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The Format of Representation of Recognized Words in Infants' Early Receptive Lexicon

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Eleven-month-olds can recognize a few auditorily presented familiar words in experimental situations where no hints are given by the intonation, the situation, or the presence of possible visual referents. That is, infants of this age (and possibly somewhat younger) can recognize words based on sound patterns alone. The issue addressed in this article is what is the type of mental representations infants use to code words they recognize. The results of a series of experiments with French-learning infants indicate that word representations in 11-month-olds are segmentally underspecified and suggest that they are all the more underspecified when infants engage in recognizing words rather than merely attending to meaningless speech sounds. But underspecification has limits, which were explored here with respect to word-initial consonants. The last two experiments show the way to investigating further these limits for word-initial consonants as well as for segments in other word positions. In French, infants' word representations are flexible enough to allow for structural changes in the voicing or even in the manner of articulation of word-initial consonants. Word-initial consonants must be present, however, for words to be recognized. In conclusion, a parallel is proposed between the emerging capacities to ignore variations that are irrelevant for word recognition in a "lexical mode" and to ignore variations that are phonemically irrelevant in a "neutral mode" of listening to native speech.

language acquisition word recognition receptive lexicon word-form representations

Young children who do not yet produce words often appear to understand a few words and short phrases in certain familiar situations. To do so, they are probably aided by various contextual cues provided by intonation, situation, behavioral routines, and so forth. For that reason, observational studies perhaps overestimate infants' capacities to understand words and should be considered with some caution. For example, Benedict's (1979) article has often been quoted as showing that the onset of word comprehension occurs at 9 to 10 months. Other observational studies (e.g., Harris, Yeeles, Chasin, & Oakley, 1995; Huttenlocher, 1974) also have suggested around 9 to 10 months for the onset of word comprehension. More recently, a wide-range study based on parental reports (from more than 1,800 families) of children aged from 8 to 16 months found that 8-month-olds are credited with understanding as many as 36 words on the average (Bates, Dale, & Thal, 1995, p. 102). Interpretations of these data in terms of linguistic word comprehension may, however, be somewhat optimistic. As Bates et al. (1995) acknowledged, parents may "[infer] comprehension from nothing more than evidence for high attention and positive affect." Menyuk and Menn (1979) have suggested that young infants who seem to comprehend a word in a naturalistic setting respond to the word sound pattern *plus* the situation. Put another way, infants might not use, at this stage, *representations* of words based on a purely linguistic code. In contrast to the optimistic view, a few studies conducted in controlled laboratory settings have detected the onset of word comprehension no earlier than 12 to 13 months (Oviatt, 1980; Thomas, Campos, Shucard, Ramsay, & Shucard, 1981). However, ERP studies provide indirect evidence of a differential processing of known versus unknown words at earlier ages: 12 months (Molfese, Wetzel, & Gill, 1993) or even 10 months for "early comprehenders" (Mills, Coffey, & Neville, 1993).

More recently, *recognition* (not necessarily *comprehension*) of words thought to be familiar

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to French infants in their environment has been shown in experimental situations from the age of 10½ months by Hallé and Boysson-Bardies (1994) using a head-turn preference procedure. Because words in these experiments were presented to children in the absence of any situational or intonational cues, recognition of familiar words was based on the sound pattern alone, that is, presumably, on a linguistic code. The hypothesis tested in Hallé and Boysson-Bardies' study was primarily that, around 10 months of age, infants would have noticed in their linguistic environment frequent words occurring in ecologically relevant situations; they would have extracted words heard in their environment in various referential situations where they could be associated to some sort of meaning. Such words could not be simply those words frequently experienced by children, but, more relevantly, words especially appealing to them (i.e., meeting certain communication needs). Among those words are presumably the words they will soon attempt to produce. Hallé and Boysson-Bardies' study thus used early words drawn from infants' production data as "familiar words" to test infants' word recognition. A second underlying hypothesis was that despite some individual variability, a "core set" of words would be shared by most infants. Hence, the authors chose those early words that had been attempted by a majority of French children. Indeed, Hallé and Boysson-Bardies' results supported both hypotheses: Items in this core set of frequently attempted familiar words were recognized by 12-month-old as well as by younger French infants aged from 10½ to 11½ months. (Factors such as prosodic contour and phonetic complexity were controlled so that word recognition rather than preference for appealing sounds could be inferred from the results.) Importantly, infants received no controlled training on familiar words during or before the experimental sessions: They recognized words they already knew. Therefore, the ability to recognize familiar words found in Hallé and Boysson-Bardies' study appears to be based on stable word representations, which children have formed in the natural conditions of daily life. The question that arises now is what sort of *format of representation* the infants use to code familiar words. This question is of particular relevance if we assume that at least some features of children's recognition of known words prefigure adult lexical access as well as lexical representation of words (e.g., the WRAPSA model, Jusczyk, 1993). This assumption seems to be implicit in some models of adult lexical access (Gaskell, Hare, & Marslen-Wilson, 1995; Luce, 1986; Marslen-Wilson, 1993; also see Walley & Metsala, 1990, p. 267, and Walley, 1993, p. 288–291, for relevant reviews).

As early as 4½ months, young infants have been found to respond to their own name more than to other names (Mandel, Jusczyk, & Pisoni, 1995). This is of course an extreme case of "familiar" word recognition, and nothing is known (or guessed) as to how very young infants may code the spoken form for their own name. There is probably little relationship, if any, with the format of 11-month-olds' representation for familiar words. As for somewhat older infants, Jusczyk and his colleagues have recently reported an impressive body of studies showing that infants as young as 7½ months are able to code and recognize a few words they had been trained on, even when these words are embedded in short sentences (Hohne, Jusczyk, & Redanz, 1994; Jusczyk & Aslin, 1995; Newsome & Jusczyk, 1994). In these experiments, Jusczyk and colleagues looked for infants' capacity to code, recall, and recognize words and, therefore, compared trained and nontrained words that were otherwise grossly equivalent in terms of frequency and phonetic complexity in the speech children are exposed to, so as to avoid the unwanted bias of natural familiarity. A key feature of the experimental procedure was that the trained and nontrained sets were counterbalanced across subjects. Hence, the word recognition capacity that was found critically depended on previous training. For example, Jusczyk and Aslin (1995) used monosyllabic words that are rather frequent in adult speech: *cup* and *dog*, or *feet* and *bike* (although perhaps not so frequent in infant-directed speech; Vihman & Boysson-Bardies, 1994). Newsome and Jusczyk (1994) used much less frequent disyllabic words (*kingdom, hamlet, doctor, candle, device, beret, guitar*, and *surprise*) and obtained largely similar results: Trained words were recognized. It could hardly be the case that infants had already associated such disyllabic words with meanings. Yet, they were able to code and retain in memory the sound patterns of the words they heard during the training phase. (This ability was limited to words with a trochaic stress pattern.) Multiple presentations of words allowed infants to recall word forms and to subsequently recognize them in different linguistic contexts (e.g., training on isolated words and test on words within short sentences, or vice versa). In a recent experiment (Hohne et al., 1994), 8-month-olds were found to be able to remember words heard in stories after a 2-week delay, but this ability seemed to be overridden by the memory of the storyteller's voice when only two storytellers were used (Jusczyk, Hohne, Jusczyk, & Redanz, 1993). Interestingly, these experiments suggest that infants coded word forms in a more abstract format than a purely acoustic format: The word forms occurring in the training and in the test were acoustically different (due to speaker's voice or to speech context, which entail various realizations of the same phones). However, infants could no longer recognize trained words when just one segment was *phonetically* changed. For example, in Jusczyk and Aslin's study, infants trained on *cup* and *dog* showed no recognition for *tup* and *bawg* presented in the test phase. The coding format infants used was thus probably based on a detailed *phonetic* (that is, not just *acoustic*) description of the word forms they had been trained on. This kind of coding would be in continuation with the detailed "universal" phonetic coding of speech sounds which underlies the capacities found in young infants to discriminate and phonetically categorize speech sounds as well as their capacities for equivalence classification (for reviews, see for example Kuhl, 1986, 1987).

In contrast with young infants' early representation of speech sounds and, later, of previously unknown trained words, the capacity to recognize known familiar words by 11 months seems to engage a qualitatively different format of representation (underlied, perhaps, by the same representational architecture but differently tuned). There are a number of reasons to predict a shift from analytic (segmentally specified) to nonanalytic (segmentally underspecified) representations at around 11 months.

Recognizing familiar words entails having coded them, which, in turn, entails having extracted words from the continuous speech input in the environment. When extracting words, children very likely rely on prosodic cues in the speech input. Moreover, for 11-month-olds, words have an internal coherence (they are perceived as bound units) which is presumably based on prosodic and rather global segmental characteristics (Myers, Jusczyk, Kemler Nelson, Charles-Luce, Woodward, & Hirsh-Pasek, 1996). Hence, 11-month-olds may extract and recognize words on the basis of global prosodic shape, that is, of nonanalytic (i.e., segmentally underspecified) representations.

We also may assume that children this age are probably in the process of attaching meanings to words, however vague or off-target these meanings may be. By that time, words have become something more than meaningless phonetic patterns. What children retain about the words they "know" must include a wider array of specifications than simply the phonetic details alone. Again, this suggests that children have built familiar word representations which are "multileveled" and whose scope is much broader than a mere pattern of sounds, and which are relatively underspecified phonetically, possibly because of the additional cognitive load entailed by semantic coding.

The notion of an initial underspecification of segmental aspects and a dominance of prosodic aspects is reminiscent of what Macken (1980) called "prosodic words," the early words *produced* by children: Early words are not represented in a detailed manner by children. The notion of a holistic coding of the early words produced by children derives from the observation that only their global shape is preserved while phonetic details are highly variable (Ferguson, 1986; Ferguson & Farwell, 1975). It might be the case that children use the same type of underspecified representations in their receptive lexicon.

A different kind of argument that could also support the notion of initially underspecified lexical representations is worth mentioning. The general idea is that because the size of the receptive lexicon is initially small, there is no need for detailed representations to distinguish items from one another. As Walley (1993) put it, when "the child's vocabulary is small, there is little *need* to represent the acoustic-phonetic patterns corresponding to words as sequentially organized phonemic segments." The need to gradually shift toward a more analytic code (e.g., segmental) would arise from vocabulary growth (in line with the notion that the "phonemic segment *emerges* first as an implicit, perceptual unit by virtue of vocabulary growth"; Walley, 1993). Even at 7 years, the items in children's lexicons are overall much more discriminable than those in adults' lexicons (Charles-Luce & Luce, 1990, 1995; but see Dollaghan, 1994) in the sense they have much less dense neighborhood. Items in 11-month-olds' lexicons should be even more discriminable. However, a quantitative difference in word neighborhood density does not necessarily entail a *qualitative* difference in word representation format. Indeed, minimal pairs may enter quite early in infants' receptive lexicon, such as *main* [*hand*] and *bain* [*bath*] in French. How can infants deal with these pairs? Walley proposed that infants only code "salient feature(s)" of early words. Indeed, this is a possible form of underspecification. Supposing that two words differing by a single segment successively enter the child's early repertoire, first *cat*, then *cap*, Walley suggested that one child might represent *cat* as [+ abrupt onset], then *cap* as [+ labial] (which we would better think of as adding to the [+ abrupt onset] specification). This kind of strategy, however, would leave the child with a considerable amount of future work each time a new item comes in to find an appropriate and efficient discriminative salient feature. An alternative possibility, which we would like to test, is that *cat* and *cap* initially have a similar, holistic, format of representation, possibly ignoring the /t/ : /p/ contrast. In the early stage of lexical development, infants may not be able to discriminate these words on the sole basis of their sound shape, without the help of contextual cues. The coding of word forms would thereafter become more and more analytic, allowing word recognition from spoken forms alone (without external context) to improve with experience. On this view, the impetus for an increasingly fine-grained coding of words, eventually leading to the emergence of segmental units of representation, is not vocabulary growth *per se*, but rather the increasing need to use the speech medium in an autonomous way.

That 11-month-old infants use a rather holistic format to code words familiar to them may seem to contradict the finding that 8-month-olds use a rather detailed and rigid format to recall and recognize words on which they have been trained. There is no contradiction if we assume a developmental change in the representational format for word-sized units. This change would coincide with the emergence of "meaning," that is, with the emergence of an early receptive lexicon (more exactly, an initial store of words, because a true "lexicon" requires some internal organization). The formation of an early store of language-specific words around 10 months of age may be the cause—as was first proposed by MacKain (1982)—of the language-specific attunement of infants' phonetic sensitivity, which is observed around the same age (Best, McRoberts, & Sithole, 1988; Werker & Tees, 1984).

At this point, however, a qualitative change in the coding format of words around 10 to 11 months remains speculative. The opinion that early lexical representations are holistic, following detailed representations of speech sounds in early infancy and followed by more analytic lexical representations in late infancy at the time of the vocabulary spurt, would reflect a general trend in development outlined by Aslin and Smith (1988): from parts to wholes then back to parts. But no empirical data have been collected yet to support the view of a holistic format of representation at 11 months, and we cannot dismiss the possibility that a phonetically detailed coding is maintained, at least partially, for those words that infants have stored in a primitive receptive lexicon.

The series of experiments reported in this article should be viewed as a first step in testing the "holistic hypothesis" in word recognition. We shall now briefly outline the principle on which these experiments are based. Eleven-month-olds prefer listening to familiar words (a good part of which they presumably recognize) than to utterly unknown words (rare or unfamiliar words). According to the holistic hypothesis, altering the phonetic shape of familiar words should be tolerated by infants (that is, would not prevent them from recognizing/preferring the underlying familiar words), at least to a certain extent. On the opposite view, that of a rigid/analytic coding format, even a small phonemic alteration should hinder the recognition of familiar words. Importantly, the alterations we are speaking about are phonemic alterations according to French phonology, not variations in pronunciation style, or in linguistic context, such as words in isolation versus words embedded in a sentence, or words uttered by different speakers. The kind of modifications tested here all belong to the *linguistic structural* level, not to the physical level of realization. This is because we already have some evidence that 4- to 7-month-old infants can abstract from speakers' voices, or from fundamental frequency (F_0) contour variations, to classify as equivalent various tokens of segmentally identical syllables (Hillenbrand, 1984; Kuhl & Miller, 1982). Jusczyk and Aslin's (1995) findings also suggest that infants manage to abstract from duration/intonation differences between words in a sentence context and words in isolation (and possibly from some allophonic differences). The scope of the study presented here is therefore limited to structural variations in word forms. Its main goal is to test the holistic hypothesis of early word representations. At the same time, even if representations are holistic, there clearly must be a limit as to how holistic they may be. Therefore, another goal of this study was to discover the limits within which word forms may vary and still be mapped to the same, holistic representation. The logic underlying this search consisted in testing the recognition of increasingly deviant forms of familiar words. In short, drastic alterations of familiar words should probably block their recognition, whereas slight deformations are not expected to hinder recognition. The specific question asked is "What is the permissible degree of deformation whereby word recognition is still preserved?"

The experiments reported here look at the effects of alterations of the word-initial consonant. In the last experiment, one step is taken toward examining alterations of the word-medial consonant.

EXPERIMENT 1: VOICING OF WORD-INITIAL CONSONANT

In Experiment 1, we used the bisyllabic familiar words used in Hallé and Boysson-Bardies (1994). (In a previous longitudinal study of French infants, Boysson-Bardies & Vihman, 1991, had shown that the most frequently attempted words were bisyllabic words.) They were altered by a small change in the word-initial consonant. Voiced consonants were changed into their unvoiced counterpart, and vice versa. (*encore* /ɑ̃kɔr/ the only word with a vowel initial, was changed into /akɔr/.) For example, *gâteau* /gato/ became /kato/, *poupée* /pupe/ became /bupe/ (see Table 1). The resulting items were nonsense words, except for /akɔr/, a rendering of *accord*: This word, however, is a low-frequency word and is certainly unknown to 11-month-olds. We used the head-turn preference paradigm (Fernald, 1985; Jusczyk, Friederici, Wessels, Svenkerud, & Jusczyk, 1993), slightly modified, to test the preference of 11-month-old infants for (altered) familiar words over unfamiliar words. The unfamiliar words, listed in Table 1, were those used in the Hallé and Boysson-Bardies' study, Experiment 2, except for two rare words that were changed in order to get a

TABLE 1
Lists of Unaltered and Altered Familiar Words and of Rare Words Used in Experiments 1 and 2.

	Familiar Words		Rare Words	
	(Unaltered)	(Altered)		
bonjour	/bɔ̃ʒur/		busard	/byzar/
gâteau	/gato/		cobaye	/kobaj/
biberon	/bibrɔ̃/		berline	/bɛrlin/
lapin	/lapɛ̃/		licence	/lisɑ̃s/
poupée	/pupe/		défaut	/defo/
ballon	/balɔ̃/		félin	/felɛ̃/
voiture	/vwatyr/		caduc	/kadyk/
canard	/kanar/		soudard	/sudar/
chaussure	/ʃosyr/		tangage	/tɑ̃gaʒ/
encore	/akɔr/		enzyme	/ɑ̃zim/
chapeau	/ʃapo/		bigot	/bigo/
oiseau	/wazo/		volute	/volyt/

better balance between the two types of words in phonetic complexity.

Method

Stimuli

All words, (altered) familiar or rare, were bisyllabic. Familiar and rare words had about the same number of phonemes (M = 4.75, SD = 0.62 in rare words; M = 4.50, SD = 0.67 in familiar words). According to Tubach and Boë's (1990) phonetic counts on spoken French (based on corpora totalling 300,000 "phones"), the average phoneme frequency was 4.19% (SD = 2.68) in altered familiar words and 3.97% (SD = 2.41) in rare words. The mean phoneme-sequence probability per phoneme unit (Hallé & Boysson-Bardies, 1994) was 4.56% (SD = 2.53) for altered familiar words and 4.66% (SD = 1.85) for rare words. None of these differences reached significance. Median phoneme-sequence probabilities (unnormalized to phoneme unit) were 8.23×10^{-7} (altered familiar words) versus 4.93×10^{-7} (rare words). To summarize, the matching of rare words to altered familiar words with respect to phonetic complexity was nearly perfect.

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 $1{,}718 \times 10^{-8}$ for (unaltered) familiar words, 102×10^{-8} for rare words. As in the previous study with unaltered words, closeness in phonetic shape of each rare word to any altered familiar word was avoided so that confusion between the two sets of words would be unlikely. All these words were recorded by a French female speaker with a Sennheiser microphone and a Denon DAT tape recorder, then digitized using an OROS 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 a different couple of words (this was possible because there were six lists of 12 words for each type of list). All lists were about 20 s in duration. Word durations ranged from 470 to 960 ms (M 688 ms, SD = 201) for familiar words, from 470 to 1,000 ms (M 760 ms, SD = 176) for rare words; this difference did not reach significance, $t(22) < 1.00$. There was no overall difference between familiar and rare words in F_0 contour or intensity, as shown by the values of various parameters such as mean F_0, F_0 excursion (as computed in Hallé, Boysson-Bardies, & Vihman, 1991), and mean intensity (Table 2).

Subjects

Eight infants were tested. They had an average age of 11 months and 5 days (range = 10.17–11.13; SD = 9 days). There were 4 boys and 4 girls. All were tested successfully. All subjects had normal perceptual and motor development. None of them was reported to produce more than two discernible words.

Apparatus

The subject sat on the parent's lap in the center of a three-sided booth (2.0 m × 1.8 m), eyes at about 75 cm from the center panel. A small blue lamp and a loudspeaker were mounted on each side panel, at eye level and about 75° from the center direction. The observer sat behind the center panel and could monitor the infant's gaze direction through a hole, without being seen. The observer used two small flashing red lights, at the right and left edges of the hole, to call the infant's gaze to the center direction; he used a response box with two "side" buttons to signal left or right gaze to the computer in the next room, and a third button to start each trial when the infant's gaze had been "reset" to the center direction. Stimulus playback was performed using a two-channel 16-bit D/A convertor (10 kHz sampling rate) whose output was amplified by a NAD stereo amplifier and fed to Pioneer 30-W loudspeakers.

Procedure

The procedure was a modified version of the procedure used by Hallé and Boysson-Bardies (1994), based on the head-turn preference procedure originally developed (although for nonspeech sounds) by Colombo and Bundy (1981, 1983) and Fernald (1985), and later adapted by Jusczyk, Friederici, et al. (1993). Experimental sessions consisted of three phases: a familiarization phase, a training phase, and a test phase. For each subject, altered familiar words always came from the speaker on one side, rare words came from the speaker on the other side; the type of the list presented first was the same in all three phases. These two factors, *side* assigned to familiar words and *type* of first list, were counterbalanced across subjects.

The familiarization phase was intended to acquaint the subject with the side assigned to each type of list: One list of one type was presented first, then one list of the other

TABLE 2
Comparison of the Stimuli Used in Experiment 1 (Rare vs. Familiar Words Altered for Initial Consonant Voicing) for F_0 Contours and Intensity

	Word Type		Comparison	
	Altered Familiar	Rare	$t(22)$	Significance
M F_0 (Hz)	169 (7)	164 (12)		*ns* (p = .16)
Max F_0 (Hz)	228 (12)	223 (7)		*ns* (p = .23)
Min F_0 (Hz)	123 (5)	123 (5)		*ns*
F_0 Excursion (%)	−59 (14)	−57 (13)		*ns*
Max Energy (dB)	72 (3)	74 (4)		*ns* (p = .22)

Note. *SD*s are shown between brackets. F_0 excursion is an index of F_0 slope, negative for falling contours, positive for rising contours.

type. In this phase, both lists were presented in full, no lamp was turned on, and no gaze duration was measured. The training phase was intended to teach the infant the contingency between gaze orientation and auditory presentation of words: Three different lists of one type were presented first, then three lists of the other type. In the test phase, a total of six rare lists and six familiar lists was presented; the lists were presented in random order, with the constraint that no more than two lists of the same type could occur in a row.

Aside from the sequencing of lists, identical procedures were followed in the training and in the test. The observer depressed the button on the side of the list currently presented whenever the subject began or resumed orienting to the speech and did not release the button 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 button on the side of that list. In each trial (i.e., list), a few words were allowed to the child before he or she started orienting to the speech (four in the training phase, three in the test phase); in case the infant did not start orienting, the list was terminated; once the child had begun orienting to the speech, the list was terminated if the subject looked away for more than 2 s (more exactly, three words, because a list was never interrupted in the midst of a word). If the child 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. Otherwise, the list was terminated after all the items (i.e., 12 items) had been presented.

In all three phases, whenever one list had been terminated, the observer turned on the center red lights, until the child looked back to the center direction. Once this was obtained, the next list was played. In the training and test phases only, the blue lamp on the side of the list to be presented was turned on (blinking four times at the onset, then steady on), and that list was then presented after a ½-s delay. The lamp was then left on during the entire trial.

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

Results and Discussion

Results of the test phase are shown in Figure 1. The mean looking time per trial was 4.83 s (*SD* = 1.59) for altered familiar versus 2.67 s (*SD* = 0.62) for rare words. This difference was significant, $t(7) = 3.57$, $p = .012$. Another way to look at the data is to consider the *preference ratio* for one type of stimuli over the other (defined as the proportion of orientation time to this type of stimuli). One advantage of the preference ratio is that the variance due to individual differences in total attention span is factored out. The mean preference ratio for altered familiar over unfamiliar words was 0.635 (*SD* = 0.088), significantly above the chance level

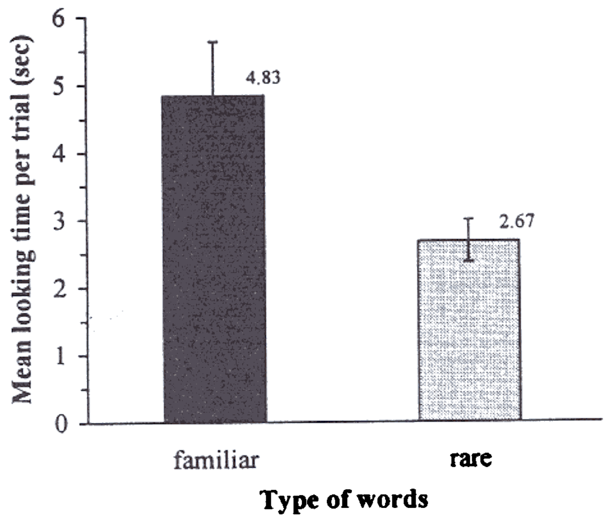

Figure 1. Mean looking times per trial to altered familiar versus rare words (change of initial consonant voicing): Experiment 1.

0.500, $t(7) = 4.35$, $p = .0035$. All eight infants oriented longer to the altered familiar words. So, altered familiar words, just like unaltered familiar words, were preferred over unfamiliar words. This finding suggests that familiar words were still recognized in spite of the phonemic alteration. Thus, the voicing of the word-initial consonant is probably not specified in the infants' representation of familiar words.

We can assume, however, that infants of this age should have no difficulty perceiving a voicing contrast, as long as it is phonemic in the language they learn (e.g., Werker & Tees, 1984). French infants should discriminate, for example, *ballon* and *pallon*; when presented with both versions of familiar words, altered and unaltered, they might prefer listening to unaltered words because they sound like better exemplars of familiar words. Another possibility is that 11-month-old infants are insensitive to the difference between altered and unaltered familiar words because they process both *as words* and because both types match equally well with their representations of familiar words. Put another way, when infants' attention is focused on the recognition of words, they may be "deaf" to certain phonemic changes they could perceive when attending to meaningless speech sounds. To clarify this issue, that of a "lexical mode" of listening to speech, an additional test was run to check whether or not infants are sensitive to the correct voicing of word-initial consonant when listening to familiar words.

EXPERIMENT 2: VOICING OF WORD-INITIAL CONSONANT IN FAMILIAR WORDS

In this experiment, 11-month-olds were tested for their preference of unaltered over altered familiar words. The issue at stake was whether or not infants would prefer listening to unaltered familiar words because they matched better with infants' representations of familiar words. The same procedure and apparatus as in Experiment I were used. The same familiar words as in Experiment 1 were used, either altered or not, in the voicing of the initial consonant.

Method

Stimuli

All the speech material was recorded again in a single recording session to avoid unwanted differences in rate of articulation, intonation, or recording level. As shown in Table 3, there was no significant differences between altered and unaltered familiar words in F_0 contour or intensity. Word durations ranged from 563 to 1,142 ms (M = 805 ms, SD = 204) for unaltered, from 498 to 1,140 ms (M = 774 ms, SD = 211) for altered familiar words; this difference was far from significant, $t(22) < 0.50$. We also compared the phonetic complexity of the stimuli, as reported earlier for altered familiar words and in Hallé and Boysson-Bardies (1994) for unaltered familiar words. The average phoneme frequency was 3.93% (SD = 2.72) for unaltered words, 4.19% (SD = 2.68) for altered words. The mean phoneme-sequence probability per phoneme unit was 4.74% (SD = 2.40) versus 4.56% (SD = 2.53). Finally, the median phoneme-sequence probabilities (unnormalized) were 7.10×10^{-7} versus 8.23×10^{-7}. Hence, the matching with respect to phonetic complexity was excellent. This was especially important in this experiment: We did not want a possible preference for one type of word over the other to be confounded by differences in phonetic/phonotactic complexity.

Subjects

Twelve infants were tested. They had an average age of 10 months and 25 days (range = 10.13–11.80; SD = 6 days). There were 7 girls and 5 boys. One additional girl was run but not retained because of a condition assignment error.

Results and Discussion

The results are shown in Figure 2. The mean looking time per trial was 4.18 s (SD = 2.19) for unaltered versus 3.53 s (SD = 1.75) for altered familiar words. This difference was not significant, $t(11) = 0.95$, $p = .366$. The mean preference ratio for unaltered over altered familiar words was 0.523 (SD = 0.205), not significantly different from the chance level 0.500, $t(11) < .050$. As is seen in Figure 3, the distribution of the preference ratio was random, widespread, and centered on 0.500: Five infants preferred the unaltered forms, 5 preferred the altered forms, and 2 showed no preference There was no systematic preference for one type of word over the other. This suggests that infants, when listening to words they largely recognize, were not sensitive to the voicing feature of the first consonant. Together with the outcome of Experiment 1, where altered familiar words were clearly preferred over unfamiliar words, we may interpret the pattern of results as indicating that infants' representations of familiar words are loose enough to allow for nonspecification of initial consonant voicing. What the outcome of Experiment 2 adds to the figure is that unaltered forms of familiar words do not match better than altered forms with infants' mental representations: Preference was random, that is, not linked to word form in any systematic way. When infants are engaged in recognizing words, they are not bothered by word-form variations that are not critical for the words to be recognized. The variations at stake, though, were phonemic, and 11-month-olds are normally able to perceive phonemic contrasts when listening to meaningless syllables. A possible explanation

TABLE 3
Comparison of the Stimuli Used in Experiment 2 (Familiar Words: Unaltered vs. Altered for Initial Consonant Voicing) for Fo Contours and Intensity

	Word Type		Comparison	
	Altered Familiar	Rare	$t(22)$	Significance
M F_0 (Hz)	171 (10)	175 (9)		ns
Max F_0 (Hz)	236 (17)	239 (10)		ns
Min F_0 (Hz)	122 (5)	124 (3)		ns
F_0 Excursion (5)	−63 (17)	−61 (10)		ns
Max Energy (dB)	64 (3)	64 (3)		ns

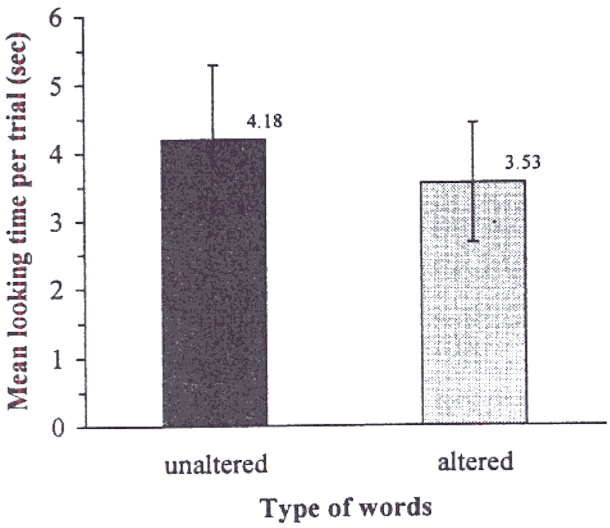

Figure 2. Mean looking times per trial to altered versus unaltered familiar words (change of initial consonant voicing): Experiment 2.

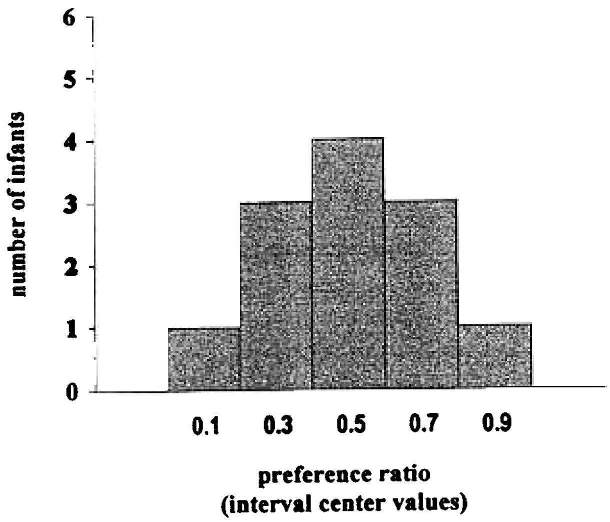

Figure 3. Distribution of the preference ratios (see text) in Experiment 2.

of the results is that infants were engaged in a "lexical" mode of listening, where word-form variations that are not relevant for infants' lexicon are ignored, just as sound variations that are not relevant to their developing sound system are ignored.

The results of Experiments 1 and 2 are a first step in demonstrating that early word representations are underspecified, that is, global rather than analytic. However, the voicing feature we chose to investigate first is probably not highly salient. Assuming that the flexibility of word representations allow for structural alterations until a certain limit, the voicing alteration was below that limit. As a means to gradually circumscribe a narrower range where the "flexibility limit" could possibly lie, the next alteration we tried was expected to go beyond the limit: Word-initial consonants were suppressed altogether. If children did not exhibit a preference for altered familiar over rare words, this would mean that the alteration was too severe and blocked recognition.

EXPERIMENTS 3 AND 4: SUPPRESSION OF WORD-INITIAL CONSONANT

Experiments 3 and 4 followed the same line of reasoning as Experiments 1 and 2. Experiment 3 tested the preference of altered familiar over rare words, whereas Experiment 4 tested the sensitivity to the difference between altered and unaltered familiar words.

Because the alteration tested was the radical suppression of word-initial consonants, all altered familiar words began with a vowel. A preference for altered familiar words over rare words thus could simply be a preference for items beginning with a vowel rather than a consonant. To avoid this potential problem, the word-initial consonant of rare words was suppressed too. Also, in order to keep a balance between the initial vowels of altered familiar words and altered rare words—they were often /a/ in familiar words but not in rare words—*banane* and *ballon* were replaced with *merci* and *coucou*, and the initial vowel of some altered rare words was changed to /a/ (Table 4). All the altered familiar or rare words were nonsense words.

In Experiment 4, as in Experiment 2, altered familiar words were compared to unaltered familiar words. After such a radical alteration as initial consonant suppression, we were expecting that infants would be sensitive to the difference between vowel-initial and consonant-initial words and might prefer the latter which build up more frequent phonotactic combinations in French (Boysson-Bardies, 1993, 1994). A preference for frequent combinations of sounds could be predicted from Jusczyk, Luce, and Charles-Luce's (1994) results. Another possibility, suggested earlier, is that

TABLE 4
Lists of Altered Familiar and Rare Words Used in Experiment 3

Altered Familiar Words		Altered Rare Words	
(bonjour)	/ɔ̃ʒur/	(busard)	/yzar/
(gâteau)	/ato/	(cobaye)	/obaj/
(biberon)	/ibrɔ̃/	(berline)	/ɛrlin/
(lapin)	/apɛ̃/	(licence)	/isɑ̃s/
(poupée)	/upe/	(défaut)	/afo/
(coucou)	/uku/	(félin)	/elɛ̃/
(voiture)	/atyr/	(caduc)	/adyk/
(canard)	/anar/	(soudard)	/udar/
(chaussure)	/osyr/	(tangage)	/ɑ̃gaʒ/
(banane)	/anan/	(enzyme)	/azim/
(chapeau)	/apo/	(bigot)	/ago/
(oiseau)	/azo/	(volute)	/alyt/

because half the words presented were familiar words, 11-month-olds would engage in recognizing words and be deaf to even such gross changes as initial consonant removal, in the sense that they would not recognize unaltered forms better than altered forms.

Method

The same procedure as in Experiments 1 and 2 was followed.

Stimuli

The speech material for Experiments 3 and 4 was recorded in a single recording session. Hence, the same utterances of altered familiar words were used in Experiments 3 and 4. As is seen in Table 5, there was no significant difference in F_0 contour or in intensity between the words compared in Experiments 3 and 4. Word durations were not significantly different, $t(22) = 1.47$, *ns*, $p = .152$, in Experiment 3. In Experiment 4, where the comparison bore on familiar words whose initial consonant was suppressed or not, unaltered words tended to be longer than altered words, as could be expected ($M = 654$ ms vs. 554 ms, range = 496–946 vs. 450–762, respectively, $t(22) = 1.94$, $p = .063$). In Experiment 3, the stimuli were well balanced for phonetic complexity: The mean number of phones was 3.50 for altered familiar words, 3.83 for altered rare words. (It was 4.58 for unaltered familiar words.) The mean phoneme frequency and phoneme-sequence probability per phoneme unit were respectively 3.95% ($SD = 2.63$) and 4.81% ($SD = 2.34$) for unaltered familiar, 4.47% ($SD = 2.64$) and 4.62% ($SD = 2.27$) for altered familiar, 4.44% ($SD = 2.61$) and 3.71% ($SD = 1.01$) for altered rare words. The median phoneme-sequence probabilities were 3.47×10^{-5} (altered familiar) and 1.12×10^{-5} (altered rare). It was 1.13×10^{-6} for unaltered familiar words: Their overall greater phonetic complexity was in fact due to their larger number of phones. As can be seen, the matching in phonetic complexity was good, except for Experiment 4.

Subjects

Twelve infants (6 girls, 6 boys) were tested in Experiment 3. They had an average age of 11 months and 2 days (range = 10.11–11.14; $SD = 12$ days). One additional boy was run but not retained: He had been suffering from otitis 1 week earlier. Twelve infants (8 girls, 4 boys) were tested in Experiment 4. The mean age was 11 months and 4 days (range = 10.15–11.11; $SD = 9$ days). Two additional infants were run but could not be tested successfully: One was hopelessly crying and oriented to the words only 3 times out of 12, the other infant kept quiet but never oriented to words.

Results and Discussion

Results are shown in Figures 4 and 5. No significant advantage was found for one type of word over the other in either Experiment 3 or Experiment 4. In Experiment 3, where altered familiar and rare words were compared (e.g., *aussure* and *aduc*, derived from *chaussure* and *caduc*), the mean looking times per trial were 4.84 s ($SD = 2.51$) and 5.32 s ($SD = 2.22$) for familiar and rare words, respectively, $t(11) = 0.92$, *ns*, $p = .38$. In Experiment 4, looking times were not significantly longer for unaltered than for altered familiar words ($M = 5.02$ s vs. 4.23 s, respectively, $t(11) = 1.11$, *ns*, $p = .289$). The preference ratios, computed as in the previous experiments, were not different from the chance level in both experiments (0.48 and 0.53, respectively). What Experiment 3 seems to show is that familiar words are not recognized when the initial con-

TABLE 5
F_0 Contours and Intensity of the Stimuli Used in Experiments 3 and 4 (Suppression of Initial Consonant): Unaltered Familiar or Rare Words Compared to Altered Familiar Words

	Word Type		
	Altered Familiar		Rare
M F_0 (Hz)	183 (12)	181 (12)	174 (14)[a]
Max F_0 (Hz)	239 (16)	241 (9)	233 (15)
Min F_0 (Hz)	128 (4)	128 (5)	129 (7)
F_0 Excursion (%)	−54 (8)	−60 (12)	−51 (4)
Max Energy (dB)	69 (1)	69 (1)	69 (1)

[a]174 versus 183: $t(22) = 1.82$, *ns*, $p = .082$; other comparisons do not approach significance.

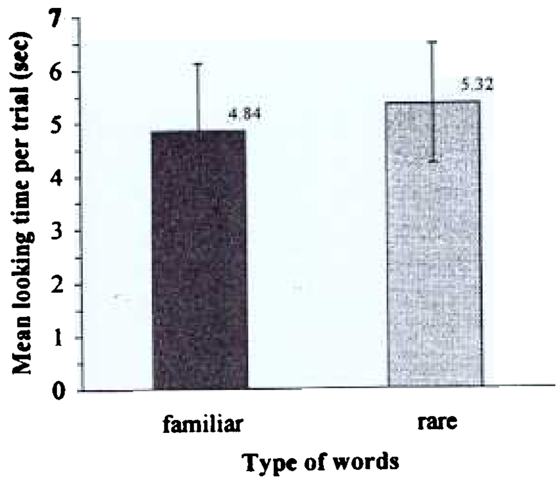

Figure 4. Mean looking times per trial to altered familiar versus altered rare words (suppression of initial consonant): Experiment 3.

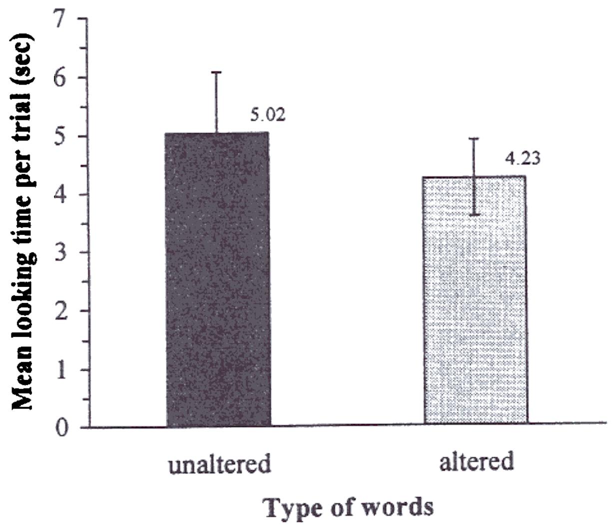

Figure 5. Mean looking times per trial to altered versus unaltered familiar words (suppression of initial consonant): Experiment 4.

sonant is removed. Although the representation of familiar words is somewhat elastic with respect to the initial consonant, as is suggested by Experiment 1, it is not flexible enough to allow for consonant suppression, that is, for a serious phonotactic alteration.

The outcome of Experiment 4 is contrary to one initial expectation. We surmised that infants would distinguish easily between, for example, *chaussure* /ʃosyr/ and *aussure* /osyr/, and prefer the unaltered version which is phonotactically more frequent: In French, vowel-initial words are much less frequent than consonant-initial words. Although unaltered items indeed tended to be preferred, the trend was far from significant. One explanation for the outcome of Experiment 4 is that altered words were primed, as it were, by their unaltered counterparts, which, according to our previous results, were probably recognized as words. Although infants could probably distinguish *chaussure* and *aussure*, they responded as if they were more interested by the similarity than by the difference. This must be because they listened to the familiar words in a "lexical" rather than in a "phonetic" mode. Of course, the same argument applies to the results of Experiment 2, where unaltered and altered familiar words were compared: When engaged in the lexical listening mode, infants pay little attention to phonemic differences they are otherwise sensitive to. In Experiment 2, such a result was thought to reflect underspecification of infants' word representations: Unaltered forms of familiar words did not match better than altered forms with infants' underspecified word representations. The similar pattern obtained in Experiment 4 may seem more surprising, because the altered forms of familiar words were not recognized in Experiment 3, where they were opposed to (altered) rare words: There was an insufficient match with familiar word representations. But we can understand the outcome of Experiment 4 if we assume that the presentation of unaltered familiar words could draw infants' attention to recognizing words. In this situation, the altered forms of familiar words were able to activate word representations. (These were possibly preactivated by the unaltered forms.) This is probably why infants seemed to be insensitive to such a large phonotactic discrepancy as the presence *versus* absence of word-initial consonant. So, not only are early word representations segmentally underspecified (at least to a certain extent), but infants can recognize words from an incomplete match when their attention is focused on (familiar) words.

Experiments 1 and 2, then 3 and 4, have illustrated one move toward circumscribing the range of tolerated word-form alterations. We have now a starting estimation of the flexibility of word representations in 11-month-olds: Words are still recognized after a change in voicing of the initial consonant; they are not after removal of the initial consonant, unless infants are biased toward processing lexical items. A lot of further research remains to be done in order to refine this initial estimation, but it would lead us beyond the scope of this article. The next part of our study is meant to illustrate a possible next move (or iteration) toward circumbscribing the limits of flexibility of word representations—going back now to a less severe alteration than removal of the initial consonant—and should rather be viewed as an opening to future research. First, an intermediate deformation of word-initial consonants is tested: more serious than change of voicing, less serious than radical removal. Second, we open the way for exploring parts of word forms other than the initial consonant, altering now the word-medial consonant.

EXPERIMENTS 5 AND 6: MANNER OF ARTICULATION

Experiments 5 and 6 were based on the same rationale as Experiment 1: They both tested the preference of altered familiar over rare words. Familiar words, however, were more severely altered. The alteration bore on the manner of articulation of the word-initial (Experiment 5) or word-medial (Experiment 6) consonant. Plosives were changed into fricatives, and vice versa (place of articulation was left unchanged when possible, minimally changed otherwise); liquids and glides were exchanged with nasal counterparts. The resulting items were nonsense words, except three items that made up low-frequency words: /valɔ̃/ (*vallon*), /vibrɔ/ (*vibrons*), and /kapo/ (*capot*).

In Experiment 5, *bonjour* became *vonjour*, *chapeau* /ʃapo/ became *capeau* /kapo/, *lapin* became *napin*, and so forth. The familiar word *encore* was replaced with *banane*, whose altered counterpart was *vanane* (see Table 6). In terms of the number of phonetic features changed, this alteration amounted to an average of three features changed, according to the set of features established for French language by François Dell (1985). The unfamiliar words were those used in Experiment 1.

In Experiment 6, *bonjour* /bɔ̃ʒuʁ/ became /bɔ̃gur/, *chapeau* /ʃapo/ became /ʃafo/, *banane* became *balane*, and so forth (see Table 6). An average of three phonetic features were changed (according to Dell, 1985).

TABLE 6
Lists of Altered Familiar Words Used in Experiments 5 and 6

	Altered Consonant	
(Unaltered)	**Initial**	**Medial**
(bonjour)	/vɔ̃3ur/	/bɛ̃gur/
(gâteau)	/ʒato/	/gaso/
(biberon)	/vibrɔ̃/	/bivrɔ̃/
(lapin)	/napɛ̃/	/lafɛ̃/
(poupée)	/fupe/	/pufe/
(ballon)	/valɔ̃/	/banɔ̃/
(voiture)	/bwatyr/	/vwasyr/
(canard)	/ʃanar/	/kalar/
(chaussure)	/kosyr/	/ʃotyr/
(banane)	/vanan/	/balan/
(chapeau)	/kapo/	/1afo/
(oiseau)	/mazo/	/wado/

Method

The same procedure as in Experiment 1 or Experiment 3 was followed.

Stimuli

For each experiment, all the speech material was recorded in a single recording session. In Experiment 5 as well as in Experiment 6, there was no significant difference in F_0 contour or in intensity between the words compared (Tables 7 and 8), although in Experiment 6, the maximum F_0 was higher in rare words by about 8 Hz, an advantage for rare words which approached significance, $t(22) = 1.83$, $p = .08$. Word durations also were overall very similar, $t(22) < 1.00$ for all comparisons. The mean number of phones was 4.58 (SD = 0.67) for familiar words and 4.75 (SD = 0.62) for rare words in both experiments. The mean probability of phonemes and phoneme-sequence probability per phoneme unit for altered familiar words were respectively 4.06% (SD = 2.67) and 3.71% (SD = 1.01) in Experiment 5, 3.96% (SD = 2.86) and 5.11% (SD = 2.69) in Experiment 6. The median phoneme-sequence probabilities were 1.93×10^{-7} (Experiment 5) and 8.60×10^{-7} (Experiment 6). The corresponding figures for rare words are the same as in Experiment 1, because the same list of rare words was used: The mean probability of phonemes and phoneme-sequence probability per phoneme unit were 3.97% (SD = 2.41) and 4.66% (SD = 1.85, respectively); the median phoneme-sequence probability was 4.93×10^{-7}: The matching in phonetic complexity between familiar and rare words was reasonably good in both experiments.

Subjects

Eight infants (4 girls, 4 boys) were tested in Experiment 5. They had an average age of 10 months and 23 days (range = 10.80–11.12; SD = 11 days). One additional infant was run but did not meet our criterion of minimum attention span (1 per trial). Twelve infants (4 girls, 8 boys) were tested in Experiment 6. They had an average age of 11 months and 4 days (range = 10.19–11.17; SD = 11 days). Four additional infants (3 girls, 1 boy) were run but not retained: Two of them did not meet the 1-s criterion of minimum attention span (they were suspected not to have recovered yet from

TABLE 7
Comparison of the Stimuli Used in Experiment 5 (Rare vs. Familiar Words Altered for Initial Consonant Manner of Articulation) for Fo Contours and Intensity

	Word Type		Comparison	
	Altered Familiar	Rare	*t*(22)	Significance
M Fo (Hz)	184 (11)	179 (13)		*ns*
Max Fo (Hz)	252 (10)	245 (13)		*ns* (*p* = .15)
Min Fo (Hz)	130 (5)	128 (9)		*ns*
Fo Excursion (%)	–66 (14)	–57 (11)		*ns* (*p* = .11)
Max Energy (dB)	74 (3)	72 (3)		*ns* (*p* = .25)

TABLE 8
Comparison of the Stimuli Used in Experiment 6 (Rare vs. Familiar Words Altered for Medial Consonant Manner of Articulation) for Fo Contours and Intensity

	Word Type		Comparison	
	Altered Familiar	Rare	*t*(22)	Significance
M Fo (Hz)	179 (12)	176 (11)		*ns*
Max Fo (Hz)	239 (10)	247 (12)		*ns* (*p* = .08)
Min Fo (Hz)	126 (7)	129 (4)		*ns* (*p* = .21)
Fo Excursion (%)	–60 (10)	–60 (13)		*ns*
Max Energy (dB)	76 (2)	76 (1)		*ns*

otitis); 1 child was excessively fussy; 1 child was later reported as having one ear blocked with wax.

Results and Discussion

Results of Experiment 5 are shown in Figure 6. The mean looking time per trial was 4.95 s (SD = 1.69) for altered familiar words versus 3.03 s (SD = 1.35) for rare words. This difference was significant, $t(7) = 3.92$, $p = .006$. The preference ratio (as defined earlier) for familiar words was also clearly above chance (*preference* = 0.619), $t(7) = 3.46$, $p = .011$. Seven out of 8 infants oriented longer to the altered familiar words: Familiar words were still recognized in spite of the alteration. Thus, infants' representations of familiar words seem to be more "elastic" than suggested by the first experiment. The word-initial consonant seems to be loosely specified, to the extent that variations in voicedness and in manner of articulation are tolerated. (Changes in place of articulation did also occur in several items, where velars exchanged with palato-alveolar.) Note that we do not report the comparison between intact and altered familiar words for the change in manner of articulation. The reason is that, in this kind of comparison, even a gross alteration does not induce preference for the intact familiar words, as it appeared in Experiment 4. In fact, this "control" comparison was conducted and yielded, as expected, a null result.[1]

So far, the possible effect of the factors *side* (of presentation of familiar words) and *type* (of the first list presented) have not been analyzed, because the number of subjects per experimental condition was small. However, because the results of Experiments 1 and 5 were very similar, we pooled them to conduct an analysis of variance (thus bearing on a total number of 16 subjects). Looking times to (altered) familiar and to rare words were taken as dependent variables and treated as within-subject repeated measures. Between-subjects independent factors were side and type. As expected, looking times were overall longer to familiar than to rare words, $F(1, 12) = 27.26$, $p = .0002$. The effect of type was not significant for the looking times to either familiar or rare words, $F(1, 12) < 0.10$. The effect

[1] In this test, items such as "chaussure" vs. "chauture" were compared. Twelve infants participated successfully in the test (M age = 11.30, SD = 8 days, range = 10.20–11.20). One infant could not complete the test for excessive fussiness. The mean looking times per trial were 3.92 s (SD = 1.75) and 4.29 s (SD = 1.75) for intact and altered familiar words respectively, $t(11) = 1.47$, *ns*, $p = .166$. The preference ratio for intact familiar words was 0.47, not different from the chance level 0.50, $t(11) = 1.50$, *ns*, $p = .159$.

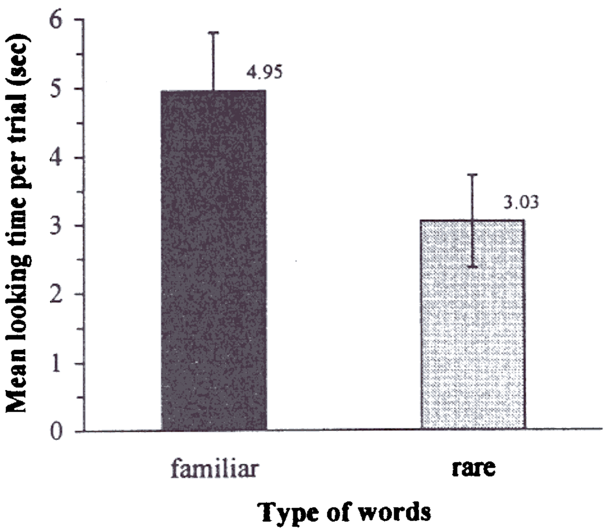

Figure 6. Mean looking times per trial to altered familiar (change of initial consonant manner of articulation) versus rare words: Experiment 5

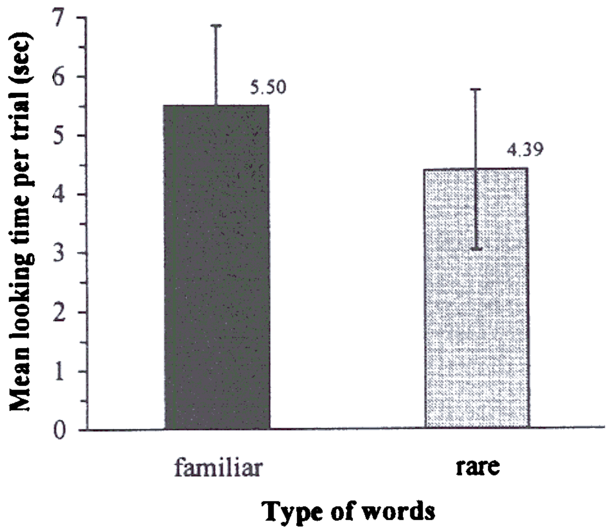

Figure 7. Mean looking times per trial to altered familiar (change of medial consonant manner of articulation) versus rare words: Experiment 6.

of side, however, was just significant for looking times to rare words, $F(1, 12) = 4.64$, $p = .05$, though not for looking times to familiar words, $F(1, 12) < 0.10$. When familiar words were presented from the right side, infants did not orient longer to familiar words but oriented less to rare words (2.33 s vs. 3.37 s, respectively): The preference was more marked on the right side.

Finally, the preference ratios of girls ($n = 9$) and boys ($n = 7$) were not significantly different (0.62 vs. 0.64, respectively,) $t(14) < 1.00$.

Results of Experiment 6 are shown in Figure 7. The mean looking time per trial was 5.50 s ($SD = 2.69$) for altered familiar words versus 4.39 s ($SD = 2.73$) for rare words. This difference was not significant, $t(11) = 1.32$, $p = .21$. There was a nonsignificant trend toward a preference for altered familiar words though: The preference ratio for familiar words was 0.57 ($SD = 0.13$), not significantly above 0.50, $t(11)$ $t(11) = 1.78$, $p = .101$. Failure to reach significance (on a two-tailed t test) was due to the large variability. The individual data show that 3 infants only preferred rare words, 9 preferred familiar words. Figure 8 shows the distribution of preference ratios: Five infants fell in the range 0.45 to 0.53 (no marked preference), 6 infants fell in the range 0.59 to 0.74 (strong preference for familiar words), and only 1 infant clearly preferred rare words (0.30). Thus, it seems that most of the noise in the data was due to this latter infant. The deviant result of this infant may be due to some unnoticed ear infection.[2] A clearer picture emerges after discarding this infant's data: 5.70 s ($SD = 2.73$) versus 4.11 s ($SD = 2.67$) looking times to familiar versus rare words, respectively, $t(10) = 2.14$, $p = .056$; 0.59 preference ratio in favor of familiar words, $t(10) = 2.87$, $p = .016$. Of course, we cannot

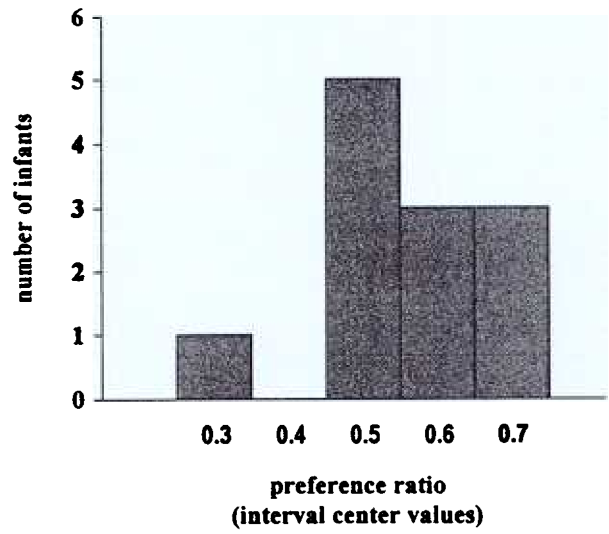

Figure 8. Distribution of the preference ratios in Experiment 6.

[2] Attrition rate was unusual in Experiment 6 (four rejections for 12 infants tested, compared to a total of five rejections for the 52 infants tested in the other five experiments) and was mainly due to ear infection problems.

base our conclusion on such "cleaned up" data. We may consider, however, that preference for familiar words approached significance in Experiment 6. Nine infants out of 12 continued to prefer listening to altered familiar over rare words (hence, they probably recognized them in spite of the phonetic alteration). But the effect was weaker and noisier than in the case of Experiments 1 and 5. We may only speculate that infants are more sensitive to an alteration of the medial than to the initial consonant of familiar words. Put another way, the onset of the second syllable (for *French* words) may be specified more strictly in infants' early word representations. More data should be collected, however, to verify this point.

GENERAL DISCUSSION

The series of experiments conducted in this study offers empirical evidence that initial representations of words in the receptive lexicon have a rather global format. This is mainly shown in the experiments where, despite certain phonemic alterations (voicing of the initial consonant in Experiment 1 and manner of articulation in Experiment 5), familiar words were still preferred over rare words (hence, presumably recognized). It is also indirectly confirmed in the experiments where two versions of familiar words were compared: altered versus unaltered familiar words. The latter experiments always indicated no systematic preference for one version over the other: no preference for the more typical forms, that is, for the original over altered forms of familiar words, as could have been expected if infants had segmentally detailed representations of familiar words. The outcome of Experiment 4, where the comparison bore on familiar words with versus without initial consonant, was more surprising: Infants apparently did tolerate such a gross deformation as the suppression of initial consonant, although they did not show recognition of familiar words without initial consonant when compared to rare words. All these results can be understood if we assume that the very fact that infants are engaged in the process of recognizing words (and that some word representations have possibly been preactivated) let them overlook or, perhaps, made them insensitive to otherwise salient phonotactic changes. To sum up, the available data favor the view that early word representations are segmentally underspecified and are at work in a "lexical" attentional mode. The representations used to recognize untrained familiar words are thus different from those used to recall and recognize trained words at 7 to 8 months, which seem to be based on a phonetically analytic code (Jusczyk & Aslin, 1995). In one case, the words processed by children are already, as a rule, included in an actual, naturally collected repertoire; in the other case, the processing of word units must engage various sophisticated segmentation and analysis capacities, and is more sensitive to phonetic variation, but is potentially the same for known and unknown words. As was suggested in the introductory section, the various findings are consistent with a developmental change in the representation of word-sized units.

Manipulations of word-initial consonants showed that the format of representation of early words is insensitive to changes of its voicing, a single-feature change, nor is it susceptible to more severe changes in its manner of articulation where, in most cases, plosives and fricatives were interchanged. However, there are limitations to the "elasticity" of word representations. One important limitation is that the initial consonant may be altered but not suppressed. This is quite in line with the predictions that the Cohort Model (e.g., Marslen-Wilson, 1987) of adult lexical access could make. In this model, emphasis is clearly on word-initial information so that removal of the initial segment of a word should preclude recognition, while, according to the most recent version of the model, a slight alteration of this initial segment could be gracefully recovered. But is the initial segment more important than the others? Is there a need for a tighter specification of the word-initial segment? Empirical data on English-speaking adults is controversial (e.g., Connine, Blasko, & Titone, 1993). Models other than the Cohort Model, such as connectionist models, do not predict a special status for word-initial information (e.g., TRACE: McClelland & Elman, 1986; NAM: Luce, 1986). At this point, however, we cannot draw inferences from the possible analogies between adults' and infants' spoken word recognition. This would be rather problematic especially because children's lexicons and underlying representations are gradually/continuously restructured along the dynamics of vocabulary growth. That the initial consonant may be altered but not suppressed for infants to recognize a word suggests that the format of representation of a word requires a structural, "skeletal" description where the syllabic structure (a metrical specification of the word) and the consonantal and vocalic slots are specified but not their content. This is very much reminiscent of Levelt's theory that speech production is planned according to frames whose content is defined, if not in detail, at least in an abstract way (Levelt, 1993; Levelt & Wheeldon, 1994; also see MacNeilage & Davis, 1990).

Experiment 6 was an exploratory investigation of the flexibility of representations in word-medial position: It seemed that word recognition was more sensitive to word-medial than to word-initial alterations. Hence, our data do not suggest that word-medial specification is looser than word-initial specification, at least for French-learning children. But the results were not clearcut and remain as yet insufficient to draw any definite conclusion. They do not contradict, though, the speculation that more weight should be attached to the second syllable of French bisyllabic words: In French, the last syllable is (in general) prosodically more prominent; French children rarely drop out syllables in their early words and tend to maintain stop consonants in the word-final syllable (Boysson-Bardies, 1994). For example, 12- to 14-month-old French children may often say "tâteau" instead of "gâteau," thus modifying the initial consonant (backward assimilation), but would not say "gâgueau" instead of "gâteau" (forward assimilation): The initial consonant of the last syllable tends to be maintained, that is, reproduced by young French children with a better accuracy than other consonants. This dominance in production of the accented, word-final, syllable suggests that it is perceptually more salient. Thus, it would make sense that word-final syllables are more precisely specified than others in receptive as well as in productive early lexicons of French infants.

Future research will have to investigate how first-word production patterns, which are language specific, are reflected in the representations used in the receptive lexicon. Clearly, the results obtained in this study do not exhaust the description of early word formats of representations. They open the way, however, to a systematic program of investigations on the various elements of words that may be represented in infants' early receptive lexicons, depending on the language being learned. For example, vowels may generally be more precisely specified than consonants for French infants, because French vowels are rarely reduced. With English-learning infants, a different pattern would probably be observed: Vowel specification should be crucial only in strong syllables (i.e., mainly in word-initial syllables).

However refined and detailed the accounts of early word representations might be obtained, the important aspect, as addressed here, is underspecification: Infants recognize words from rather global representations, ignoring certain phonemic variations they are, in theory, sensitive to (as we know from perceptual experiments using meaningless syllables).[3] Other research has shown that children, after the end of their 1st year and until about their 5th year, do not fully use the decontextualized perceptual abilities they demonstrated in infancy when they have to discriminate minimal pairs of words (Barton, 1976, 1980; Eilers & Oller, 1976; Shvachkin, 1973), although they can when they have to discriminate meaningless syllables (Werker & Tees, 1984). Similarly, children aged 4 to 5 years (preliterate children) are better at detecting overall similarity than at detecting a common phoneme in speech sounds (Treiman & Breaux, 1982). More recent studies by Werker and colleagues (Stager, 1995; Stager & Werker, 1995; Werker, Cohen, & Lloyd, in press) also indicate that children aged 14 months are quite bad at perceiving certain phonemic contrasts when they appear in syllables they have been trained to associate with distinct referent pictures. For example, children would respond correctly to such contrasts as /ni:m/ versus /lɪf, but would have trouble with /bɪ/ versus /dɪ/. All these findings and ours may be explained most parsimoniously by assuming that infants may listen to speech sounds in various attentional modes: As has been suggested earlier, there is a "lexical mode" where infants' attention is focused on word recognition, distinct from a "neutral mode"

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[3] This could be related to the theory of underspecification of phonological representations in the adult mental lexicon (Archangeli, 1988; Lahiri & Marslen-Wilson, 1991; Marslen-Wilson & Warren, 1994). Note, however, that "phonological" underspecification basically accounts for tolerance of regular variation in speech perception, such as contextual assimilation. In contrast, infants' underspecified representation tap into the immature and as yet not stabilized coding of words in an emerging lexicon. Infants' tolerance for variation, however, may be viewed as a precursor of adults' tolerance for (systematic) phonological variation.

(neutral with regard to word recognition and/or comprehension). Our contention is that the speech input may activate different types of representations in infants, depending on what kind of forms they recognize and thus possibly begin to attend to. On this view, *pattern recognition* is basic and at the source of many perceptual abilities. Whichever type of patterns infants perceive and gradually come to recognize, the evolutionary trend is the same: the emergence of equivalence perception. Variations that are not relevant to recognition of (familiar) patterns become ignored. The driving force pulling in this direction is probably, as we contend, the emergence of meaning, somewhere between 9 and 12 months. As we have observed, when infants begin to recognize words, they can also abstract from variations in word forms that are not relevant given the set of words they recognize. This general ability to abstract from irrelevant variability is also applied to the recognition of sound patterns that are meaningless but nonetheless frequently recurring in the speech input infants are exposed to (with the effect of shaping infants' early productions). Hence, 10- to 12-month-olds begin to ignore the sound contrasts that are irrelevant to the sound system of the language they learn. At least when the sounds involved can be assimilated to native phones (Best, 1994; Best, McRoberts, Lafleur, & Silver-Isenstadt, 1996; Best, McRoberts, & Sithole, 1988). They have become much less sensitive to detailed phonetic differences than to overall similarity between speech sounds. The evolutionary trend is thus the same as for recognition of words: from analytic to holistic. A tempting speculation is that the emergence of meaning, brought about by the increasing need and ability to communicate, is responsible for this evolution.

An important question to ask is how word representations change over time. Clearly, early holistic representations should gradually lead the way to more adult-like analytic representations, because they become inefficient when ever-growing lexicons contain many minimal pairs. The position we favored here was that different representations for words coexist at a given point in development and correspond to different attentional modes. Another view is that a *single* representational architecture underlies apparently different kinds of coding words. On the latter view, lexical representations are distributed and multileveled, encompassing both word-form and semantic/contextual aspects. Development is viewed as a more and more precise tuning of various weights assigned to various representational levels, in the way recently proposed, for example, by Gaskell et al.'s (1995) connectionist model: "... the process of learning to understand speech may involve a gradual tightening of the constraints involved in the goodness-of-fit computation in lexical access" (p. 416). In favor of the notion of multiple and qualitatively different representations, electrophysiological data suggests qualitatively different neurophysiological organizations in the early stages of lexical acquisition (when children's repertoire of words is still very limited) compared to the later stage that corresponds to vocabulary spurt: Electrophysiological studies of Mills and colleagues (Mills, Coffey, & Neville, 1993; Mills, Coffey-Corina, & Neville, 1993) show that the emergence of a left hemisphere advantage when processing known words is related to the shift between a small and slowly increasing vocabulary and vocabulary spurt. This finding indirectly suggests that infants do not begin to process known words in an analytic rather than holistic way before 18 to 20 months. To this date, however, we are lacking direct empirical behavioral evidence for such a developmental pattern. Future research will have to address this issue.

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