequences during familiarization, infants who heard word phrases during familiarization were more likely to devote greater attention to members of a novel category during the test phase.

In this task, we cannot ascertain precisely the conceptual or perceptual processes underlying the infants' categorization. For example, we cannot determine whether the infants actively compared exemplars with some rudimentary conceptual understanding that the members of the category were ''the same kind of thing'' (Younger, 1993), whether they generalized across exemplars based on simple defining features or relations of features, or whether their categorization was guided by family resemblance structures (Kemler Nelson, 1984). We also cannot judge whether the facilitative effect of words on infants' categorization is related to the infants' familiarity with the stimulus categories presented. Some parents reported that their infants were familiar with these animals from toys, picture books, etc.; other parents reported that their infants were unfamiliar with these object categories. But, there were too few subjects in each group to permit a direct test of this factor. Thus far, we have only examined animal-type categories. It will be important in future work to explore this phenomenon with other categories, including categories of both biological and non-biological kinds.

Our results do not specify which characteristics of the word phrases might be responsible for the facilitation of categorization at 9 months. However, it is possible to rule out some candidate interpretations. First, we doubt that categorization was facilitated by the grammatical status of the novel word as a count noun. Although older children are sensitive to grammatical status and use it to help map novel words to their meanings (Echols, 1992; Markman, 1991; Markman & Hutchinson, 1984; Waxman & Gelman, 1986; Waxman, 1991; 1994; Waxman & Markow, 1995), at 9 months, infants' abilities to discriminate among instances of grammatical form classes (e.g., count nouns, verbs, and adjectives) in the spoken language are immature (Gleitman, Gleitman, Landau, & Wanner, 1988; Gleitman, 1990; Pinker, 1984; Waxman & Markow, 1995). Thus, we believe it is unlikely that the observed facilitative effects of word phrases on categorization reflect a specific influence of count nouns at 9 months. Second, we doubt that the facilitative influence of words

is based on infants' comprehension of the specific words presented in the word conditions. Based on the parental reports of their infant's language comprehension in the current studies, and on detailed studies of the emergence of language comprehension and production (e.g., Fenson et al., 1994), it is unlikely that the word phrases we presented were known to the infants. In fact, the results for the content-filtered word condition in Experiment 3 refute that explanation, to the extent that content-filtering rendered the specific words less identifiable.

We interpret the facilitative influence of word phrases on object categorization in 9-month-olds within a developmental framework. We propose that this effect reveals both (1) the influence of infant-directed speech and (2) the influence of novel words. Developmentally, there appears to be a progression such that early in infancy, auditory stimulation may heighten infants' attention (Kaplan et al., 1991; Mendelson & Haith, 1976). Our finding that looking times typically were longer on auditory than on silent trials during familiarization is consistent with this general effect of auditory stimulation.

We also know that infants devote particular attention to infant-directed speech as compared to other sources of auditory stimulation. Fernald (1992) described a developmental model in which the function of infant-directed speech changes over time during infancy. Initially, infant-directed speech engages and modulates the infant's attention (e.g., Kaplan, Goldstein, Huckeby, Owren, & Cooper, 1995). Later, ''words begin to emerge from the melody'' near the end of the infant's first year (Fernald, 1992, p. 403). At this point, infant-directed speech may facilitate language comprehension by clarifying the word and phrase boundaries (Fernald & McRoberts, 1991; Newport, Gleitman, & Gleitman, 1977). For example, for 7- to 10-month-old infants, prosodic cues are important in segment-parsing (Hirsh-Pasek et al., 1987; Jusczyk et al., 1992; Jusczyk, 1993; Kemler Nelson et al., 1989). Jusczyk and colleagues demonstrated the importance of prosody by low-pass filtering word phrases, so that specific words were indistinct but prosodic contours were preserved. Nine-month-old infants demonstrated sensitivity to segment boundaries under these circumstances. This is consistent with Fernald's suggestion that infant-directed speech serves as an important source of support as infants establish their first ''sound–meaning correspondences'' (1992, p. 403). Indeed, by 8 to 9 months, infants distinguish segments of speech with words they have previously heard from segments with unfamiliar words (Jusczyk & Aslin, 1995; Newsome & Jusczyk, 1994).

Our data are consistent with this developmental progression in infants' attention to infant-directed speech. In our studies, the phrases in the *Word* and *Content-filtered Word* conditions were presented in this speech register, and incorporated the characteristic prosodic and melodic contours. The infants could have experienced both the word phrases and the content-filtered phrases as speech-like and thus engaged, in at least some rudimentary manner, in mapping words to meaning. A recent study provides further evidence that novel words influence 9-month-old infants' categorization: In a manual habit-

uation task, all infants heard infant-directed speech, but facilitation of object categorization at the basic level occurred only in conditions where novel words were presented and not in control conditions involving no novel words (Waxman & Balaban, 1996).

What processes might underlie the facilitative effect of words on 9-month-old infants' object categorization? Infants heard the same auditory event (word phrase, tone sequence, or content-filtered word phrase) presented with varied exemplars of an object category over a short time period. Ward (1990) suggested that when children hear a novel word, it ''leads to important differences in the way they process information about objects in their immediate environments'' (p. 326). This may also be true for infants who are beginning to acquire language. Perhaps the repetition of the word phrases served as an invitation to form categories (Waxman & Markow, 1995) by focusing infants' attention on the commonalities among objects. This aspect of categorization would not be invoked to the same extent for infants who heard tone sequences.

In sum, our results suggest that word phrases facilitate object categorization in infants as young as 9 months. This indicates that a linkage between words and object categories is available to infants in their initial attempts to map words to their meanings. We have proposed that this effect reflects both the influence of infant-directed speech and the influence of novel words. These findings extend our understanding of infants' emerging language and conceptual development over the first year of life.

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