INFANT BEHAVIOR AND DEVELOPMENT **17**, 19–129 (1994)

Emergence of an Early Receptive Lexicon: Infants' Recognition of Words

PIERRE A. HALLÉ
BÉNÉDICTE DE BOYSSON-BARDIES
Laboratoire de Psychologie Expérimentale, Paris

This experiment examines whether 11-month-old and 12-month-old infants are able to recognize familiar words in a situation yielding no extralinguistic cues. Two experiments were run to compare infants' interest for familiar words, chosen in the early productive vocabulary of young infants, against rare words infrequent in French usage. Both experiments used a preference paradigm in which preference was indexed by attention span. Lists of familiar words were auditorily presented to each child in the absence of any possible referent object. A preference for familiar words was found to be very consistent in 12-month-olds and just emerging in 11-month-olds. These results were interpreted as revealing the existence of a developing receptive lexicon by 11 months of age.

language acquisition receptive lexicon word recognition familiar words phonetic complexity

The emergence of a lexicon is of paramount importance in the process of language acquisition. Developing a lexicon, however primitive, entails coding and storing word-sounds in some way for comprehension and perhaps in another way for production. When are coding and storing word-sounds first evidenced in infants? This is the question that motivates this experiment.

During the last 20 years or so, contributions in the field of early word comprehension have generally pointed to the asymmetries between production and comprehension processes. Huttenlocher (1974) stressed that "[receptive language] involves *recognition* of words and *recall* of objects, acts, and relations for which they stand, whereas [productive language] involves *recognition* of objects, acts, and relations and *recall* of the words that stand for them" (p. 335). In that light, word comprehension must logically be ahead of word production when it is considered that production of intended meaning by means of words requires at least partial understanding of these words.

Indeed, a sizeable body of studies based on observations from naturalistic settings, diaries, or parental reports have consistently reported a substantial lag of production behind comprehension. Goldin-Meadow, Seligman, and Gelman (1976) found a developmental shift at about 2 years from a "receptive stage" to a "productive stage" where production and comprehension lexicons moved into alignment. In a longitudinal study of children from 9 to 18 months, Benedict (1979) found that comprehension development is ahead of production development by several months; she located the onset of word comprehension at around 9 months and the onset of word production at around 12 months. The two studies mentioned also indicate that words produced with meaning are, as is logical, understood. Snyder, Bates, and Bretherton's (1981) data, based on intensive maternal interviews, globally supported Benedict's (1979) estimation: 13-month-olds had a receptive lexicon of about 45 words and a productive lexicon of about 11 words. Clark and Hecht (1983) have suggested that observational studies, diary studies, or parental report studies tend to overestimate comprehension capacities in young children. To put it more properly, those studies do not permit us to separate the contributions to com-

The authors gratefully acknowledge support from a grant from le Ministère de la Recherche et de la Technologie (1990), from la Fondation de la Recherche Médicale (1989), and from the Japanese Society for the Promotion of Science to P.A.H. (1989–1990). Gratitude is expressed to the infants and parents who participated in this study, to Catherine Marlot and to Hugo Berroyer who helped as research assistants on the project.

Correspondence and requests for reprints should be sent to Pierre A. Hallé, CNRS Paris, Laboratoire de Psychologie Expérimentale, 28 rue Serpente, 75006 Paris, France.

prehension of linguistic and nonlinguistic cues. This is because children can rely on nonlinguistic knowledge in many situations to display "correct" responses. They also may respond to some features only of verbal commands disregarding other potentially contrastive features: Huttenlocher (1974) reported the example of Wendy, 11 months, stopping to rip out pages of a book when told "No!" by her mother but also when told "Yes!" with the same forbidding intonation. Indeed, in the studies mentioned and others, researchers have always strived to avoid misinterpretation of children's responses to speech, in particular, testing them contrastively as in the "*no* versus *yes*" example. Still, it seems that young children recognize sound patterns within sentences in conjunction with specific contexts: They may store words as sound sequences plus situation (Menyuk & Menn, 1979). Experimental settings, on the other hand, may suffer the drawback of not eliciting children's responsive behavior as easily as naturalistic settings do. Do we get more reliable data from experimental studies?

Experimental procedures that have been widely used involved a verbal command on one hand and a visual presentation of referent objects (or events) on the other hand. Thomas, Campos, Shucard, Ramsay, and Shucard (1981) tested 11- and 13-month-olds on their comprehension of reportedly unknown versus known object words. In each trial, infants were presented a word (known, unknown, or nonsense) while being shown an array of four objects among which were two referent objects for the known and unknown words. Thirteen-month-olds looked proportionally longer to the referent of the known word when that word was spoken than when the nonsense word was spoken. This result was not obtained for unknown words nor was it for either known or unknown words in the 11-month-old group (Behrend, 1987). Hence, a developmental shift seems to occur between 11 and 13 months: Children become clearly able to recognize known words and match them with referent objects. Oviatt (1980) also found a developmental change circa 11 months in children's ability to match trained names, which they had not known previously, to live referent objects or to simple actions. So, the capacity to memorize, for however short a time, and recognize pairings between word-sounds and objects seems to emerge at about 11 months. (Oviatt termed this "recognitory comprehension.") Golinkoff, Hirsh-Pasek, Cauley, and Gordon (1987) studied slightly older infants aged about 16 months in a new, more controlled paradigm adapted from Spelke (1979) who used filmed events to study infants' intermodal perception. Golinkoff et al. presented simultaneously to children two video events together with an auditory stimulus matching only one. They found that children consistently looked longer to matching screen for both objects and actions.

Controlled settings of experimental studies have attempted to set aside unwanted circumstances that may bias infants' responses such as object preference, focal intonation, maternal cuing, context cuing, and so forth. It remains that in these experiments, infants were always presented simultaneously with both a word (within a sentence of familiar format) and possible referents, so that we still do not know whether word-sound alone can be used by infants to access a representation of the referent it stands for. In other words, that infants do recognize some familiar pairings of word-sound and object (or event) does not entail that the sole processing of linguistic code leads to comprehension. Indeed, given the state of the art, there is simply no device for testing comprehension of words in the absence of any candidate referent: How could we demonstrate that a child, when presented a word and nothing else, has access to its meaning?

We can, however, test recognition of words by means of simple behavioral tasks such as set in preference paradigms: Children supposedly prefer listening to or attending to words they recognize over words they don't. Glenn and Cunningham (1982) used an experimental setting where children were tested at home on their preference for one of two versions of a nursery rhyme their mother used to sing to them. One version was the usual nursery rhyme recorded by their mother; the other version was sung on the same tune and tempo, but each word was replaced by a nonword basically obtained through inversion of phoneme order. Normal infants aged 8 to 12 months ($\bar{M} = 9.1$) preferred listening to the usual version. Glenn and Cunningham (1982) concluded that these infants could recognize familiar words in nursery rhymes. Inversion of phoneme order, however, resulted in sound combinations that are infrequent in English. For example, "the mouse ran up the clock" was changed to "eth soame nar poo eth clod." The preference exhibited by these infants might have been a preference for familiar sound combinations over unfamiliar or foreign-sounding ones. This is suggested by recent research showing that infants have begun to pick up frequent phonotactic patterns of words in their native language between 6 and 9 months (Jusczyk, Charles-Luce, & Luce, in press).

Aside from behavioral studies, electroencephalographic (EEG) data bearing on early processing of words have been recently reported by Neville (1992). Her data show differential brain activity in immediate response to known versus unknown words presented auditorily in isolation. Therefore, in the absence of nonlinguistic context, infants process differently known and unknown words: Known words trigger additional activity that may mean at least recognition and probably more. In children aged 13 to 17 months, presentation of known words induces EEG activity bilaterally though somewhat more strongly in the *right* hemisphere. In 20-month-old children, EEG activity occurs mainly in the *left* hemisphere. Moreover, in younger children, the right hemisphere advantage correlates negatively with lexical development. These findings suggest a developmental change in the way children process words, and this change roughly coincides with the vocabulary spurt observed in production which many have interpreted as a shift from gestalt to analytical coding of words (Ferguson & Farwell, 1975; Macken, 1980).

In this experiment, we used preference paradigms to test for word recognition, *independent of context*, by younger infants aged 11 to 12 months. This seems to be a reasonable age range for a number of reasons. First, there is some indication that 11-month-olds can segment fluent speech into words, in the sense that they perceive words as bounded units (Woodward, personal communication, 1987). Indeed, this capacity may be a prerequisite to acquiring a lexicon. Second, during the second half of the first year, children's sensitivity to contrasts between sounds and combinations of sounds narrows to those which are linguistically relevant in their native language. Of particular relevance for this emerging perceptual attunement to native language is the sensitivity to sound combinations within words, that is, to word phonotactic patterns. It seems that children disregard irrelevant contrasts and can dispose, as it were, of more resources to attend to word-sound contrasts relevant in their native language. At 9 months, infants prefer words that respect native phonotactic constraints (Jusczyk, Friederici, Wessels, Svenkerud, & Jusczyk, 1993) and prefer frequently occurring phonotactic patterns over infrequent ones (Jusczyk et al., in press): These preferences entail recognition of familiar word-sound patterns. So, it seems plausible that 11-month-olds are equipped with some of the capacities necessary (if not sufficient) to recognize words in the language they learn.

In order to test the hypothesis that children can recognize words in the absence of sentence context and of possible referent object, this experiment used preference paradigms aiming at measuring the preference, as indexed by attention span, for familiar words belonging to the early production lexicon over unfamiliar words. Words were presented in lists of words, and no referent-objects were used. Accordingly, this experiment tested for word recognition in the absence of situation and context cuing, that is, it tested for the existence of a receptive lexicon devoid of nonlinguistic representations.

EXPERIMENT 1

The first experiment mainly aimed at determining whether infants exhibit a preference for familiar words over rare words and when this preference emerges. Two age groups were tested: one 11-month group and one 12-month group.

Method

Subjects. Twelve infants in each group were tested. Infants in the 11-month group had a mean age of 10 months and 30 days (range = 10.20–11.09). Infants in the 12-month group had a mean age of 11 months and 30 days (range = 11.17–12.14). There were 7 males and 5 females in each group. Three additional subjects in the 11-month group and 2 in the 12-month group were run but could not be tested successfully: One was eliminated due to errors in the experimental procedure, 1 because he fell asleep during the test, and 3 because they started crying, could not be soothed, and could not complete the session. All subjects were having a normal perceptual and motor development. None of them was reported to produce more than four discernible words.

Stimuli. We used 12 familiar and 12 rare words (Appendix A). All but one were two-syllable words. Familiar words were the adult glosses of the most frequent attempts at words encountered in a previous longitudinal study of 5 French infants ages 14 to 18 months (Boysson-Bardies & Vihman, 1991). Rare words were chosen among words infrequent in French usage, but infrequent phonetic forms were avoided. Tubach and Boë's (1990) phonetic count (based on corpora totalling 300,000 "phones") was used to estimate the average probability of phonemes used in familiar and rare words: The average probability of phonemes was 4.02% in familiar and 4.39% in rare words. Hence, phonemes in rare words were, in the average, no more infrequent than those in familiar words. Frequency of use was checked using lexical frequency tables published by le Centre de Recherche pour un Trésor de la Langue Française (Imbs, 1971): The median frequency of use was $2{,}012 \times 10^{-8}$ for familiar words and 116×10^{-8} for rare words (M = 18,169 and 499×10^{-8} respectively). Care was taken to avoid closeness in phonetic shape of each rare word to any familiar word so that confusion between the two sets of words would be unlikely. All these words were recorded by a female French speaker with a Sennheiser microphone and a Denon DTR-100P DAT tape recorder then digitized using a 16 bit A/D converter (10 kHz sampling rate) and stored in computer files. The speaker was told to pronounce words at an even tempo, intonation, and intensity. Six pseudo-random lists were constructed with the 12 familiar words. These were "familiar lists." Likewise, six "rare lists" were constructed. Different lists began with different words. All lists were about 21 s in duration. Word durations ranged between 512 and 990 ms (M = 738 ms) for familiar words and between 680 and 1082 ms (M = 826 m) for rare words; this difference did not reach significance, $t(22) = 1.54$, $p > .10$. There was no overall difference between familiar and rare words in fundamental frequency (F0) contour or intensity.

Apparatus. The subject sat on a parent's lap in the center of a three-sided booth (2 m × 1.8 m) with the infant's eyes at about 75 cm from the center panel. A small lamp and a loudspeaker were mounted on each side panel at eye level and about 75 degrees from the center direction. The observer stood behind the center panel and could monitor the infant's gaze direction through a hole without being seen. The observer used a doll which was swayed gently above the center panel to call the infant's gaze to the center direction. Two Morse keys were used to signal right/left gaze to a computer in the next room, the "Escape" key of the computer keyboard was pressed to abort, and any other key was pressed to start or resume the course of the experimental session. Stimuli playback was performed using a two-channel 16 bit D/A convertor (10 kHz sampling rate) whose output was amplified by a Luxman LV-111 stereo amplifier and fed to Pioneer 30 Watt loudspeakers.

Procedure. The procedure, which was a modified version of the procedure used by Juszcyk et al. (1993), based itself on the head-turn-preference procedure originally developed by Fernald (1985). Experimental sessions consisted of two phases: a familiarization phase and then a test phase. For each subject, familiar words always came from the speaker on one side, rare words came from the speaker on the other side. The type of words presented first was the same in the test and familiarization phases. These two factors, side-assigned to familiar words and type of first list, were counterbalanced across subjects.

In the familiarization phase, intended to acquaint the subject with the side assigned to each type of list, three different lists of one type were presented first then three lists of the other type. In the test phase, a total number of 6 rare lists and 6 familiar lists were presented (12 trials); the type of the lists presented after the first one was randomly changed but subject to the constraint that no more than 3 lists of the same type could occur in a row.

In both familiarization and test phases, the observer depressed the Morse key on the side of the list currently presented whenever the subject began or resumed orienting to the speech and did not release the key until the infant looked away from the speech. The total gaze duration for each list was measured by the total time the observer had pressed the Morse key on the side of that list. In the familiarization phase, all lists were presented in extenso. In the test, presentation of a list was given up after the first three words if the subject had not started orienting to the speech; once the subject had begun orienting to the speech, the list was sometimes terminated before its last item (always in the midst of a pause between words) if the subject stopped orienting to the speech for more than 2 s. If the infant had looked away for less than 2 s, then looked back again, presentation of the list was not terminated, but the time spent looking away was not included in the total gaze duration.

In both phases, the presentation was interrupted after every trial until the subject looked back to the doll in the center direction. Once this was obtained, the lamp on the side of the list to be presented next was turned on, and that next list was started. In the familiarization phase, the next list was started after the infant began orienting to the lamp; in the test phase, the next list was started immediately. This was intended to make sure that, during the familiarization phase, the infant would both orient and listen to the speech sounds. The lamp was left on during the whole presentation of the current list in the test phase but was turned off after the first word in the familiarization phase.

During the session, the observer was not informed as to which side was assigned to familiar words. (Side was specified to the computer program by a second assistant, who was not involved in the observations.) In addition, both observer and the infant's parent listened to music over headphones in order to be deaf to the stimuli presented.

Results

Results of the test phase are summarized in Figure 1. The mean looking times per trial were 5.11 s for familiar versus 3.97 s for rare words in the 11-month group (SD = 1.70 and 1.60, respectively). Means were 7.33 s versus 4.03 s in the 12-month group (SD = 2.50 and 1.80, respectively). Analyses of variance (ANOVAs) were conducted with looking time to familiar words and looking time to rare words taken as dependent variables and treated as within-subject repeated measures. In each age group, independent factors were side (side of presentation of familiar words: left or right) and type (type of the list presented first: familiar or rare). Hence, there were four experimental conditions. The mean looking time per trial to familiar words and to rare words, and the proportion of looking time to familiar words,

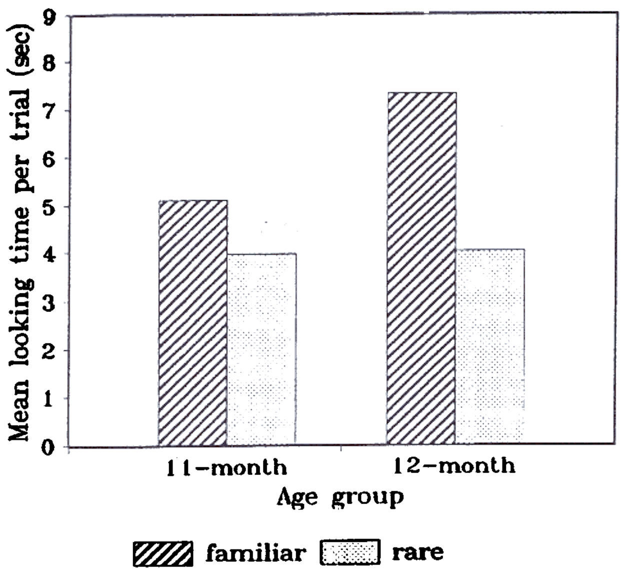


Figure 1. Test of Experiment 1: Mean looking times per trial to familiar versus rare words (11- and 12-months-olds).

averaged across infants, are shown in Table 1 for each experimental condition. Analyses showed that the difference between looking times to familiar and rare words was significant in both groups and especially in the 12-month-group (11-month: $F(1, 8) = 6.81$, $p < .04$; 12-month: $F(1, 8) = 13.08$, $p < .007$). No significant effect of either side or type and no interaction of side × type was found. In the 11-month group, however, there was a marginally significant trend for looking times to rare words to be longer when a rare list was presented first, $F(1, 8) = 4.38$, $p = .07$. In the 12-month group, there was a (nonsignificant) trend for looking times to rare words to be longer when presented to the right side.

Analyses of raw durations, as just discussed, incorporate the variance due to differences in total attention span (total looking time to both types of words). A possible means to factor out this variance is to analyze the *preference* for familiar words (defined as the proportion of looking time to familiar words). In the 12-month group, the mean preference was 0.647 ($SD = 0.126$), very significantly above the chance level 0.5, $t(11) = 4.02$, $p < .003$; in the 11-month group, it was 0.563 ($SD = 0.101$), marginally significantly above 0.5, $t(11) = 2.17$, $p = .06$. These results suggest a more marked preference for familiar words in 12-month-olds. A supplementary ANOVA of the data with age group as single independent factor showed that the overall difference between the two age groups was marginally significant, $F(1, 22) = 3.33$, $p = 0.08$); looking times to familiar words, however, were longer in the 12-month group, $F(1, 22) = 6.35$, $p < 0.02$. So, the preference for familiar words seems to be stronger in 12-month-olds.

Further t tests indicated no significant effect of sex on the preference for familiar words in either group (11-month: 0.562 for females, 0.565 for males, $t(10) < 0.05$; 12-month: 0.600

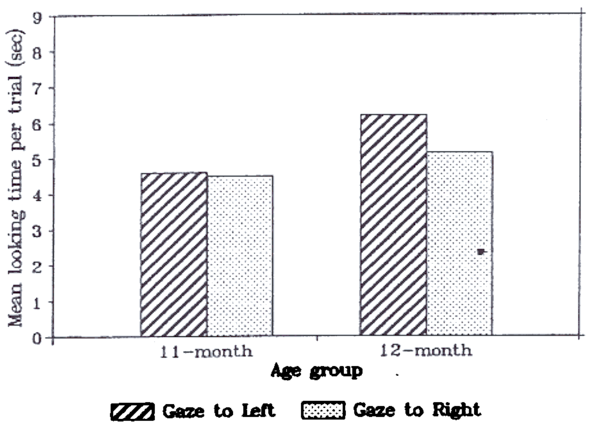
TABLE 1
Test of Experiment 1: Looking Time *per Trial* to Familiar Words and Rare Words, and Preference for Familiar Words, Averaged Across 11- and 12-Month-Old Infants for Each Experimental Condition

Condition		Looking Time (s)			
Side	Type of List First	To Familiar Words	To Rare Words	Total Time	Preference
11-Month-Olds					
Right	Familiar	4.68	2.53	7.12	0.640
Right	Rare	5.55	5.13	10.68	0.503
Left	Familiar	4.27	3.73	8.00	0.535
Left	Rare	6.05	4.48	10.53	0.574
M (*SD*)		5.11 (1.70)	3.97 (1.60)	9.08 (2.80)	0.563 (0.10)
12-Month-Olds					
Right	Familiar	6.52	2.67	9.02	0.716
Right	Rare	8.60	3.77	12.37	0.676
Left	Familiar	8.45	4.98	13.43	0.632
Left	Rare	5.75	4.70	10.45	0.562
M (*SD*)		7.33 (2.50)	4.03 (1.80)	11.32 (3.20)	0.647 (0.13)

for females, 0.679 for males, $t(10) = 1.08$, $p > 0.3$). Disregarding the type of words presented, gaze duration toward the right and left side did not differ significantly; likewise, no advantage was found for the type of list presented first. This is illustrated in Figure 2.

Familiarization data were also analyzed: The mean preference for familiar words was 0.515 in 11-month-olds ($SD = 0.121$) and 0.504 in 12-month-olds ($SD = 0.146$). Clearly, no preference has emerged yet in the familiarization phase. In this phase, children actually attend more to the first three lists presented, whatever their type, as illustrated in Figure 3. The proportion of looking time to the first three lists was 0.568 in the 11-month group, $t(11) = 2.37$, $p < 0.05$, and 0.597 in the 12-month group, $t(11) = 3.42$, $p < 0.006$.

(a)



(b)

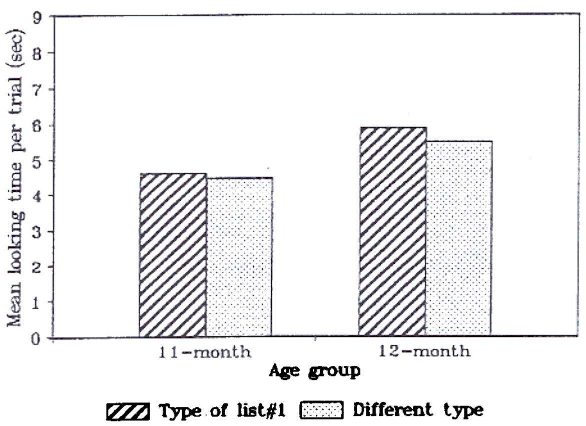


Figure 2. Test of Experiment 1: Mean looking times per trial (a) to the left versus the right side and (b) to the type of list presented first versus the other type.

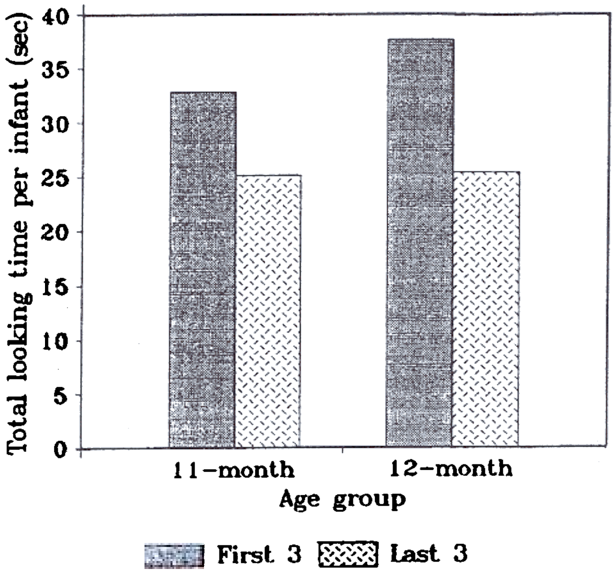


Figure 3. Familiarization of Experiment 1: Total looking times to the first three lists presented versus the last three lists presented (11- and 12-months-olds).

Discussion

A marked preference for familiar words was found in 12-month-olds. It is just emerging in 11-month-olds. The different experimental conditions determined by the side and type factors did not significantly affect the preference found. It is suggested that preference was due to recognition, but another kind of explanation deserves examination: Infants may have preferred familiar words because their detailed phonetic structure was simpler (perhaps more frequent) than that of rare words. Indeed, there is a natural tendency in languages for phonetically more complex words to be less frequent and vice versa. French is no exception, and the words we used reflected this trend. Although we used only disyllabic words and strove to avoid infrequent sounds in rare words (phonemes in rare words were no less frequent than those in familiar words), we may have used less-frequent sound combinations in rare words. A rough estimate of a given phoneme-sequence probability can be derived from Tubach and Boë's (1990) data which include the conditional frequencies for each phoneme to follow each other phoneme. For example, the probability of the sequence "[pupe]" can be approximated by:

$$p([\text{pupe}]) = f(\text{p}/\#) \times f(\text{u}/\text{p}) \times f(\text{p}/\text{u}) \times f(\text{e}/\text{p}),$$

where $f(u/p)$ is the conditional frequency of [u] following [p]. This probability reflects both sequence length and probabilities of the phoneme combinations involved. Given the huge variability of this probability for both word-types, the median is more informative than the mean: The median phoneme-sequence probability was 15.9×10^{-7} for familiar words and 0.25×10^{-7} for rare words. This large difference, however, may be mainly explained by the larger number of phonemes in rare words (M = 5.7 and range = 5–7 phonemes in rare words vs. M = 4.4 and range = 4–6 in familiar words). When computing phoneme-sequence probability *per phoneme unit*, that is, the geometrical mean of all frequencies in a product such as the [pupe] example, mean probabilities of 5.04% (SD = 2.30) for familiar words and 4.84% (SD = 1.70) for rare words were found. The difference is far from significance, $t(22) < 0.5$. Thus, rare words did not use less-frequent sounds or sound combinations than familiar words, but simply had more phonemes, hence, more complex phonotactic patterns. For example, rare words contained nine clusters whereas familiar words contained none. Familiar words contained a majority of consonant-vowel (CV) syllables (16 out of 23) and a few consonant-vowel-consonant (CVC) syllables (5), whereas rare words contained a majority of CVC or more complex closed syllables (13 out of 24) and a few CV syllables (6). Since CV is the most frequent syllable-type in French spoken language (Wenk & Wioland, 1982), rare words used less-frequent phonotactic patterns than familiar words.

Now, if infants' preference for familiar words was due to more frequent phonotactic patterns, the stronger preference exhibited by 12-month-olds as opposed to 11-month-olds would indicate a higher sensitivity to phonotactic patterns in words. Hence, a developmental shift from 11 to 12 months is found. This is somewhat unlikely in light of the recent findings of Jusczyk et al. (in press) which indicate that preference for frequent phonotactic patterns over infrequent ones has clearly emerged at 9 months.

Nonetheless, the contention that preference for familiar over rare words be induced by simpler sound patterns should not be ruled out on solely speculative grounds. Experiment 2 was designed, in part, to align sound-pattern complexity in familiar and rare words so that an unambiguous answer could be given to the objection raised by Jusczyk et al. (1994).

EXPERIMENT 2

In Experiment 2, phonetic aspects were more strictly controlled. New familiar and rare words were used to allow for similarity with respect to phonotactic patterns, number of phonemes, and estimated probabilities of sound sequences. Preference for familiar over rare words, if still observed, could then hardly be accounted for by a lesser degree of phonetic complexity.

Experiment 2 was also designed to test for hemispheric specialization in the processing of words. Indeed, Neville's (1992) recent findings have made this issue most compelling. It can be expected, that left hemisphere specialization for speech is not yet achieved in infants at 11 to 12 months, although a different opinion has been put forward by Molfese (1990). Infants' coding of words might still partly rest on (right hemisphere) gestalt representations. Experiment 2 addressed this issue by means of a monaural presentation of words over headphones whether on the left or on the right. As in Experiment 1, we used a preference paradigm in which preference was indexed by attention span. The relevant gaze orientations, however, were changed in order not to interfere with auditory presentation side. Two lamps, both mounted in the center direction, were used to train children to look upwards or downwards according to the type of words presented. As in Experiment 1, familiar and rare words were still presented from opposite sides and associated to different lamps.

Method

Subjects. Sixteen infants aged approximately 11 months were tested. They had a mean age of 10 months and 30 days (range = 10.13–11.16). There were 8 males and 8 females. Six additional subjects were run but could not be tested successfully: Two infants could not stand wearing the headphones, 2 were hopelessly crying, and 2 failed to orient to the speech for more than 1 s per trial. All subjects were having a normal perceptual and motor development. None of them was reported to produce more than 4 discernible words.

Stimuli. A new set of 12 rare words was used, and "boire" was replaced with "biberon" [bibʁɔ̃] in the set of familiar words so that all words were now disyllabic (Appendix B). Familiar and rare words had about the same number of phonemes (M = 4.75, range = 4–6 phonemes in rare words; M = 4.5, range = 4–6 phonemes in familiar words). The mean probability of phonemes was 3.93% (SD = 73.4) in familiar and 3.79% (SD = 9.40) in rare words. The mean phoneme-sequence probability per phoneme unit was 4.74% (SD = 2.40) for familiar words and 4.36% (SD = 1.90) for rare words, a difference which was far from significance, $t(22) < 0.5$. Median phoneme-sequence probabilities (unnormalized to phoneme unit) were 7.5×10^{-7} for familiar and 3.0×10^{-7} for rare words (compared to 15.9 vs. 0.25 in Experiment 1). There was no cluster in rare words and one in familiar words. Rare words contained a majority of CV syllables (13 out of 24) and 10 CVC syllables. To summarize, the matching of rare words to familiar words, with respect to phonetic complexity, was much better in Experiment 2 although still imperfect. The median frequency of use was 1.718×10^{-8} for familiar and 102×10^{-8} for rare words according to the data reported by Imbs (1971). Again, care was taken to avoid closeness in phonetic shape of each rare word to any familiar word. All the words were recorded by a female French speaker then digitized, using the same devices as in Experiment 1, and stored in computer files. Six pseudo-random familiar lists were constructed with the familiar words and six rare lists with the rare words. Different lists had to begin with different words. All lists were about 15 s in duration. Word durations ranged between 468 and 800 ms (M = 613 ms) for familiar words and between 500 and 804 ms (M = 638 ms) for rare words; this slight difference was far from significant, $t(22) < 1$. There was no overall difference between familiar and rare words in F0 contour or intensity.

Apparatus. This differed from Experiment 1 in several respects. The infants wore light stereo Koss headphones which were specially adapted to infants. Two blue lights were mounted in the center of the front panel 30 cm below and 30 cm above the observation hole located approximately at the subject's eye level. The observer used two small flashing red lights, positioned at the right and left edges of the hole, to call the infant's gaze to the center direction. A response box with two "position" buttons was used to signal upward/downward gaze to the computer in the next room, a third button was used to start or resume the course of the experimental session, and the session could be aborted by depressing both position buttons. (The computer keyboard was not needed anymore.) Stimuli playback was performed using the same devices as in Experiment 1 with the exception that headphones now replaced the loudspeakers.

Procedure. Experimental sessions consisted of two phases: a training phase followed by a test phase. For each subject, familiar words always came from the earphone on one side and rare words from the earphone on the other side; likewise, familiar words were always associated with the lighting of one lamp and rare words with the lighting of the other lamp. The type of list presented first was the same in the training and test phases. Three factors were counterbalanced across subjects: side, lamp position assigned to familiar words, and type of first list.

In the training phase, three different lists of one type were presented first followed by three lists of the other type. In the test phase, a total number of 6 rare lists and 6 familiar lists were presented. The types of lists presented after the first one were randomly changed but were subject to the constraint that no more than two lists of the same type could occur in a row.

Aside from the sequencing of lists, procedures identical to those in Experiment 1 were followed in the training and in the test. The observer depressed the button associated with the lamp currently turned on whenever the subject began or resumed looking to it, and the button was not released until the infant looked away. The total gaze duration for each trial was measured by the total time the observer had pressed the button appropriate to the list that was presented. As in Experiment 1, three words were allowed before a subject started looking to the appropriate lamp. Once the subject had begun orienting to that lamp, the list was sometimes terminated if the subject looked away for more than 2 s.

The presentation was interrupted after each trial until the subject looked back to the center direction. Once this was obtained, the lamp assigned to the list to be presented next was turned on, and that next list was started immediately The lamp was left on during the entire trial. The observer was not informed as to which lamp was assigned to familiar words during the session. (Lamp position, and more generally, experimental condition, was specified in advance to the computer program by a second assistant who was not involved in the observations.) The infant's parent listened to music over headphones in order to be deaf to the stimuli presented.

Results

Results of the test phase are summarized in Figure 4. The mean looking time per trial was 5.77 s (SD = 1.90) for familiar versus 4.37 s (SD = 1.90) for rare words. ANOVAs were conducted taking looking time to familiar words (more properly, to the lamp assigned to these words) and looking time to rare words as dependent variables treated as within-subject repeated measures. Independent factors were side (side of presentation of familiar words: left or right), type (type of the list presented first: familiar or rare), and position (position of the lamp assigned to familiar words: top or bottom). Hence, there were eight experimental conditions. The mean looking time per trial to familiar words and to rare words, and the proportion of looking time to familiar words, averaged across infants, are shown in Table 2 for each experimental condition. Analyses revealed a significant difference between looking times to familiar and rare words (complete three-way design: $F(1, 8) = 6.12$, $p < .04$; t-test paired comparison: $t(15) = 2.67$, $p < .02$). Given the small number of subjects assigned to each condition, partial design analyses were run: One-way designs tested for the effect of individual factors, and two-way designs tested for interactions. Familiar words were attended to longer when associated with the top lamp (6.7 s vs. 4.9 s: $F(1, 14) = 4.87$, $p < .05$), but there was also a (nonsignificant) trend for rare words to be attended to longer when associated

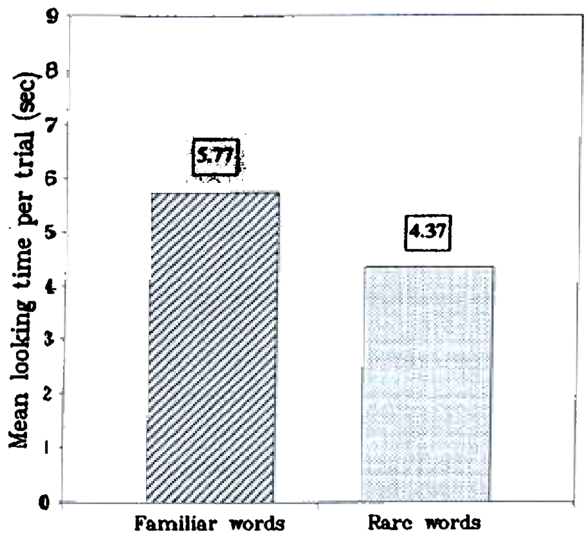


Figure 4. Test of Experiment 2: Mean looking times per trial to familiar versus rare words.

with the bottom lamp, that is, in the same experimental condition (5.0 s vs. 3.7 s: $F(1, 14) = 2.14$, $p = .16$). Hence, for whichever lamp assigned to familiar words, the preference for familiar words (as defined in Experiment 1) was the same (top lamp: $M = 0.577$ $SD = .093$; bottom lamp: $M = 0.570$ $SD = .149$). There was a slight trend for familiar words to be attended to longer when presented from the left (6.3 s vs. 5.2 s: $F(1, 14) = 1.48$, $p = .24$). Another indication of this trend was that 7 out of 8 infants preferred familiar words when presented from the left, whereas only 5 out of 8 infants preferred familiar words when presented from the right. There was a marginal side position interaction, $F(1, 12) = 2.99$, $p = .11$: Familiar words were attended to longer when presented from the left and associated with the top lamp. No other effect or trend was found.

Analyses of the preference for familiar words confirmed that the mean preference, 0.574 ($SD = .120$), was significantly above the chance level 0.5, $t(15) = 2.46$, $p < .03$. They revealed no significant effect of either side, position, or type. Further *t*-tests indicated no significant effect of sex on the preference for familiar words ($M = 0.584$, $SD = .092$, for females; $M = 0.563$, $SD = .149$, for males: $t(14) < 0.5$).

Disregarding the type of words presented and the side of presentation, gaze duration toward the top and bottom lamp did not differ. Likewise, no advantage was found for one side of presentation over the other when disregarding the type of words and lamp position. Finally, no advantage was found for the type of list presented first.

Training data were analyzed in the same way as test data. The mean preference for familiar words, 0.588 ($SD = .098$), was above the chance level 0.5, $t(15) = 3.59$, $p < .003$. So, preference had already emerged in the training phase. There was a slight trend for rare words to be attended to longer when associated to the bottom lamp (as in the test phase), but there was no trend for familiar words to be attended to longer in the same experimental condition (i.e., when associated with the top lamp). No other effect or trend was found. Unlike the familiarization phase of Experiment 1, no

TABLE 2
Test of Experiment 2: Looking Time *per Trial* to Familiar Words and Rare Words, and *Preference* for Familiar Words, for Each Experimental Condition

Condition			Looking Time (s)			
Side	Position	Type of List First	To Familiar Words	To Rare Words	Total Time	Preference
Right	Top	Fam.	7.28	6.53	13.82	0.540
Right	Top	Rare	6.42	3.52	9.93	0.640
Right	Bot.	Fam.	4.33	2.05	6.38	0.695
Right	Bot.	Rare	2.80	3.90	6.70	0.424
Left	Top	Fam.	5.00	3.80	8.80	0.563
Left	Top	Rare	8.07	6.30	14.37	0.567
Left	Bot.	Fam.	6.70	3.92	10.62	0.635
Left	Bot.	Rare	5.55	4.95	10.50	0.528
M (*SD*)			5.77 (1.90)	4.37 (1.90)	10.14 (3.10)	0.574 (0.12)

on French vocabulary. Dictionary of frequencies. Literary vocabulary of the 19th and 20th centuries]. Centre de recherche pour un Trésor de la Langue Française (CNRS). Nancy, Paris: Librairie Marcel Didier.

Jusczyk, P.W., Charles-Luce, J., & Luce, P. (in press). Infants' sensitivity to high frequency vs. low frequency phonetic sequences in the native language. *Journal of Memory and Language*.

Jusczyk, P.W., Friederici, A., Wessels, J., Svenkerud, V., & Jusczyk, A.M. (1993). Infants' sensitivity to the sound patterns of native language words. *Journal of Memory and Language, 32*, 402–420.

Macken, M. (1980). Developmental reorganization of phonology: A hierarchy of basic units of acquisition. *Lingua, 49*, 11–50.

Menyuk, P., & Menn, L. (1979). Early strategies for the perception and production of words and sounds. In P. Fletcher & M. Garman (Eds.), *Language acquisition: Studies in first language development*. Cambridge: Cambridge University Press.

Molfese, D.L. (1990). Auditory evoked responses recorded from 16-month-old human infants to words they did and did not know. *Brain and Language, 38*, 345–363.

Neville, H.J. (1992, July). *Role of experience in neurocognitive development*. Paper presented at NATO's Advance Research Workshop on "Changes in speech and face processing in infancy: A glimpse at developmental mechanisms of cognition," Carry-le-Rouet, France.

Oviatt, S.L. (1980). The emerging ability to comprehend language: An experimental approach. *Child Development, 51*, 97–106.

Snyder, L.S., Bates, E., & Bretherton, I. (1981). Content and context in early lexical development. *Journal of Child Language, 8*, 565–582.

Spelke, E.S. (1979). Perceiving bimodally specified events in infancy. *Developmental Psychology, 15*, 626–636.

Thomas, D.G., Campos, J.J., Shucard, D.W., Ramsay, D.S., & Shucard, J. (1981). Semantic comprehension in infancy: A signal detection analysis. *Child Development, 52*, 798–803.

Tubach, J.P., & Boë, L.J. (1990). *Un corpus de transcription phonétique (300,000 phones): Constitution et exploitation statistique*. Internal Report Teélécom Paris 90 D 002.

Wenk, B., & Wioland, F. (1982). Is French really syllable-timed? *Journal of Phonetics, 10*, 193–216.

14 October 1992; Revised 4 January 1993 ■

APPENDIX A

Familiar and Rare Words in Experiment 1

Familiar Words	Rare Words
bonjour [bɔ̃ʒuʁ]	beaudroie [bodʁwa]
gâteau [gɑto]	charpie [ʃaʁpi]
boire [bwaʁ]	berline [bɛʁlin]
lapin [lapɛ̃]	licence [lisɑ̃s]
poupée [pupe]	éclipse [eklips]
ballon [balɔ̃]	friable [fʁijabl]
voiture [vwatyʁ]	caduc [kadyk]
canard [kanaʁ]	iguane [igwan]
chaussure [ʃosyʁ]	tangage [tɑ̃gaʒ]
encore [ɑ̃kɔʁ]	jactance [ʒaktɑ̃s]
chapeau [ʃapo]	scrupule [skʁypyl]
oiseau [wazo]	volute [volyt]

APPENDIX B

Familiar and Rare Words in Experiment 2

Familiar Words	Rare Words
bonjour [bɔ̃ʒuʁ]	busard [byzaʁ]
gâteau [gɑto]	cobaye [kobaj]
biberon [bibʁɔ̃]	berline [bɛʁlin]
lapin [lapɛ̃]	licence [lisɑ̃s]
poupée [pupe]	diffus [dify]
ballon [balõ]	fusain [fyzɛ̃]
voiture [vwatyʁ]	caduc [kadyk]
canard [kanaʁ]	soudard [sudaʁ]
chaussure [ʃosyʁ]	tangage [tɑ̃gaʒ]
encore [ɑ̃kɔʁ]	enzyme [ɑ̃zim]
chapeau [ʃapo]	bigot [bigo]
oiseau [wazo]	volute [volyt]