Long-Term Auditory Word Priming in Preschoolers: Implicit Memory Support for Language Acquisition

Barbara A. Church
State University of New York at Buffalo

and

Cynthia Fisher
University of Illinois

Three experiments explored long-term auditory word priming in young preschoolers. Children 2.5 and 3 years old and adults more accurately identified low-pass-filtered words that had been presented once in an initial study phase (Experiment 1) than words that had not been presented. The auditory priming effect showed no significant change from 2.5 years of age to college age. An effect of similar magnitude was also found in 2-year-olds (Experiment 2). Similar to findings with adults, auditory word priming in 3-year-olds did not significantly increase following a semantic encoding task, although explicit recognition memory improved under semantic study conditions (Experiment 3). The similar auditory word priming in preschoolers and adults suggests that the same learning mechanisms are at work in both groups. We argue that the powerful perceptual learning mechanism underlying auditory word priming has just the right properties to play a crucial role in the development of an auditory lexicon. © 1998 Academic Press

In order to identify spoken words, children must create long-term representations of the sound patterns of words in their language and use those representations to identify new instances of words. Some familiar characteristics of the language learning problem yield a number of constraints on the kinds of learning mechanisms that could permit the development of representations for word identification. First, at least to some extent, children must be capable of building such representations before attaching meaning to each word sound. An ability to identify repeated uses of a word, as a sound pattern without fixed meaning, is required to collect the cross-situational and cross-sentence observational data relied on in virtually all theories of the acquisition of word meaning (e.g., Fisher, Hall, Rakowitz, & Gleitman, 1994; Pinker, 1984; Siskind, 1996; Waxman & Markow, 1996; Woodward & Markman, 1997). Second, the presemantic sound representations a child builds, and the identification processes that operate on them, must allow the child not only to match the new instance to a previously encoded sound pattern, but to do so in ordinary connected speech. Locating and identifying words in continuous speech presents a number of well-known perceptual problems. These problems fall into two interconnected classes: word segmentation and acoustic/phonetic variability.

One perceptual difficulty posed by connected speech is the identification of word boundaries. Spoken words are not routinely separated by pauses or other acoustic, prosodic, or phonetic cues to their boundaries, as written words are...
separated by spaces on the page. There is some evidence that adults can infer word boundaries from acoustic cues such as the duration of segments in different word positions (e.g., Gow & Gordon, 1995; Nakatani & Dukes, 1977; Quené, 1992) and the stress patterns typical of words in their language (e.g., Cutler & Norris, 1988; Nakatani & Schaffer, 1978). Young infants are sensitive to some of these acoustic cues as well (e.g., Friederici & Wessels, 1993; Jusczyk, 1997) and can use the native language stress pattern as a perceptual grouping cue by about 9 months of age (Jusczyk, 1997; Morgan & Saffran, 1995). However, such prelexical segmentation cues leave considerable ambiguity about the location of word boundaries in connected speech. For this reason, many theories of word recognition postulate that word segmentation is, at least in part, an outcome of rather than a prerequisite to word identification (e.g., Klatt, 1980; Marslen-Wilson, 1987; McClelland & Elman, 1986; McQueen, Cutler, Briscoe, & Norris, 1995).

Recent research suggests that even young infants use the distributional properties of sound patterns across multiple utterances to aid detection of word boundaries (e.g., Goodsitt, Morgan, & Kuhl, 1993; Jusczyk & Aslin, 1995; Saffran, Newport, & Aslin, 1996). In order for this kind of distributional analysis to occur, information about multiple instances of a sound pattern in different contexts, and the contexts in which it appears, must be represented. This information must be encoded and used flexibly: a previously heard pattern must be classified as the same in a new context, while still retaining sufficient information about the surrounding context to help establish the word’s distributional properties. This type of learning requires a memory mechanism that allows partial matches of information across different contexts without the loss of this important context information.

Another perceptual problem that the language learner must solve is introduced by the enormous amount of acoustic variability in tokens of the same word. Factors such as the surrounding phonetic and prosodic context, the speaker’s voice, and the speech rate radically alter the acoustic properties of the signal in which a word is conveyed (e.g., Fisher & Tokura, 1996; Klatt, 1980; Lively, Pisoni, & Goldinger, 1994; Miller & Volaitis, 1989; Mullennix & Pisoni, 1990; Nusbaum & Goodman, 1994). For these and other reasons, words excised from the supporting context of fluent speech are often difficult to identify (e.g., Pollack & Pickett, 1963).

The problems of contextual variability are apparently not lessened in child-directed speech. One study found that words extracted from fluent speech to young children were actually less identifiable out of context than words from fluent speech to adults (Bard & Anderson, 1983). This variability in the speech signal presents a perceptual learning problem for the child acquiring language. The child must represent information about the sound patterns of words in a form abstract enough to allow matches to occur across the wide range of acoustic variability found in the speech signal, yet detailed enough to discriminate lexical neighbors.

The traditional view of how this problem is solved is that listeners normalize the speech signal, stripping away acoustic variability associated with voices, intonation contours, and so on, revealing the consistent core sound pattern for each word. However, some recent work on word recognition in adults has questioned this assumption. Variability in speech can be seen, not as irrelevant noise in which linguistic invariants are shrouded, but as lawful variation which encodes linguistically useful information other than word identity (e.g., Goldinger, 1998; Lindblom, Brownlee, Davis, & Moon, 1992; Pisoni, 1992). For example, in addition to identifying words, listeners also identify voices and prosodic patterns and are sensitive to pronunciation variations that accompany dialect and register differences. Signs of the effects of “linguistically irrelevant” information on phonetic or word identification can be seen from infancy through adulthood. Infants find some speech categorization tasks more difficult if multiple voices are included (Jusczyk, Pisoni, & Mullennix, 1992). Greater difficulty identifying words when voices or other properties vary can be found in preschoolers (Ryalls & Pisoni, 1997).
and in adults (e.g., Goldinger, 1996; Pisoni, 1992). These findings suggest that the problems of variability in speech are never “solved,” and words are never entirely disentangled from the details of their various acoustic realizations. If this emerging view of lexical/phonological representation is correct, then the learner must represent acoustic and phonetic variability among word tokens, retaining enough information about the variability itself to allow the child to interpret it and to compensate for it in word identification.

The problems of contextual and acoustic/phonetic variability are similar. In both cases, we have argued that children must detect abstract correspondences between current and prior sound patterns in order to (1) identify a word across contexts without unambiguous prelexical segmentation cues and (2) identify a word across acoustically or phonetically variable targets. At the same time, however, children must in some way encode more specific information about context and acoustic/phonetic variability. These details are not irrelevant. Rather, they are required to collect the distributional information that will partly determine word boundaries and allow the child to learn about regular sources of variation in the speech signal other than word identity. This similarity is no accident: Acoustic/phonetic variability is in part contextually determined. Phonological adjustments and coarticulation across word boundaries guarantee that the acoustic/phonetic structure of a word depends on surrounding context. To illustrate, compare the casual American English pronunciation of “would you” and “would I.” In the former, palatalization often occurs, producing a /ɨ/ at the boundary of the two words. This sound pattern is accepted as part of “would” only in the context “would you.”

Finally, a related representational dilemma is created by the acoustic and phonetic variability produced by the repetition of words so common in child directed speech (e.g., Bard & Anderson, 1983; Snow, 1972). Repeating a word gives the child multiple opportunities to represent the sound pattern, learn about its distribution in sentences, and link it with a possible meaning. However, just as in speech to adults, repeated words in child-directed speech tend to be shorter, quieter, and lower pitched than first-mentioned words (e.g. Fisher & Tokura, 1995; Fowler & Housum, 1987). Thus the sound pattern information being presented to the child can be seriously degraded after the initial token. Any representational advantage conveyed by multiple repetitions may be counteracted by the difficulty of perceptually processing the repeated tokens. To overcome this problem, the child must often represent the sound pattern information well enough on the first presentation to allow the degraded repetitions to be perceived as the same word. Thus the child can reap a great advantage for lexical learning if the initial representation of sound pattern information is rapid and occurs almost unavoidably as a consequence of attending to a word.

In summary, in order for children to identify words in the variable environment of ordinary speech, a number of perceptual problems must be solved. These perceptual problems suggest certain requirements for a learning mechanism that could create representations and processes for word identification. Any viable mechanism would need to (1) build sound representations without requiring prior knowledge of the word’s meaning, (2) flexibly represent the sounds of words to generalize across variability due to vocal or linguistic context, (3) allow the representation of enough acoustic and contextual detail in the signal to permit learning about words’ distributional properties and learning about other sources of lawful variability in the speech signal, and (4) build sound representations rapidly and automatically.

Recent work in the adult memory literature points to a candidate learning and memory system that displays these properties. Research examining long-term auditory word priming in adults has revealed a basic learning mechanism that updates adults’ representations of the sounds of words to reflect recent auditory experience (e.g., Church & Schacter, 1994; Goldinger, 1996; Schacter & Church, 1992). Each time a word is heard, a lasting representation of the sound pattern is encoded that then facilitates
or biases subsequent identification of the same word.

This research in long-term auditory word priming can be placed within a larger perceptual representation systems framework. A basic premise of this framework is that when any stimulus is attended to and perceptually processed, representations relevant to its perceptual identification are encoded as an integral part of the perceptual identification process (e.g., Schacter, 1990, 1994; Tulving & Schacter, 1990; see also Cohen & Eichenbaum, 1993; Moscovitch, 1994; Squire, 1994). Considerable evidence suggests that auditory word priming has exactly the properties which we argued above are required to produce the representations necessary for word identification.

First, long-term auditory priming appears to depend on representations that are auditory, not semantic, in nature. Several findings show that long-term auditory priming is modality specific (e.g., Jackson & Morton, 1984; McClelland & Pring, 1991), suggesting that the mediating representations are specifically auditory. Long-term auditory priming is also unaffected by whether the study task, in which listeners are initially exposed to a set of words, focuses their attention on the sound or the meanings of the words (Church & Schacter, 1994; Schacter & Church, 1992). This suggests that merely listening to an item produces the priming without requiring attention to the item’s meaning. In addition, research with a word-meaning deafness patient suggests that long-term auditory priming does not require access to the meanings of the words (Schacter, McGlynn, Milberg, & Church, 1993).

Second, auditory word priming spans a variety of acoustic/phonetic changes in the word token from study to test, such as a change in speaker, pronunciation, or intonation. Thus abstract matches can occur, encompassing the wide variability found in natural speech (e.g., Church, 1995; Church, Dell, & Kania, 1996; Church & Schacter, 1994; Goldinger, 1996; Schacter & Church, 1992).

Third, though auditory word priming spans a variety of acoustic/phonetic changes, it can be reduced by these changes from study to test. This reveals that though abstract matches occur, acoustic/phonetic details are retained and can affect word recognition (e.g., Church, 1995; Church, Dell, & Kania, 1996; Church & Schacter, 1994; Goldinger, 1996; Schacter & Church, 1992). Auditory word priming seems to have both abstract and specific components. Recent research also suggests that study-to-test changes in the coarticulatory context, such as an unrelated coarticulated context word preceding the target word, can reduce priming under some circumstances (Church & Poldrack, 1997). Thus representations and processes relevant for word identification may reflect information about the surrounding context.

Fourth, the learning revealed in long-term auditory word priming occurs rapidly, after only one exposure, and seems to be a nearly automatic consequence of the word identification process. Two kinds of evidence support the latter conclusion. First, as mentioned above, long-term auditory priming is relatively insensitive to changes in the type of processing engaged in during initial exposure to the words. Second, work with amnesic patients has shown that long-term auditory priming does not require the ability to explicitly remember that the stimuli were presented before (Schacter, Church, & Treadwell, 1994; Schacter, Church & Bolton, 1995). Both of these findings suggest that the encoding and retrieval of the sound pattern information in auditory word priming is simply a natural result of word identification.

Thus adults possess a memory mechanism with just the properties necessary to support the acquisition of the sound patterns of words. It allows abstract matches across acoustic variability, while retaining information about acoustic details and context. These findings suggest that the representations mediating long-term auditory priming combine both the flexibility and context sensitivity necessary for the acquisition of sound representations for word identification. The encoding and retrieval of sound pattern information seems to be a relatively automatic consequence of the word identification process and seems not to depend on access to word meaning. Given all these points of similarity, we suggest that the perceptual
representation mechanisms underlying long-term auditory priming could lay the foundation for an auditory lexicon. If the same mechanism operates in acquisition, then the kinds of perceptual priming phenomena seen in adults should be found in young children during periods of rapid word learning. This analysis suggests continuity across development of basic learning mechanisms involved in word identification (see Nusbaum & Goodman, 1994, for a similar argument).

The experiments reported in this paper test this continuity of learning hypothesis by asking (1) whether preschoolers show the same rapid facilitation for word identification seen in adults and (2) whether the representations mediating the facilitation are similar to those seen in adults. We do this by examining long-term auditory priming in 2-, 2.5-, and 3-year-olds and adults. If a basic mechanism underlying auditory word priming in adults also plays a role in the initial establishment of auditory representations for word learning, then young word learners should show long-term auditory priming. Moreover, if the representations mediating this long-term priming effect are specifically auditory rather than semantic in nature, then the magnitude of the facilitation should be relatively consistent from childhood to adulthood, despite very large changes in knowledge about the meanings and grammatical properties of words. Though identification and comprehension will be different, the basic memory mechanism and the priming should be relatively constant.

EXPERIMENT 1

Experiment 1 compares long-term auditory priming in 2.5- and 3-year-olds and adults. Children and adults listened to a list of study words chosen to be familiar to young children and made simple judgments about the sounds of the words. After a short distractor task, the children were asked to repeat and the adults to write down a series of low-pass-filtered words. Half of the filtered words were from the study list and half were new. Priming was measured by comparing performance on the studied words with performance on the nonstudied items.

The extent of low-pass filtering was varied between the children and the adults to equate their baseline identification performance. The magnitude of a priming effect by its nature depends on the level of baseline performance. Any direct comparison of the magnitude of priming between groups with substantially different baselines is therefore problematic (e.g., Chapman, Chapman, Curran, & Miller, 1994). By presenting more harshly filtered words to the adults than to the children, we roughly equate the difficulty of the task and permit more straightforward comparison of priming effects themselves. The harsher filter reduced the acoustic information reaching the ears of the adults compared to the children; thus to equate baselines for the children and the adults we must compare priming performance across acoustically different stimuli. This difference will temper somewhat our conclusions regarding the relative magnitude of priming effects in children and adults. However, even when stimuli are acoustically identical, they are probably not perceptually identical for young children and adults. Developmental improvements in word identification are well documented: For example, 5-year-olds require a higher signal-to-noise ratio to identify familiar words than do older children and adults (Elliott et al., 1979). This suggests that less perceptual information is effectively available to young children to support word identification. By reducing the acoustic information presented to the adults, we may make the word-identification task more similar for adults and preschoolers than it would be with clearly presented words. Certainly, it is more similar in overall difficulty.

Elicited repetition is a task often adapted to explore what children can perceive about speech as well as what they can produce (e.g., Gerken, Landau, & Remez, 1990). We use repetition simply as a measure of whether the child can identify a word and test any advantage conferred by a single presentation of the word in the initial study phase. Accurate repetition requires the perceptual identification of the stimulus items; thus we can be sure that wherever we find a priming effect occurring across several minutes in the experimental setting, we are
tapping perceptual representations which characterize the long-term storage of word sounds for word recognition.

Methods

Participants. Twenty-four 2.5-year-olds (28 to 32 months, mean age = 30.4 months), 24 3-year-olds (36 to 43 months, mean age = 40.5 months), and 24 college-age adults participated in the experiment. Twelve girls and 12 boys participated at each child age level with gender balanced across experimental conditions and lists. The children were given a small toy or book for their participation. The college students participated in exchange for partial credit in an introductory psychology course. Children and their parents were recruited from a participant file drawn from birth announcements in a local newspaper. All of the participants in all of the experiments were native English speakers. An additional 21 2.5-year-olds (mean age = 29.9 months) and 9 3-year-olds (mean age = 40.7 months) were tested but were not included because they did not respond during the experimental task.1

Materials. Thirty-two concrete nouns were selected for the test list from the norms produced by a large scale study of productive vocabulary development (Fenson et al., 1994). Only words which 50% of the parents in that study judged their children used by 24 months were included. The words were divided into two study lists of 16 matched for number of syllables, first phoneme, average age of production, the percentage of children in the 18- to 30-month age range whose parents reported they produced the word in Fenson et al.’s (1994) study, and general semantic category (e.g., animals, food, toys). Each of the words was recorded by two speakers, one male and one female, using the SoundEdit 16 software package running on a Macintosh computer.2 Two low-pass filtering procedures were used. The mild filtering for the children’s test items reduced frequency information in a steeply sloping fashion. The mean frequency of the reduction slope was 1 kHz and the maximum reduction was 20 db. This mild filtering made the words sound slightly quieter than the unfiltered versions. The more severe filtering used for the adults reduced the same frequency information in the same steeply sloping fashion, but the maximum reduction was 60 db. Therefore, the exact same frequencies were affected, but the level of reduction was three times greater for the adults than for the children. This level of filtering made the words sound quite muffled and difficult to identify. This level of filtering was chosen because pilot data indicated that it produced a baseline performance level similar to the children’s baseline performance.

Sixteen clearly presented study words were recorded onto each of four study tapes. Half of the words on each tape were spoken by the male and half by the female speaker. Two test lists of 32 mildly low-pass-filtered words were recorded onto tapes for the children; the same test lists were recorded in their more severely filtered forms for the adults. On each test tape half of the items were spoken by the male and half by the female speaker. Study and test tapes were designed to be combined so that all of the words spoken by each of the speakers would appear equally often in each of the experimental conditions. However, any word uttered by a particular speaker during the study phase was said by the same speaker during the test phase of the experiment.

A tape deck, amplifier, and speaker were used to present the stimuli to the children, and a tape deck and headphones were used with the adults. A toy robot, toy cookies, and a box with a slot in the top were used to make the experiment a game for the children. A small tape recorder

---

1 “Not responding” means the child simply refuses to speak to the experimenter or to participate in the task or the child only gives irrelevant responses like “robot,” “cookie,” or “mommy.” The experiment was discontinued if the child failed to respond to all of the first eight experimental items (four in the shorter word list for Experiment 2) or stopped responding leaving eight or more items unheard at the end of the list.

2 Two different speakers were used in order to permit comparison with a related experiment examining the effect of a study-to-test voice change. For present purposes, using two voices rather than one in this task should simply increase the baseline difficulty somewhat (e.g., Mullennix & Pisoni, 1990).
was also used to record the experimental session with the children. The adults were given a response booklet with three pages. The first page had a 2-point clarity rating scale at the top and 16 spaces for the participants to write down their ratings of the study words. The second page had 20 simple addition problems designed to take up about 2 min, and the third page had 32 spaces for the adults to write down answers from the test phase of the experiment.

Design and procedures. A 3 × 2 mixed factorial design was used. The dependent measure was the proportion of correct identifications of low-pass-filtered stimuli. The between-participants variable, Age, had three levels (2.5-year-olds vs 3-year-olds vs adults). The within-participants variable, Study, had two levels (studied vs nonstudied).

The children were brought to the lab by their parents and tested individually, usually with the parent sitting quietly in the room with the child and the experimenter. Each session began with a 10- or 15-min play session in the waiting room to acclimate the child to the lab and experimenter. After the play session, the child was taken into the test room and seated in a chair in front of a table. On the table was a toy robot, a speaker, two boxes of toy cookies of different colors, and a box with a hole in the top for putting the cookies into. The experimenter sat next to the child where she could reach the tape deck to control the presentation of the stimuli.

In the study phase, the child was told that a robot was just learning how to talk, so when he said a word they should decide whether he said the word “really well or just O.K.” and put one of the robot cookies into his box. On each of the 16 study trials, the experimenter prompted the child to listen, played the word, then asked the child whether the robot said the word “really well or just O.K.” and reminded the child to give the robot a cookie. We did not expect (or receive) systematic answers to the sound judgment question; this task was used simply to draw the children’s attention to the words. After the study phase the experimenter encouraged the child to help count and pick up the cookies in the robot’s box. The experimenter continued this task for approximately 2 min.

After the distractor phase, the test phase began. During the test phase, 32 mildly low-pass-filtered words were played. Half of the words had been presented during the study phase and half of the words were new. On each test trial, the experimenter prompted the child to listen, played a word, then prompted the child to repeat what the robot said and to give it a cookie. A single practice word (“bottle”) was played; if the child did not repeat the item when prompted, the experimenter repeated it to demonstrate the task. The child’s responses were tape recorded for transcription and coding.

The college students were also tested individually. During the study phase of the experiment, they listened to 16 clearly presented words and were asked to judge whether each word was spoken “really well or just O.K.” They wrote their answers down in their response booklet and had 5 s between items to make their decisions. After the study phase, participants completed 20 simple addition problems designed to take approximately 2 min. During the test phase of the experiment, participants heard 32 severely low-pass-filtered words, half studied and half new. Participants were instructed to write down what they thought each filtered word was. They were given 7 s between items to write down their answers. Items were fully counterbalanced so that across participants each item appeared equally often in the studied and nonstudied conditions.

Coding of children’s responses. Children’s attempts to imitate were broadly transcribed in the International Phonetic Alphabet from audiotapes of the sessions, and each response was coded as an accurate or inaccurate attempt at the target word. Sixteen trials (1.04% of data) were omitted because of tape error or because a parent or experimenter said a test word before the child responded. The first-pass transcription and coding was checked by a second listener, and a third listener mediated all disagreements. An attempt was considered accurate if it included no more than one of the following errors: omitting or replacing one target phoneme or omitting an initial or medial unstressed syllable from a multisyllabic target. Any change which resulted in a different English word was coded as
TABLE 1

Proportion (SE) of Correctly Repeated Studied and Nonstudied Words in Experiment 1

<table>
<thead>
<tr>
<th>Age group</th>
<th>Studied</th>
<th>Nonstudied</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5-year-olds</td>
<td>0.538 (.041)</td>
<td>0.465 (.039)</td>
<td>0.073</td>
</tr>
<tr>
<td>3-year-olds</td>
<td>0.657 (.032)</td>
<td>0.596 (.038)</td>
<td>0.061</td>
</tr>
<tr>
<td>Adults</td>
<td>0.635 (.033)</td>
<td>0.505 (.021)</td>
<td>0.130</td>
</tr>
</tbody>
</table>

Results

As can be seen in Table 1, all of the age groups were more likely to identify words that were heard in the study phase. This pattern is very similar across age groups, as predicted by the continuity hypothesis laid out in the introduction. The effect of priming can be thought of as the proportion of performance above baseline that is attributable to the effects of study. If the scores are proportionalized in this fashion, the effect of priming is 13.6% for 2.5-year-olds, 15.1% for 3-year-olds, and 26.3% for adults.

Discussion

In Experiment 1, 2.5-year-olds, 3-year-olds, and adults were all significantly better able to identify words that had been heard during the study phase than words that had not. As predicted, when baseline performance was equated, preschoolers showed significant long-term auditory priming roughly similar in magnitude to that seen in adults. This need not mean that there are no differences at all in priming between adults and preschoolers. The mean amount of priming did vary among the three groups and perhaps with a more powerful test small significant differences among the groups would be revealed. Such differences could stem from a variety of causes, including a tendency on the part of young children to fail to attend to some of the study words. However, the fact that

3 One-tailed t tests seemed justified for the planned comparisons since, to our knowledge, there are no theories of priming or word recognition that would predict that hearing the words during the study phase would impair identification relative to baseline items.

4 Analyses were also done to determine if identification or priming were affected by either the sex of the child or the sex of the speaker. The sex of the child produced no significant effects in any of the experiments. There was, however, a significant main effect of the sex of the speaker, F(1,46) = 9.0845, MS_e = .024, p < .001; F(1,31) = 35.497, MS_e = .083, p < .001; revealing that the children had an easier time identifying words spoken by the female speaker. The interaction between Speaker’s Sex and Study was not significant, F(1,46) = 2.869, MS_e = .018, p > .05; F(1,31) = 2.160, MS_e = .03, p > .10.
no significant differences in priming were found among the age groups in the present experiment, even given the large increases in lexical knowledge from 2.5 to 3 years old and preschool age to college age, suggests that the basic learning mechanism and the representations mediating priming across the age groups are similar. This is consistent with the hypothesis that the same learning and memory mechanisms that help adults update their perceptual representations of speech information operate in young children to help them learn to represent the sound patterns of words (e.g., Nusbaum & Goodman, 1994; Schacter & Moscovitch, 1984).

The period of rapid word learning does not begin at 2.5 years, however, and the continuity of learning hypothesis predicts that children should show similar auditory priming as early as they have developed the basic perceptual representation processes that allow for rapid word learning to take place. Experiment 2 was designed to test this hypothesis by further extending the results to younger 2-year-olds.

EXPERIMENT 2

Experiment 2 asked whether 2-year-olds would show long-term auditory priming similar to the findings with older children in Experiment 1. The following changes were instituted to reduce the difficulty of the task for younger children: The study and test lists were half the length of those used in Experiment 1, and a single voice was used. Twice as many children participated in the experiment in order to collect data for all of the items. Because of these methodological differences, direct statistical comparison with the previously tested age groups was not possible. However, an adult control group was tested with the same stimuli (and procedural modifications similar to those used with the adults in Experiment 1) for comparison to the 2-year-olds. It was predicted that 2-year-olds would show significant long-term auditory priming and that the priming effect would be of a magnitude similar to that seen in the adult control groups and the groups tested in Experiment 1.

Methods

Participants. Forty-eight 2-year-olds (24 to 27 months, mean age = 26.0 months), drawn from the same participant pool described in Experiment 1, and 48 introductory psychology students at the University of Buffalo participated in the experiment. For the 2-year-olds, 24 girls and 24 boys participated with gender balanced across experimental conditions and lists. The children were given a small toy or book for their participation. The college students were given course credit for their participation. An additional 41 children (mean age 25.8 months) were tested but did not respond during the experimental task. The parents of the 2-year-olds were asked to complete the MacArthur Communicative Development Inventory (Fenson et al., 1994) and return it by mail to the lab. An analysis of the data from the returned checklists revealed that the 2-year-olds who did not complete the study (25 forms returned, mean productive vocabulary score = 311.12, $SD = 186.04$) had lower productive vocabulary scores than the children who did complete the experiment [29 forms returned, mean productive vocabulary score = 458.55, $SD = 170.00$; $t(52) = 3.04$, $p < .01$]. Given the high production demands of the task, children with lower productive vocabulary scores had more difficulty making it through the task.

Materials and procedures. The materials and procedures were the same as those used for the children and adults in Experiment 1, with four modifications: (1) the two matched 16-word study lists used in Experiment 1 were divided into 4 matched lists of eight words, and the 32-word test list was divided into two 16-word test lists; (2) only the female voice was used; (3) experimenters used either a puppet or a toy robot with the children, whichever seemed to engage the child’s interest; and (4) the low-pass filter used with the adults reduced the high-frequency information by a maximum of 80 db rather than 60 db. Agreement in repetition accuracy coding for a randomly chosen 25% of the sessions with the children, calculated as in Experiment 1, was 89.6%. Fourteen trials
were omitted due to experimenter error or parental coaching.

Results

As can be seen in Table 2, the 2-year-olds (like the older preschoolers and adults in Experiment 1) were more likely to correctly repeat filtered words that had recently been presented than those that had not, and the magnitude of the priming effect was similar to the magnitude seen in the adult control group.

A 2 × 2 analyses of variance looking at performance as a function of Age (child versus adult) and Study (studied word versus not studied word), by both participants and items, revealed a significant main effect of Study \[F_1(1,94) = 9.444, \text{MS}_e = .030, p < .005; F_2(1,31) = 15.288, \text{MS}_e = .013, p < .001\]. This reflected the fact that both groups identified more studied than nonstudied words. There were no significant effects of Age or significant interactions between Age and Study (all \(F\)'s, 1); indicating that the two groups' initial baseline performances were adequately matched, and there were no significant differences between the magnitude of the priming for the groups. Matched, one-tailed \(t\) tests comparing repetition performance during the filter test revealed a significant advantage for studied over new words for both the children \([t_1(47) = 1.98, p < .05; t_2(31) = 2.78, p < .01]\) and the adults \([t_1(47) = 2.36, p < .05; t_2(31) = 2.87, p < .05]\). The size of the priming effect for the 2-year-olds (.068 or 12.8% corrected for baseline) and the adults (.085 or 15.5% corrected for baseline) was within the range of effects seen in Experiment 1. The 2-year-olds' baseline identification performance was also very near to the baseline for the 2.5-year-olds (.465) in Experiment 1.

Discussion

Taken together, Experiments 1 and 2 indicate that preschool children as young as 2 years old show long-term auditory priming similar to that seen in adults. These findings are consistent with the continuity of learning hypothesis (see also Nusbaum & Goodman, 1994; Schacter & Moscovitch, 1984), which postulates that the same learning and memory mechanisms underlying adult performance on implicit memory tasks are implicated in children's ability to acquire representations of the sound patterns of words in their language.

Although the similarity of priming performance across the age groups is consistent with this hypothesis, it is far from conclusive evidence that it is correct. There are many reasons why very different representations and learning mechanisms might yield similar performance on a given task, and the adult priming effects were numerically larger than the children's in both Experiment 1 and 2. Therefore, further findings of similar patterns in children and adults on long-term auditory priming tasks are needed to provide converging evidence for the continuity of learning hypothesis.

One of the seminal findings in research examining implicit memory performance is that it is not affected to the same degree as explicit memory performance by differences in the initial learning task. In particular, performance on some types of implicit memory tasks is relatively unaffected by manipulations of the type or level of processing required in the encoding phase, while explicit memory performance is highly influenced by this kind of encoding manipulation (for review see Roediger & McDermott, 1993; Schacter, 1987; cf. Challis & Broadbeck, 1992). Much research has documented that people are more likely to correctly recognize or recall information if they used an encoding procedure that focused their attention on the meaningful or associative properties rather than surface perceptual features of the stimuli to be remembered (e.g., Craik & Tulving, 1975). However, long-term priming in perceptual identification and cued generation tasks is unaffected or less affected by this kind of
encoding manipulation. These findings have led a number of theorists to suggest that implicit memory performance in such tasks is largely mediated by representations of the perceptual form of the stimuli, while explicit memory decisions rely upon more conceptual representations and processes (e.g., Jacoby & Dallas, 1981; Roediger & Blaxton, 1987; Schacter, 1990, 1994).

For present purposes, particular theoretical distinctions between implicit and explicit memory processes are less relevant than the pattern of findings itself: in the adult literature, long-term auditory priming in a variety of tasks is unaffected or less affected by the levels of processing encoding manipulation than auditory recognition memory or cued recall tasks (e.g., Church & Schacter, 1994; Schacter & Church, 1992). This finding is consistent with the hypotheses that long-term auditory priming is mediated by representations of the sound patterns of words rather than their meanings and that these sound patterns are encoded and retrieved as an automatic part of the speech perception and word identification processes. Experiment 3 was designed to further test the continuity hypothesis by determining whether the same pattern can be found in young children’s performance in implicit and explicit memory tasks.

EXPERIMENT 3

If the same perceptual memory mechanism supports long-term auditory priming in both children and adults, and if the priming in both groups is mediated by similar representations of the sound patterns of words, then young children should show the same pattern of effects of encoding manipulations on priming and explicit recognition memory seen in adults. As found for adults, children’s long-term auditory priming should be relatively unaffected by whether the study phase focuses their attention on the way the words sound or on their referents, but the children should show better explicit memory performance when the encoding task focuses their attention on the words’ referents. This pattern of performance would provide further evidence consistent with the hypothesis that the same learning and memory mechanisms underlie performance in children and adults. Experiment 3 tested this prediction by examining 3-year-olds’ performance on the low-pass-filtered word repetition test (an implicit memory task) and a recognition memory test (an explicit memory task) following a study task that either focused their attention on the way the word sounded (nonsemantic encoding) or on the object named by the word (semantic encoding). Adult participants were not tested in this experiment. It was assumed that with such a small number of highly distinctive items (child related words spoken in motherese) adults’ recognition memory performance would be at ceiling regardless of study condition.

Methods

Participants. Seventy-two 3-year-olds (36 to 42 months, mean age = 39.8 months), recruited from the same participant pool described in Experiment 1, participated. Their responses were compared to those of the 24 3-year-olds in Experiment 1 (see Design and Procedures, below), who participated in a nonsemantic study phase followed by a low-pass-filtered word repetition test. Pilot testing suggested that 2.5-year-olds did not understand the instructions for the recognition test; so only 3-year-olds were tested in Experiment 3. The children were given a small toy or book for their participation. Seven additional 3-year-olds were tested but did not respond during the test phase of the experiment (five in the semantic-study, repetition-test condition and one in each of the two recognition-test conditions).

Materials. The stimuli and materials were the same as those used with the children in Experiment 1 with the addition of two new test tapes with unfiltered words for the recognition test conditions and 64 small toys used for the object choice encoding conditions. Thirty-two of the toys depicted the critical words in the experiment, and the other 32 were chosen as foils. Each toy and its foil were roughly matched for size, brightness, and visual complexity, but chosen to be very readily discriminable (e.g., a button as the target and a ring as the foil). A bag was used for the children to place the toys in.

Design and procedures. The dependent mea-
asures were the proportion of correct repetitions in the implicit filter identification test conditions, and the proportion of “old” responses in the explicit recognition memory test conditions (measured by the child answering “yes” to the question “Did the robot say this word before?”). In both test conditions, Type of Encoding varied between participants (nonsemantic, sound judgments vs semantic, object choice), and Study (studied versus nonstudied items) varied within participants. The 3-year-olds’ data reported in Experiment 1 filled one cell of this $2 \times 2$ design, the nonsemantic encoding task followed by the implicit filter identification test.

All of the children participated in the initial play session. After entering the experimental room they participated in a study phase, a distractor phase in which they counted and put away materials from the study phase, and a test phase in which they listened to 32 words. Half of the words had been presented during the study phase and half were new.

**Study Phase.** Children in the nonsemantic encoding condition completed the same sound judgment task described in Experiment 1. Children in the semantic encoding condition participated in a different study task. After listening to each study word, the children were asked to select the toy the robot asked for from two choices placed in front of them and to place the toy in the robot’s bag. Half of the target toys were presented on the child’s left and half on the right. The left–right position of each target and foil was determined in a pseudo-random fashion with the constraint that the target items never appeared on the same side more than three times in succession. If the child made no choice on the first study task item, the experimenter chose for him or her, to demonstrate the task. No corrections were given. Children generally did quite well in the choice study phase, making an average of 1.73 errors (out of 16) in choosing the named object. Children assigned to the explicit recognition test made somewhat more choice errors at study ($M = 2.08, SD = 2.72$) than children assigned to the filter identification test ($M = 1.38, SD = 1.61$), but the difference between the groups was not statistically significant [$t(46) = 1.10, p > .25$].

**Test Phase.** Children in the implicit test condition completed the same filter identification task, followed by the same transcription and response coding procedures described in Experiment 1. Independent coding of 25% of the children’s repetitions, as in Experiment 1, yielded 94% agreement with the original accuracy codes. Children in the explicit condition heard clearly presented words and were asked to decide whether they had heard the robot say each word before. The experimenter noted the child’s response (yes or no) on each trial. Each test tape began with a practice item, as before; the experimenter demonstrated the task on this item if the child did not respond. All counterbalancing procedures were the same as described in Experiment 1. Across all conditions, 30 trials (1.30% of data) were omitted because of tape error or parental coaching.

**Results**

The top panel of Table 3 shows the mean proportion of correctly identified items in the filter identification test; the bottom panel of Table 3 shows the mean proportion of “old” responses in the recognition test. As predicted, priming was relatively constant across the two encoding conditions, but the child’s ability to discriminate between old and new items was much better when the children participated in the object choice encoding task.

Separate $2 \times 2$ analyses of variance were
performed to test the hypotheses that implicit test performance would not be affected by the encoding manipulation, but explicit test performance would be significantly improved under the semantic encoding condition. Separate analyses were appropriate for the different types of tests because of their different dependent measures. The first part of the predicted pattern was examined with a $2 \times 2$ ANOVA’s comparing repetition performance in the implicit filter identification task (Table 3, top panel). This revealed a main effect of Study in both participant and item analyses: $F_1(1,46) = 14.495$, $MS_e = .009, p < .001$; $F_2(1,31) = 12.319$, $MS_e = .014, p < .001$, showing significant priming. There was also a main effect of Type of Encoding, significant by both participants and items: $F_1(1,46) = 6.624$, $MS_e = .045, p < .02$; $F_2(1,31) = 25.526$, $MS_e = .016, p < .001$, indicating that children in the semantic study conditions were better at identifying words. However, the interaction between Type of Encoding and Study was not significant ($F$’s < 1), indicating that the degree of priming did not depend on the type of encoding task the child performed. As predicted by the continuity of learning hypothesis, 3-year-olds show the same pattern of implicit memory performance seen with adults. Implicit memory performance in the filter identification task was not significantly affected by the encoding manipulation.

The second part of the adult pattern was also found with the children. Recognition memory performance was significantly better for items encoded in the semantic study task. A $2 \times 2$ analyses of variance on the proportion of “old” responses in the explicit test conditions (Table 3, bottom panel) revealed a significant main effect of Study: $F_1(1,46) = 19.818$, $MS_e = .024, p < .001$; $F_2(1,31) = 15.292$, $MS_e = .041, p < .001$. The children were more likely to say “old” if the word had appeared in the study phase than if it had not, thus showing some recognition memory in this task (though, not surprisingly, the 3-year-olds’ recognition memory for isolated words was not very good). There was also a main effect of Type of Encoding, significant by items but not by participants: $F_1 < 1$; $F_2(1,31) = 38.648$, $MS_e = .006, p < .001$, indicating that items in the nonsemantic encoding conditions were more likely to elicit the response “old” than the same items in the semantic condition. This may indicate that some children in the more difficult nonsemantic condition eventually adopted the strategy of saying yes to all or most items. These analyses showed the predicted significant interaction between Type of Encoding and Study: $F_1(1,46) = 5.478$, $MS_e = .024, p < .03$; $F_2(1,31) = 17.422$, $MS_e = .011, p < .001$. Planned comparisons revealed that the children in both encoding conditions were significantly more likely to say “old” to studied items in the recognition test than non-studied items ($t(23) = 2.563, p < .05$ for nonsemantic encoding; $t(23) = 3.726, p < .05$ for semantic encoding). However, the interaction showed that the children’s ability to discriminate old from new items was significantly better under the semantic encoding condition.

In addition, the encoding task manipulation had an unanticipated effect on the children’s behavior during the study phase. When asked “What did the robot want?” children usually replied by repeating the studied word as well as by selecting the named object. Among the 3-year-olds who participated in the filter identification test, those in the semantic encoding condition repeated most of the words during the encoding task ($M = 12.75$ out of 16, $SD = 5.28$), whereas those in the nonsemantic encoding condition did so only rarely ($M = 1.33$, $SD = 2.62$; $t(46) = 9.48, p < .001$). The tendency to repeat words during the study task was not correlated with priming scores (Spearman $rho = .058, N = 48$), but was somewhat correlated with baseline performance in the filter identification test (accuracy in repeating new words; Spearman $rho = .279, N = 48$). These findings provide additional evidence that the priming measured in the filter identification task is primarily based on auditory/perceptual representations. Children in the semantic encoding condition

---

5 The high false alarm rate, especially for children in the nonsemantic study condition, probably reflects a general bias to respond “yes” to the experimenter’s questions. Such “yea-saying” biases are frequently found when young children are asked difficult yes–no questions (e.g., Landau, Smith, & Jones, 1988).
condition almost always pronounced each word in the study phase as well as listening to it; this was not the case for children in the nonsemantic encoding condition. This might allow for priming of production representations as well as priming of sound representations. Nevertheless, there was no significant difference in priming between these two conditions, and priming scores were not correlated with the tendency to repeat words in the study phase. While we would expect that representations chiefly relevant for speech production can also be primed (e.g., Wheeldon & Monsell, 1992), the current studies document auditory perceptual priming in preschoolers’ identification of spoken words.6

Discussion

The results of Experiment 3 show that long-term auditory priming in preschool children is unaffected by whether the study task focuses attention on the word’s sound or its meaning. However, the children’s ability to explicitly recognize that a word was presented before is influenced by this encoding manipulation. Perhaps most important for the present experiments, the pattern of results mimics the findings in the adult memory literature (Church & Schacter, 1994; Schacter & Church, 1992). This detailed similarity in influences on priming in children and adults provides further evidence for continuity across development of the learning and memory mechanisms mediating long-term auditory priming.

Furthermore, the pattern is consistent with the hypothesis that the processes and representations underlying long-term priming on these types of tasks are more perceptual than conceptual in nature (e.g., Jacoby & Dallas, 1981; Roediger & Blaxton, 1987; Schacter, 1990, 1994) and that the representations mediating long-term auditory priming are encoded relatively automatically during the process of word recognition (Church & Schacter, 1994; Schacter & Church, 1992). Merely hearing and attending to words helps people to identify those words again. In preschoolers and adults, the degree of facilitation appears to be independent of additional processing to identify the word’s referent.

GENERAL DISCUSSION

Prior research has documented in adults a powerful learning mechanism for forming and updating perceptual representations of the sound patterns of words to reflect recent experience (e.g., Church, 1995; Church & Schacter, 1994; Goldinger, 1996; Schacter & Church, 1992). Explorations of these implicit learning phenomena indicate that the underlying mechanisms have the same properties that we suggested in the Introduction would be needed for children to acquire appropriately detailed, flexible, and context sensitive long-term representations of words (e.g., Church & Schacter, 1994; Goldinger, 1996; Schacter & Church, 1992). Moreover, in the adult literature, the mechanisms that mediate long-term perceptual priming can be seen as integral parts of their respective perceptual identification systems (e.g., Cohen & Eichenbaum, 1993; Schacter, 1990). If this view is correct, then these mechanisms should be operational early in development (e.g., Nusbaum & Goodman, 1994; Schacter & Moscovitch, 1984). For these reasons we argued that the same perceptual learning procedure that mediates long-term auditory word priming in adults should be fully functional in young word learners and that it could play an important role in the initial establishment of an auditory lexicon.

Consistent with our hypothesis, we found that young children show patterns of long-term auditory priming very similar to those seen in adults. In Experiments 1 and 2, children as young as 2 years old more accurately identified mildly low-pass-filtered words that they heard presented once a few minutes before than words that were not played previously. Given similar word identification baselines accomplished

---

6 The younger children in Experiments 1 and 2 also did not frequently repeat words in the study phase. The 2.5-year-olds in Experiment 1 repeated an average of 1.29 (of 16) words in the study phase (8% of the time), and the 2-year-olds in Experiment 2 repeated an average of .90 items (of eight; 11% of the time). In neither case was the tendency to repeat items at study significantly correlated with priming scores (Spearman rho’s = .139 and .002, respectively).
through differential filtering of the test stimuli for children and adults, this facilitation showed no significant increase from 2 years old to college age.

Auditory word priming in preschoolers was also robust against manipulations of the task during the initial presentation of the repeated words. As previously found for adults (Church & Schacter, 1994; Schacter & Church, 1992), the magnitude of the priming effect for the 3-year-olds in Experiment 3 appeared not to depend on whether the encoding task encouraged them to access the referent of each studied word. Our encoding manipulation was not ineffective, however; the referential encoding task significantly improved the 3-year-olds’ ability to discriminate old from new items on a recognition memory test. A corresponding pattern of results has also been found in a study of priming in visual picture identification tasks in school-age children (Naito, 1990), and a number of other studies have shown comparable priming in children and adults on a variety of visual tasks (e.g., Drummey & Newcombe, 1995; Parkin & Streeter, 1988; Russo, Nichelli, Gibertoni, & Cornia, 1995).

The similarity of auditory word priming in preschoolers and adults, not only in magnitude but also in its characteristic insensitivity to variations in encoding task, strongly supports the hypothesis that the same learning mechanism is at work in both groups. For both young learners and adults, word identification systems incorporate a learning procedure which updates long-term representations of the sounds of words to reflect ongoing linguistic experience. This implicit learning facilitates later identification of the same word and does so rapidly—on only one exposure, even in 2-year-olds, whose ability to identify words based on their sounds without contextual support can be strikingly faulty (e.g., Gerken, 1994). This facilitation is a simple result of attention to a word, not dependent on the conceptual or referential encoding conditions which improve explicit recognition memory. Thus we have evidence for the kind of relatively automatic learning about the sound patterns of words, apparently independent of access to the word’s meaning, that would be needed to permit the initial acquisition of lexical phonological representations.

Nusbaum and Goodman (1994) have made a similar argument for the continuity across development of the basic mechanisms underlying learning about speech. They point out that theories of speech perception need to explain both how children initially form representations for word identification and how adults use experience to compensate for acoustic and contextual variability. Some recent theories of spoken word recognition suggest that continuous learning about speech is essential to account for the contextual adaptability of speech perception in adults (Church, 1995; Goldinger, 1996, 1998; Pisoni, 1993). These theories postulate that even adult listeners continually acquire new information about sources of variability in speech, including words, speakers, intonation, and acoustic surround, and use these representations to improve word identification performance. Nusbaum and Goodman (1994) suggest, simply, that if both children and adults need to continually acquire new information about sound patterns, then it becomes reasonable to ask whether the learning mechanisms which permit this are continuous throughout development.

Many studies have made it clear that there are enormous developmental changes in ability to identify spoken words. Even school-age children require a larger signal-to-noise ratio to identify highly familiar words (e.g., Elliott et al., 1979) and need to hear a longer segment of a word to identify it in a gating task (e.g., Elliott, Hammer, & Evan, 1987; Walley, 1988) as compared to adults. Such performance differences certainly suggest significant developmental change in systems relevant to speech processing. On the other hand, the present studies and other evidence from studies of speech processing in infants, children, and adults suggest considerable continuity across development in adaptive mechanisms for speech perception.

First, and most strikingly, listeners of all ages show persistent frequency or familiarity effects in a variety of tasks. Frequent or very familiar words are easier to identify for both adults (see
Lively, Pisoni, & Goldinger, 1994, for a review) and preschoolers (e.g., Gerken, 1994; Walley & Metsala, 1990), and infants attend longer to frequent words than to rare words (e.g., Hallé & de Boysson-Bardies, 1996). These frequency or familiarity effects hold true even for meaningless sound patterns. For example, 9-month-olds attend longer to lists of nonwords with sound sequences that frequently occur in their language (e.g., Jusczyk, Luce, & Charles-Luce, 1994), and 3- to 4-year-olds can more accurately repeat nonwords containing frequent compared to rare sound sequences (Beckman & Edwards, 1996; Gathercole, Willis, Emslie, & Baddeley, 1991). All of these phenomena indicate a strong link between repeated perception or production of particular sound patterns and subsequent processing of identical or similar items. This suggests an influential role in speech processing for the kind of learning mechanism we have proposed. Such findings, among others, have fostered recent lexical and instance based approaches to phonological representation, word recognition, and phonological development (e.g., Beckman & Edwards, 1996; Goldinger, 1996, 1998; Lindblom, 1992; Luce, Pisoni, & Goldinger, 1990; Pisoni, 1993).

Second, even young children’s word recognition shows signs of the flexible use of acoustic detail and contextual information found in adult auditory word priming. The current experiments do not bear on this issue, as study and test versions of each item were identical. However, recent findings based on an adaptation of the auditory priming paradigm reveal that 3-year-olds show priming for familiar words across tokens and contexts (Fisher & Church, in press). In a short-term and a long-term task, children more accurately repeated primed words in medial position in long sentences, identifying and repeating more content words in sentences containing a primed word. In these tasks, the phonetic and prosodic context and the word token differed from study to test. Thus auditory word priming in 3-year-olds shows at least some abstraction across tokens and contexts, spanning context change and acoustic variability as it does in adults.

At the same time, however, several recent findings provide evidence for context sensitivity in young children’s learning about the sound patterns of words. Infants at or just below the age to comprehend their first words use distributional information to isolate new word sized units in a continuous stream of speech (Goodsitt, Morgan, & Kuhl, 1993; Jusczyk & Aslin, 1995; Jusczyk, 1997; Saffran, Aslin, & Newport, 1996). Infants can accomplish this across naturally produced tokens of the words or nonwords, despite the unavoidable acoustic variability (see Jusczyk, 1997, for a review). These findings bear a striking similarity to the auditory learning phenomena under discussion, requiring both abstraction across contextual variation and preservation of context information to achieve the demonstrated sensitivity to distributional cues.

In summary, the current findings, along with several diverse lines of evidence linking speech processing in infants, preschoolers, and adults, reveals considerable continuity across development in learning procedures which adjust or update long-term representations of the sounds of words. The similarity in auditory word priming between preschoolers and adults also suggests some gross similarity between the phonological representations used for word recognition. Priming—the degree of facilitation in word identification attributable to repetition—depends not only on the basic learning mechanisms that mediate that facilitation but also on prior representations and processes relevant to word identification. Infants undergo considerable reorganization of their speech discrimination and categorization abilities during the first year of life, showing new sensitivity to a variety of aspects of the phonology of their native languages, including prosodic organization (e.g., Jusczyk, Cutler, & Redanz, 1993; Mehler et al, 1988; Nazzi, Bertocciini, & Mehler, 1998), phonemic contrasts (e.g., Best, 1994; Werker, 1994), and phonotactic regularities (Jusczyk, Friederici, Wessels, Svenkerud, & Jusczyk, 1993). Each of these changes should influence the kinds of representations and processes that are available when infants attend to speech and therefore what is learned from the exposure. Even at the end of the first year, as
toddlers comprehend and utter their first words, their word representations may differ in principled ways from those of adults (e.g., Charles-Luce & Luce, 1995; Hallé & de Boysson-Bardies, 1996; Stager & Werker, 1997). By the time the children turn 2, they typically have begun to learn new words quite rapidly (e.g., Goldfield & Reznick, 1990), suggesting that they have begun to represent the sound patterns of words in a manner at least roughly similar to adults.

However, it is far from clear how detailed this similarity is. There are suggestions in the literature that word representations in young word learners are holistic, or less likely than those of adults to be organized into phoneme sized units (e.g., Charles-Luce & Luce, 1995; Jusczyk, 1997; Walley, Smith, & Jusczyk, 1986). On the other hand, there appear to be qualitative similarities between preschoolers’ and adults’ word representations: Gerken et al. (1995) and Graham and House (1971) found that 3- and 4-year-olds’ perceptual confusions among words were more like adults’ than a very extreme holistic representation hypothesis would predict.

Much more research is needed to shed light on the structure and content of spoken word representations. However, we believe that the priming paradigm employed here will be a useful tool for exploring the development of spoken word recognition. In particular, the focus on long-term learning from speech as well as absolute performance in a word recognition task may help to detect similarities and differences in patterns of spoken word recognition against a background of large developmental improvements in performance. In these experiments, we have found a basic way in which young preschoolers’ word identification processes resemble those of adults—rapid encoding of perceptual information facilitates later identification of the same word. This evidence is consistent with the continuity of learning hypothesis—that the same perceptual learning mechanisms which may permit adults to adapt to changing speakers and acoustic circumstances (e.g., Nusbaum & Goodman, 1994; Pisoni, 1993) also plays a role in the initial acquisition of an auditory lexicon.

Further study of the properties and effects of this learning mechanism should provide valuable information about how young children represent and learn from spoken words.

REFERENCES


Drumley, A. B., & Newcombe, N. (1995). Remembering versus knowing the past: Children’s explicit and im-


Lindblom, B., Brownlee, S., Davis, B., & Moon, S. J.


(Received December 8, 1997)
(Revision received June 26, 1998)