
Fast Mapping Skills in the Developing Lexicon

Lisa Gershkoff-Stowe

Indiana University, Bloomington

Erin R. Hahn

Furman University, Greenville, SC

Purpose: This preliminary investigation was a longitudinal study of fast mapping skills in normally developing children, 16–18 months of age. The purpose was to examine the effects of practice on the accessibility of words in lexical memory.

Method: Eight children were taught the names of 24 unfamiliar objects over 12 weekly training sessions. The amount of practice children had with individual words varied as a function of session. Data were compared to a control group of children—matched on productive vocabulary—who were exposed to the same experimental words at the first and last sessions only.

Results: The results showed that for children in the experimental group, extended practice with a novel set of high-practice words led to the rapid acquisition of a second set of low-practice words. Children in the control group did not show the same lexical advantage.

Conclusions: The data suggest that learning some words primes the system to learn more words. Vocabulary development can thus be conceptualized as a continual process of fine-tuning the lexical system to enable increased accessibility to information. Implications for the treatment of children with word-finding difficulties are considered.

KEY WORDS: fast mapping, word learning, lexical activation, toddlers

Researchers have long been intrigued by the fast, one-shot word learning that is characteristic of children in their second year of life. Despite limitations of basic attentional and memory processes, and only rudimentary social–pragmatic skills, the average toddler typically accrues a lexicon of more than 500 words before the age of 3 years (Fenson et al., 1994). The ability to learn and retain new words with only minimal exposure is known as *fast mapping* (Carey & Bartlett, 1978; Heibeck & Markman, 1987). Many investigators regard children’s success at fast mapping as especially remarkable, considering that they lack the conceptual requirements believed to be essential to support the appropriate interpretation of words (for a discussion, see Gillette, Gleitman, Gleitman, & Lederer, 1999). Fast mapping has been observed in typically developing children as young as 13 months of age (Kay-Raining Bird & Chapman, 1998; Schafer & Plunkett, 1998; Woodward, Markman, & Fitzsimmons, 1994) as well as those with specific language impairments (Dollaghan, 1987; Ellis Weismer & Hesketh, 1996; Gray, 2003; Rice, Buhr, & Oetting, 1992); hearing loss (Lederberg, Preszbindowski, & Spencer, 2000); Williams syndrome (Stevens & Karmiloff-Smith, 1997); and Down syndrome (Chapman, Kay-Raining Bird & Schwartz, 1990; Mervis & Bertrand, 1995).

Carey and Bartlett (1978) first documented the phenomenon of fast mapping in a pioneering study of preschool-age children. They observed that 3-year-olds appeared to learn the meaning of a word when contrasted with another word known to the child. For example, when told “bring me

the chromium tray; not the blue one, the chromium one,” children successfully mapped the unfamiliar color term in the presence of the familiar one. Carey (1987) proposed that children learn the meaning of a word in two separate phases: (a) a fast mapping phase, in which the child establishes an initial link between word and referent, and (b) a subsequent, *slow mapping* phase. In the fast mapping phase, the child has only partial knowledge of the meaning of the word, whereas in the second phase of acquisition, the initial word representation becomes supplemented through additional experience, eventually coming to resemble the adult meaning.

The phenomenon of fast mapping has generated much interest among child language researchers. Building on Carey’s (1987) original work, numerous studies have focused on possible constraints or biases that guide children to interpret words in particular ways. In these experiments, children are typically exposed to nonostensive learning in an ambiguous context (Golinkoff, Mervis, & Hirsh-Pasek, 1994; Heibeck & Markman, 1987). For example, Evey and Merriman (1998) presented 24-month-olds with two simple line drawings of a cake and a novel object and told them to “find the dax.” Within this context, fast mapping was interpreted as occurring when children attached the new word to the previously unnamed object.

Other studies of fast mapping have focused instead on the speed or robustness with which the initial word-to-referent mapping occurs. Here, the interest is not how children disambiguate the meaning of words but, rather, how general processes of learning and memory support lexical acquisition—for example, the number of exposures it takes to learn a new word (Houston-Price, Plunkett, & Harris, 2005) or the kind of information learned and retained in memory (Chapman et al., 1990; Markson & Bloom, 1997). In many of these tasks, infants are taught words ostensibly through basic associative mechanisms—that is, through the direct pairing of an auditory label and visual object (Schafer & Plunkett, 1998; Woodward et al., 1994).

In this investigation, we used similar ostensive methods. Our interest was in the developing ability to map names to unfamiliar objects at a time when children have fewer than 100 words in their expressive vocabulary. Lederberg et al. (2000) suggested that ostensive learning is especially optimal for children with small vocabularies who may otherwise be unable to demonstrate fast mapping. They examined the fast mapping skills of deaf preschoolers in two contexts: (a) one in which children had to infer the meaning of a novel word and (b) a second in which the link between object and referent was made unambiguous by the experimenter. They found that the ability to fast map a word through brief ostensive exposure preceded the ability to infer that a novel word refers to a novel object. Furthermore, this ability was related to vocabulary size, such that children with larger expressive

and receptive vocabularies were more proficient at fast mapping new words than were children with smaller vocabularies.

A Model of Word Retrieval

Little is known about the influence of lexical retrieval processes on word learning in very young children. Particularly puzzling to researchers is the nature of the connection between speaking and listening. Early in development, children understand much more than they say. Later in development, the discrepancy is less apparent, and children often begin to use a word productively immediately after hearing it spoken. This change reflects an important transition in the child’s ability to fast map new words in production and is generally associated with the onset of the vocabulary spurt or naming explosion (L. Bloom, 1973; Ganger & Brent, 2004; Gershkoff-Stowe & Smith, 1997; Goldfield & Reznick, 1990; Mervis & Bertrand, 1994).

One reason for the asymmetry in understanding and saying may be that the two tasks place different demands on retrieval processes—that is, the retrieval of a word for production may require activation strengths that are greater than those needed to access a word in comprehension (Capone & McGregor, 2005). This idea is based on a common model of adult lexical access in which the retrieval of a word is not an all-or-none event but, rather, involves a process of graded activation (Stemberger, 1989). To comprehend the meaning of a word, the listener begins with an auditory cue that activates a phonological representation stored previously in memory. Activation then spreads from the phonological level to the semantic level where, given sufficient activation of the associated concept, the word is comprehended. In contrast, the retrieval of a word for production involves the reverse flow of information and derives its initial activation from a set of nonlinguistic cues that originates in semantic memory and spreads to the phonological level. Given sufficient strength to activate the associated sound form of a word, the word is accessed for production.

This model of lexical access suggests that activation derives from two sources: (a) the strength of connections that link units to one another and (b) the strength associated with each unit at a given moment in time. Because infants acquire many of their early concepts before acquiring the sound forms themselves, it is likely that concepts will initially possess higher levels of activation than the sound forms to which they are linked. What does this suggest, then, for the ease with which words are comprehended and produced? For a beginning word learner, hearing a particular word should provide a temporary boost to the initially low level of activation associated with the proper phonological unit. This activation then spreads to the semantic level, where the more highly activated concept needs only a small contribution from the phonological level to become available for access.

In comparison, attempts to say a word begin with the already highly activated concept, which may robustly spread activation to the phonological level. However, two general weaknesses of the retrieval system at this early stage of development conspire to make early naming a difficult task: (a) inadequate links between concept and form and (b) initially weak states of phonological activation for most words. As a consequence, the child often fails to retrieve the desired name. Such an experience may be similar to the *tip-of-the-tongue phenomenon* that adults sometimes experience (Brown & McNeill, 1966)—that is, the child “knows” the correct word but is unable to retrieve it (Elbers, 1985; Gershkoff-Stowe, 2007).

As conceptualized here, improvements in children’s ability to access stored representations in comprehension should support children’s ability to generate the associated words for production. This is because accessing the sound form of a word depends, in part, on the strength of the link to the concept itself, which becomes more robust each time the word is accessed. Additionally, the degree to which words and concepts are strengthened depends on several well-documented lexical factors, including word frequency and neighborhood density. Words that are high in frequency are processed faster and are less susceptible to error than words that are low in frequency (Dell, 1990; Stemberger & MacWhinney, 1986; see also Gershkoff-Stowe, 2002, for similar effects in young children). Practice, then, should strengthen the activation level of individual words, both when hearing the word spoken and when saying the word oneself.

A second factor known to influence lexical access is the phonological and semantic neighborhood characteristics of a word. Phonologically similar neighborhoods consist of words that differ by the addition, deletion, or substitution of a single phoneme (Luce & Pisoni, 1998). Adult studies of speech production show that access is facilitated when words are from high-density phonological neighborhoods with many phonetically similar words than from sparse neighborhoods with few phonetically similar words (Harley & Bown, 1998; MacKay, 1987; Vitevitch & Sommers, 2003). Words are also connected to other words at the semantic level (Levelt, 1989). For example, *dog* and *cat* belong to the same taxonomic category of animals and are similar in overall shape. Semantic similarity is a potent force in early word learning, as suggested by several studies of children’s novel word extensions (Baldwin, 1992; Gershkoff-Stowe, Connell, & Smith, 2006; Smith, 2000). The importance of semantic similarity is also revealed in adult studies of lexical access; target words are named more quickly when primed with words that are related in meaning (e.g., when *table* is primed by *chair*; Meyer & Schvaneveldt, 1971; Neely, 1977; Plaut & Booth, 2000).

Several measures have been used to determine the semantic relatedness among words, including feature

similarity, association, and co-occurrence (Buchanan, Westbury, & Burgess, 2001; Mirman & Magnuson, 2006). Because of the shifting and dynamic nature of these relationships, however, semantically similar neighborhoods are difficult to define (Nelson, McEvoy, & Pointer, 2003). This is especially true for children whose knowledge of semantic categories continually changes as new words and concepts are learned. Moreover, for children as well as adults, contextual factors play an important role. For example, 2- and 4-year-old children can be induced to overgeneralize words in response to pictures of objects that are visually similar to a target object (Gershkoff-Stowe et al., 2006). Adults are readily able to form new categories on the fly (e.g., “things to carry out of a burning house”) by semantically linking otherwise unrelated items (e.g., jewelry, photo albums, pets). These *ad hoc categories* emerge in response to momentary goals and the individual’s long-term knowledge of objects and their properties (Barsalou, 1983).

One developmental implication of these similarity neighborhoods is that as the early lexicon begins to expand, improved access to phonological and semantic information should result from increased activation that spreads through a widening network of related concepts and words. This prediction is consistent with recent studies indicating significant gains in processing efficiency between 1 and 2 years of age (Fernald, Perfors, & Marchman, 2006; Fernald, Pinto, Swingley, Weinberg, & McRoberts, 1998). Such findings help account for the characteristic rate change in productive vocabulary growth as children go from saying one word at a time to saying many new words at once (Goldfield & Reznick, 1990). We believe these developments reflect significant changes in the underlying operations of the lexicon as productive vocabulary grows. Specifically, we propose that the language processing system undergoes a shift from incremental improvements on a word-by-word basis to general, systemwide growth in word retrieval skills. This shift occurs gradually as the size and density of the lexicon assume a critical mass of words—the result of increased lexical competition and mutual support in the form of spreading activation (Marchman & Bates, 1994; Plunkett & Marchman, 1993).

The existence of systemwide changes in lexical access has been suggested by several studies of object naming involving typically developing children as well as children with language impairment. Gershkoff-Stowe (2001, 2002) has found that the pace at which normally developing toddlers acquired a productive vocabulary was closely related to developments in their overall ability to store and retrieve words (see also Capone & McGregor, 2005; Dapretto & Bjork, 2000). McGregor and colleagues (McGregor, Newman, Reilly, & Capone, 2002) also found that children with a history of specific language impairment exhibited a general weakness in the processing and storage

of words relative to children with normal language development.

The goal of this investigation was to shed light on the underlying nature of fast mapping by exploring children's emerging ability to access information in lexical memory. As a first step, we conducted a 3-month longitudinal study with children 16–18 months of age, using comprehension as a measure of fast mapping. This age group is of theoretical interest because it is just before the time when many children experience a sudden and rapid spurt in productive vocabulary growth (L. Bloom, 1973; Gershkoff-Stowe & Smith, 1997). As suggested by several studies of early vocabulary growth, the majority of children's first words are nouns (Dromi, 1987; Gershkoff-Stowe & Smith, 2004; Goldfield & Reznick, 1990; Nelson, Hampson, & Shaw, 1993). Accordingly, we focused training on the names of objects to maximize the probability that fast mapping would be observed. Children in an experimental condition were taught the names of unfamiliar objects at 12 weekly sessions. To separate the contributions of maturation and familiarity with the procedure from experience with learning words more generally, we taught a second group of children the same set of words under similar training conditions but at only two sessions scheduled 12 weeks apart.

We expected that both groups of children would show improvements in identifying individual high-practice words as a result of repeated exposure. More important, however, we hypothesized that extended experience with a single collection of words would enhance the ability to access object names in response to systemwide changes in the activation strength of many new items. Accordingly, we predicted that children in the experimental group would show greater improvements in the ability to fast map new words from Session 1 to Session 12 than would children in the control group. We also examined the possibility that learning inside the laboratory would translate to vocabulary gains outside the laboratory. This prediction was based on findings from a longitudinal training study in which toddlers who were taught novel words for novel objects showed corresponding gains in real-world object name vocabulary (Smith, Jones, Landau, Gershkoff-Stowe, & Samuelson, 2002). To test this hypothesis, we compared changes in the size of children's noun vocabulary by asking parents to complete the same vocabulary checklist at Session 1 and again at Session 12.

Method

Participants

Eight English-speaking children (3 boys, 5 girls) participated longitudinally and were compared to a second group of 8 children (3 boys, 5 girls), matched for productive

vocabulary size. Each child participated in multiple word-learning trials involving the testing of 12 object names per session. Children ranged in age from 16 to 18 months ($M = 16.8$) at the start of the study and were recruited from local day care centers and public birth records in Pittsburgh, Pennsylvania, and Bloomington, Indiana. The mean age for children in the experimental group was 17.1 months ($SD = 0.93$), compared to 16.5 months for their language-matched controls ($SD = 0.51$). One additional child was tested in the experimental group, but his data were excluded because he failed to remain consistently on task.

Parents completed the MacArthur–Bates Communicative Development Inventory: Words and Gestures (CDI:WG), a widely used measure of early vocabulary growth (Fenson et al., 1993). Our primary aim in selecting a vocabulary measure was to obtain measures of both word comprehension and production for the purpose of tracking children individually. The CDI:WG consists of 396 words and 19 semantic categories. Although designed for younger children, we chose this version rather than the Words and Sentences version because only the former asked parents for information about the words their child said and understood. The mean number of words in receptive vocabulary was 164 (range: 98–235) for children in the experimental group and 191 (range: 79–272) for children in the control group, $t(7) = -0.73$, $p = .49$. Production rather than comprehension was chosen for matching children because it is considered to be a more reliable and predictive measure, particularly as receptive vocabulary size increases beyond 100 words (see Tomasello & Mervis, 1994). Table 1 shows the number of words in productive vocabulary for each child in the experimental group and his or her matched control. Parents reported that children in the experimental group produced an average of 39.5 words (range: 11–98) at the start of the study compared to 37.3 words (range: 15–96) in the control group. Paired t tests showed that this difference was not significant, $t(7) = 1.87$, $p = .10$.

Table 1. Number of words in productive vocabulary for individual children in the experimental and control conditions at the initial session based on the MacArthur–Bates Communicative Development Inventory.

Participant	Experimental group ($M = 39.5$; $SD = 26.6$)	Control group ($M = 37.3$; $SD = 26.8$)
1	40	37
2	23	17
3	33	31
4	23	17
5	37	33
6	51	52
7	11	15
8	98	96

Materials and Design

The materials consisted of 24 brightly colored photographs (21.5 cm × 28 cm) of real-world objects. A sample of the objects is shown in Figure 1. Target words were selected on the basis of their low incidence in the receptive and expressive vocabularies of young children (Dale & Fenson, 1996) and were assumed to be unfamiliar to children below the age of 18 months. The words were phonologically distinct and consisted of one and two syllables. The objects included both artifacts (e.g., *trumpet*, *kettle*) and natural kinds, labeled at either the basic level (e.g., *crab*) or subordinate level (e.g., *toucan*).

The 24 pictures were divided into four sets of six objects each, the names of which were matched approximately for object category, syllable length, and phonological complexity. The sets varied as a function of practice—that is, by the number of times they were presented to children in the experimental group over the 12 weeks of the experiment. There were two high-practice sets, one medium-practice set, and one low-practice set. The same pictures within a set were used across sessions.

Children in the experimental group saw only two sets (i.e., 12 pictures) per session. The schedule of presentation of the high-, medium-, and low-practice sets across the 12 sessions is outlined in Table 2. Children saw two high-practice sets for 8 of the sessions, one high-practice and one medium-practice set at every third session, and one high-practice and one low-practice set at the final session. The

Table 2. Schedule of training and testing of high- (h), medium- (m), and low- (l) practice sets in the experimental condition by session.

Session	Practice
1	12h
2	12h
3	6h, 6m
4	12h
5	12h
6	6h, 6m
7	12h
8	12h
9	6h, 6m
10	12h
11	12h
12	6h, 6l

two high-practice sets were included to counterbalance words across Sessions 3, 6, 9, and 12. The medium-practice words set was included as an additional within-subject control that allowed us to examine children's familiarity with the experimental procedure as well as their experience with individual sets of words. Fast mapping was measured for each set at the first session in which children were introduced to the words: Session 1 for the high-practice words, Session 3 for the medium-practice words, and Session 12 for the low-practice words. That is, given equivalent exposure—a single session—we compared children's learning of the high-,

Figure 1. Sample pictures used.



medium-, and low-practice words as a function of time in the experiment.

Children in the control group saw two high-practice sets at Session 1 and one high-practice and one low-practice set at Session 12. For the intervening visits, the children looked at and named 12 familiar objects in a picture book. Both groups of children thus obtained similar experience naming and identifying pictures of objects over the 12-week course of the study; the critical difference between the groups was the amount of practice children were given with the new, unfamiliar words. The complete sets of words for each group are listed in the Appendix.

Procedure

Children in the experimental group participated in both a training and testing phase at each session. In the training phase, the parent and experimenter together labeled each of the 12 pictured objects a minimum of six times per session. Naming occurred in an ostensive context when both the child and adult were jointly focused on the referent. This interaction was structured naturalistically: Words were typically embedded in propositional statements to support the processing of word-referent pairings (Dollaghan, 1985). Thus, the child might hear the parent say, for example, "See the crab? The crab lives in the ocean!" No attempt was made to systematically manipulate the amount or kind of the semantic information provided.

Parents were instructed to use only the experimental words rather than synonyms (e.g., *toucan* rather than *bird*) and to provide only one potential referent by focusing on the whole object rather than a part (e.g., *crab* rather than *legs*). The experimenter also requested that parents avoid deliberate attempts to name the objects outside the laboratory. In weekly interviews to assess compliance, parents reported few occasions when additional naming occurred.

Testing probes were administered immediately after training. In the testing phase, the experimenter arranged 6 of the 12 pictures in front of the child. The same exemplars were used in both training and testing. The child was asked to point to the correct picture as the experimenter named each object. For example, the experimenter asked, "Where's the crab?" The order and location of the pictures were randomly arranged at each session and for each child. The same procedure was repeated for the remaining 6 pictures presented at that session. When errors occurred, the experimenter provided the child with the correct name and picture. No other feedback was given.

The training and testing procedures were identical for the experimental and control groups with the exception of the scheduled presentation of stimulus sets. On

the first and last of the 12 experimental visits to the laboratory, children in the control group were trained and tested on the same set of unfamiliar words used in the experimental group. In the intervening sessions, the children were trained and tested on a set of 12 pictures of common, everyday objects (e.g., dog, baby, car) that were assumed to be familiar to children below the age of 18 months. The same set of pictures was used at each of the 10 middle sessions. As in the experimental group, children were provided with the correct name during training and testing; no additional feedback was given. This design thus provided a between-subject control for the number of visits to the laboratory and the nature of the experience with the procedure. The two groups differed primarily in their exposure to word-referent pairs. Specifically, the experimental group was exposed to the high-practice set during each of the 12 sessions, whereas the control group was exposed to the high-practice set during Sessions 1 and 12 only.

All sessions were videotaped for later coding. Groups were compared for accuracy in picture identification, frequency of adult picture labeling during the training phase, and frequency of children's talking during the training phase. We randomly selected a total of 5 children (3 from the experimental group and 2 from the control group) to assess reliability between two independent coders. Percentage agreement was based on the first and last experimental sessions. Reliability was .94 for adult input (range: .91-.95), based on 1,299 responses, and .89 for children's talking (range: .78-1.00), based on 122 responses. Children's unintelligible utterances were not counted. Reliability was .94 for children's comprehension of the object words (range: .91-.96). Comprehension scores were slightly lower than expected because of multiple pointing strings that children sometimes produced. Differences were resolved by reviewing the tapes and by discussion.

Results

The main question was whether extended practice with a novel set of high-practice words would facilitate the acquisition of a second set of low-practice words with which children had little familiarity. An additional question was whether learning new names for objects inside the laboratory would make children more skilled at fast mapping words outside the laboratory. Before addressing these questions, we examined three preliminary issues: (a) whether exposure to the experimental words was comparable between conditions; (b) whether children demonstrated similar amounts of interest in the task, as measured by how much talking they generated in the laboratory; and (c) whether the two groups of children learned the names of the high-practice words equally well at Session 1.

Adult Input to Children

Over the course of the 3-month study, children in the control group were hearing the familiar picture book words outside of the laboratory. Hence, we made no attempt to control or measure their exposure to the words inside the laboratory. More critical to the main hypothesis was whether the two groups of children had equivalent amounts of exposure to the experimental high-practice words at the first and last sessions at which direct comparisons of learning were made. The results indicate that the mean number of times children heard the objects named during the training phase of the experiment did not differ systematically as a function of condition. At Session 1, the parent and experimenter jointly labeled each of the 12 high-practice objects a mean of 9.9 times ($SD = 2.28$) in the experimental group and 11.1 times ($SD = 2.48$) in the control group, $t(7) = 1.11, p = .30$. At Session 12, the parent and experimenter labeled the 6 high-practice words, on average, 11.3 times ($SD = 3.08$) in the experimental group and 10.3 times ($SD = 2.56$) in the control group, $t(7) = 0.86, p = .42$; they labeled the 6 low-practice words 11.8 times ($SD = 1.79$) and 10.7 times ($SD = 2.12$), respectively, $t(7) = 1.56, p = .16$.

In addition, within each condition there were no significant effects concerning how often children heard the objects named per session for the high-practice, medium-practice, and low-practice words (all p values $> .05$). For the experimental group, we calculated the mean proportion of times that the children heard the adults use the high-practice words during the 12 experimental sessions ($M = 11.0$); the medium-practice words during Sessions 3, 6, and 9 ($M = 11.5$); and the low-practice words during the final session ($M = 12.8$). For the control group, we calculated the mean proportion of times that the children heard the adults say the high-practice words in Sessions 1 and 12 ($M = 11.3$) and the low-practice words in Session 12 ($M = 11.1$). Together, the results indicate that adult input to children was, on the whole, equivalent both for the experimental and control conditions and across the three different levels of practice.

Children's Talking in the Laboratory

Between the first and last sessions of the study, children in the control condition looked at and named familiar objects in a picture book. Because the same book was used at each session, it is possible that children's attention in the experiment waned over time compared with children in the experimental condition, who were exposed to different pictures of unfamiliar objects over the course of 12 weeks. As a measure of children's engagement in the task, we counted all intelligible utterances that were produced by each group during training. This word count

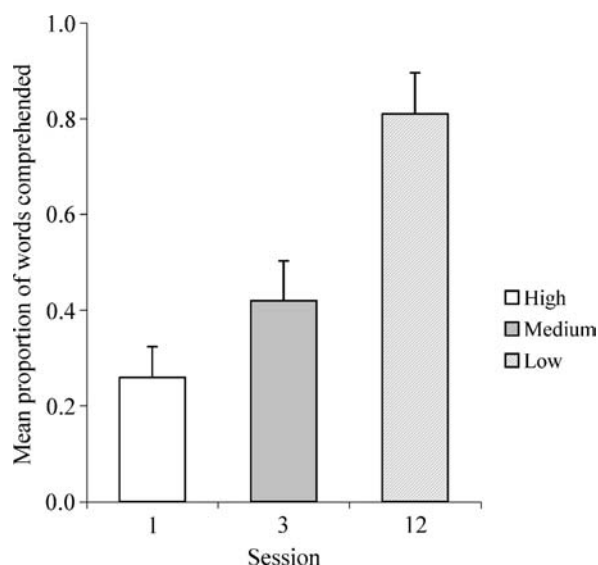
included nouns, modifiers, and verbs, as well as deictic utterances such as "that." A paired t test comparing the mean frequency of talking per session for each child yielded a significant difference, $t(7) = -2.29, p < .05$, although in the opposite direction from that predicted. Children in the control group produced an average of 12.48 words ($SD = 8.37$) per session, whereas those in the experimental group produced only 5.26 words ($SD = 5.13$). This result suggests that recurring presentation of a single picture book did not dampen children's enthusiasm in the word learning task; instead, repeated exposure to the same set of familiar pictures seems to have encouraged children's talking during training.

It is possible, however, that the observed difference between the two groups is due to a high rate of interest in the task early in the experiment but not later. To determine whether the distribution of attention was roughly even across sessions, we counted the number of children in each group who showed a decrease in talking from Sessions 2–6 to Sessions 7–11. This analysis revealed a decline in both groups, although the actual reduction in the number of words spoken by the children was small: 3 participants in the experimental group ($M = 1.1$ words; range: 0.4–1.8) and 4 participants in the control group ($M = 4.3$ words; range: 1.0–7.6). It is important to note, however, that for all children, this decline was accompanied by a higher proportion of unintelligible utterances, a category that was not included in the word count. The observed decline thus appears to be an artifact of the coding procedure. Rather than demonstrating reduced levels of children's interest in the task, the data suggest a rise in the number of attempts made to communicate verbally.

Comprehension of the Experimental High-Practice Words

A remaining question is how well children learned the high-practice words in both conditions. As expected, children in the experimental group showed a gradual increase in the proportion of high-practice words correctly identified in the comprehension task over the 12 weeks of the study. Twenty-three percent of the high-practice words were correctly identified at testing in Session 1 with only minimal exposure compared to 81% in Session 12. Although there was wide variation among individual children in terms of how many high-practice words they comprehended at each session, the same general pattern of increase was observed, $F(11, 77) = 7.60, p < .001, \eta_p^2 = .52$. Children in the control group correctly identified only 21% of the high-practice words at Session 1 but showed little gain at Session 12 with only 35% correct (see Figure 2). A 2×2 repeated measures analysis of variance revealed main effects of session, $F(1, 7) = 30.24, p < .001, \eta_p^2 = .81$,

Figure 2. Mean proportion of words fast mapped in comprehension at first presentation for high-practice (Session 1), medium-practice (Session 3) and low-practice (Session 12) sets.



and group, $F(1, 7) = 18.73, p = .003, \eta_p^2 = .73$. In addition, there was a significant Session \times Group interaction, $F(1, 7) = 7.81, p = .03, \eta_p^2 = .53$, indicating that children in the experimental group comprehended more high-practice words at Session 12 than did children in the control group. This effect of condition was not apparent at Session 1.

In the weeks between the first and last session, the control group of children received training on a set of familiar words in a picture-book context of parents reading and naming common, everyday objects. This ensured that children in both conditions received equivalent experience in the experimental task, the critical difference being whether they received extended practice with a single set of familiar words (e.g., *dog, baby, car*) or with multiple sets of novel words (e.g., *squid, bagpipe, crab*). Although not every child in the control group showed evidence of knowing every word when tested at weekly intervals, as a whole, children in the control group comprehended many more of the familiar words than the unfamiliar high-practice words.¹ Of primary interest, however, were the final sessions of testing, in which the children correctly identified 76% of the familiar words at Session 11, compared to only 35% of the unfamiliar words at Session 12. This result suggests that, similar to children in the experimental group, those in the control group were capable of performing the basic word learning test and were comfortable with the experimental procedure.

¹The fact that children did not perform at ceiling with the familiar words in the comprehension task at every session is consistent with previous findings of children's early lexical growth (Gershkoff-Stowe, 2002).

Comprehension of the Experimental Low-Practice Words: Evidence of Fast Mapping

The central question that this study posed was whether frequent exposure to a set of novel words would support the rapid acquisition of additional words. If so, children in the experimental group would be expected to show a fast mapping advantage relative to children in the control group. This was assessed by comparing the number of low-practice words comprehended in Session 12. Recall that both groups of children had the same opportunity to learn the low-practice words during training and differed only in the amount of practice they received with the high- and medium-practice words. A paired t test confirmed the main hypothesis: Children in the experimental group correctly identified 71% of the low-practice words at testing, compared with 38% for the control group, $t(7) = 2.64, p = .03$, Cohen's $d = 1.26$.²

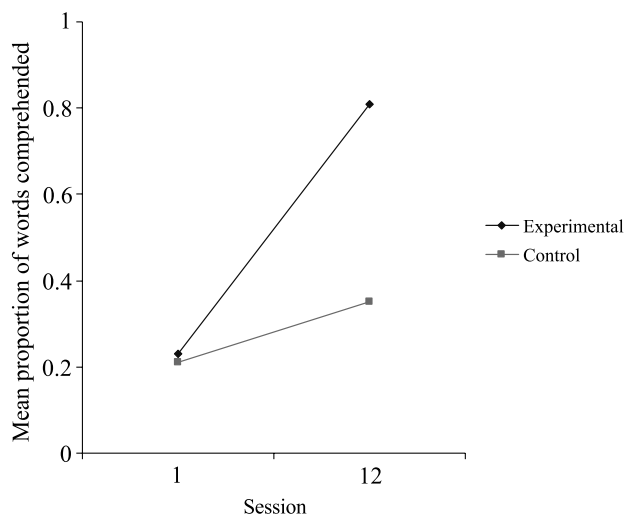
The Medium Practice Set as a Within-Subject Control

Additional evidence was found that children are capable of fast mapping new words when given extended practice mapping a set of new words to novel objects. We compared the mean proportion of words comprehended by children in the experimental group at first presentation for the high-practice, medium-practice, and low-practice words at Sessions 1, 3, and 12, respectively. The results are presented in Figure 3. As previously noted, children correctly identified only 23% of the high-practice words at Session 1. In contrast, children correctly identified 35% of the medium-practice words and 71% of the low-practice words at the first session in which they were introduced. A one-way repeated measures analysis of variance revealed that this difference was significant, $F(2, 14) = 11.94, p = .001, \eta_p^2 = .63$. Furthermore, a Bonferroni post hoc test revealed that comprehension of the low-practice words at first test was significantly greater than comprehension of both the high-practice and medium-practice words at first test.

One interpretation of the findings, however, is that for children in the experimental group, improved performance

²Children in both groups were presented with mixed sets containing high- and low-exposure items for testing in the comprehension task at Session 12. This aspect of the procedure, however, raises the possibility that children in the experimental group used familiarity to narrow the test options for identifying the low-exposure items. If this were the case, then comprehension errors for the low-exposure items should consist of low-exposure foils, and errors for the high-exposure items should consist of high-exposure foils. Instead, we found that children tended to select the low-exposure foils for both the low- and high-exposure items. This suggests that children were attracted to the novelty of the low-exposure items and were not simply relying on an elimination strategy. Furthermore, children's responses in the control group revealed a similar pattern of error for the high- and low-exposure items. Together, these data suggest that the high-exposure foils were not driving children's correct performance on the low-exposure items.

Figure 3. Mean proportion of high-practice words comprehended at Sessions 1 and 12 as a function of condition.



at Session 12 is confounded with experimental practice—that is, familiarity with the procedure, and not with practice learning words, may have been responsible for the observed effect. If children’s heightened performance was simply due to time in the experiment, then we would expect a significant increase in word comprehension after 6 weeks of training. Accordingly, we examined children’s comprehension of the high- and medium-practice words at second presentation, which for the medium-practice set occurred 4 weeks later, at Session 6. The results revealed no difference in performance at 2 weeks and 6 weeks. Children correctly identified 47% of the high-practice words at Session 2, compared to 48% of the medium-practice words at Session 6, $t(7) = -0.208$, $p = .84$, Cohen’s $d = -0.03$.

These results suggest that familiarity with the laboratory procedure itself is not solely responsible for the rapid learning of the low-practice words at Session 12. Instead, it appears that the pace of children’s word learning accelerated as children obtained sufficient amounts of practice with a novel collection of words. This idea is supported by the additional finding that at third presentation, children’s comprehension performance of the medium-practice words at Session 9 ($M = 0.71$) surpassed their performance of the high-practice words at Session 3 ($M = 0.50$), $t(7) = -2.72$, $p = .03$, Cohen’s $d = 0.64$.

Productive Vocabulary Growth Outside the Laboratory

We hypothesized that children’s improved fast mapping skills inside of the laboratory might correlate with developments in vocabulary growth outside of the

laboratory. Accordingly, we compared children’s productive vocabulary size at the beginning and end of the 12-week experiment, based on the MacArthur–Bates CDI. Children gained an average of 90.9 words (range: 13–218) in the experimental group and 64.0 words (range: 26–93) in the control group. This difference, although large and in the predicted direction, failed to reach statistical significance, $t(7) = 0.88$, $p = .41$, Cohen’s $d = 0.52$. Furthermore, we examined growth of receptive vocabulary over the 12-week study and again found a nonreliable increase, also in the predicted direction: Children gained 107 words, on average (range: 52–199), in the experimental group and 86 words in the control group (range: 36–164). We consider the implications of these results in the discussion below.

The findings from this study suggest that rapid word learning occurs in response to extended practice with words—practice in the experimental word learning task, practice through the repetition and access of identical words, and, more interestingly, practice with words in general.

Discussion

At the core of the debate on early lexical acquisition is the question of how children accomplish the task of learning words quickly and with little apparent effort. Increasingly, researchers are recognizing the need to integrate contributions from studies of learning, attention, and memory—studies that emphasize the cognitive processes underlying the ability to fast map (P. Bloom, 2000; Golinkoff et al., 2000; Hollich, Hirsh-Pasek, & Golinkoff, 2000). In the research reported in this article, we tracked the development of children’s word learning over a period of 3 months, at an age when a sudden onset in the rate of new word acquisitions is often observed (Bates, Bretherton, & Synder, 1988; Gershkoff-Stowe & Smith, 1997; Lifter & Bloom, 1989; Reznick & Goldfield, 1992). We presented data showing that children who received extended training on the names of a number of unfamiliar objects progressed from learning each word individually to learning many words at once. We attribute this finding to changes in the strength of lexical activation as the result of repeated practice: Knowing some words appears to prime the system to knowing more words.

Practice With Words

Practice effects are, of course, ubiquitous in learning (Newell & Rosenbloom, 1981). Yet, to date, the role of practice in the lexical development of novice word learners has received little attention. In most models of adult lexical retrieval, the accessibility of a word reflects the speaker’s past history of use, namely, how often and how recently

an item has been practiced (Anderson & Schooler, 1991). The more an item is selected for comprehension or production, the stronger the level of activation will be and, hence, the greater the probability of access. This idea suggests that practice with individual words in a rapidly expanding lexicon changes the operation of the lexicon through the accumulated activation of many items. This is accomplished through an increase in the base of lexical and semantic units and the strengthening of connections between them.

Although the present results should be interpreted with caution because of the modest sample size and use of unique training sets, they underscore the importance of examining potential changes in the strength of activation of words in response to repeated practice. Additional studies are needed to determine whether the findings extend beyond the laboratory to the real world of the child, particularly with respect to vocabulary size and to word classes other than nouns. Must children obtain a critical number of words, for example, before improvements in processing efficiency arise (Marchman & Bates, 1994)? Are the findings specific to novice word learners, or do they extend to older children and adults? Our conjecture is that similar mechanisms would be found in learners at any age as they acquire more and more information within a given semantic domain (e.g., dinosaur names, chess moves). Such improvement is likely to stem from increased lexical density, leading to new pressures to reorganize information that better supports the accurate retrieval of words (Storkel, 2002). We further speculate that the nature of this change is neither abrupt nor discontinuous but rather emerges from a coalescence of changes over multiple episodes of learning.

The present findings are consistent with a proposed shift in how words are processed, from local increases in the activation strength of individual words to systemwide increases in the activation strength of multiple words. Such a shift might account for the apparent spurt in receptive and productive vocabulary growth that occurs for most children toward the end of the second year (Reznick & Goldfield, 1992). The shift might also help to explain the transitory increase in naming errors associated with this early period of accelerated vocabulary growth. Specifically, Gershkoff-Stowe and Smith (1997) reported a rise and fall in retrieval errors concomitant to the vocabulary spurt that involved object words known to the child. Errors were greatest at the time when the child was just beginning to produce many new words, but errors rapidly declined in the weeks that followed. Gershkoff-Stowe and Smith (1997) attributed this curvilinear pattern to changes in the strength of activation of words in response to increased competition. They suggested that word representations that were initially fragile were strengthened as children acquired more words and gained practice retrieving and producing those words. With the

simultaneous increase in the strength of many individual items, even newly learned words were better able to resist interference from possible lexical competitors. These results, together with the fast mapping advantage found in the present experiment, suggest that systemic changes in lexical processing arise as children accrue practice with learning new words and from continued exposure to familiar words.

Although the precise nature of this systemwide change is unknown, automaticity likely plays a key role. Many activities, such as walking, drinking from a cup, or riding a tricycle, involve a shift from controlled to automatic processes (Shiffrin & Schneider, 1977). Among adults, automaticity underlies much processing in memory and attention. A classic example is the Stroop effect (Stroop, 1935). In the Stroop task, respondents are asked to name words in different colored inks but are unable to ignore the word's meaning when it is incongruent with the color of the ink (e.g., *green* written in blue ink). The interference that occurs when seeing the word and accessing its meaning is taken to reflect the automaticity of component processes within the word production system.

Automaticity is considered to emerge gradually as a result of consistent and sustained practice. Although the biological mechanisms that enable automatic processing are not well understood, recent studies using functional magnetic resonance imaging techniques indicate that the development of automaticity in adults involves noticeable changes in brain activity (Schneider & Chein, 2003). In particular, there is a reduction in the amount of cortical activity associated with working memory and attentional control as new skills are acquired. This change in activity is thought to indicate a shift from serial to parallel processing.

A similar shift may occur in the act of learning words—a development that is reflected in the fast mapping associated with the vocabulary spurt (Mervis & Bertrand, 1994; Reznick & Goldfield, 1992). In support of this idea, event-related potential studies of infants 13 and 20 months old revealed an emerging specialization of neural systems that mediate language comprehension before and after the period of initial rapid vocabulary growth (Mills, Coffey-Corina, & Nelville, 1997). Mills et al. (1997) found, in addition, that this early functional specialization was linked to language experience independent of chronological age. In particular, studies showed that neural changes occurred as a function of vocabulary size and familiarity with individual words (Mills, Plunkett, Prat, & Schafer, 2005). In light of these and other findings, Mills et al. (2005) proposed that neural processes may become more automatic as the amount of brain activity needed to discriminate words decreases and working memory capacity increases. Automaticity, then, may be conceptualized an emergent property of the language processing system.

Neighborhoods of Collective Activity

A fundamental question that the present study raises is why children showed improved recognition of the novel words (i.e., the low-practice words at Session 12) with repeated prior exposure to the high- and medium-practice words. If familiarity were simply the answer, then we should find that children in the control group who heard the names of 12 highly familiar objects (e.g., *bunny*, *apple*, *dog*) performed as well as, or perhaps better than, children in the experimental group. However, this was not the case. We believe the answer lies, instead, in changes that occurred in response to extended learning involving a new set of words. These words, acquired gradually over the 12 weeks of the study, were contextually related. Collectively, they formed what might be considered a unique “neighborhood”—gradually increasing in strength as the number and density of task-related words also increased (Charles-Luce & Luce, 1990). Our use of the term *neighborhood* reflects the theoretical idea that through associative learning processes and prior experience, words and concepts can organize into larger units or systems that facilitate “fast, efficient, and parallel access to a broad base of related past knowledge” (Nelson et al., 2003, p. 49; see also Shiffrin & Steyvers, 1997).

The idea that a small set of contextually related words can create a structural neighborhood that facilitates the spread of activation to other newly acquired words is consistent with adult studies showing that networks of association affect memory performance in tasks of recognition and cued recall (Nelson et al., 2003). In the present study, children were provided with limited information about the nature and function of the novel objects, yet they were united by the context in which the words were acquired. These words were neither phonologically nor semantically similar (indeed, children were provided with little information about the objects). With the introduction of six additional new (low-practice) words at Session 12, children in the experimental group, but not their language-matched controls, readily fast mapped the experimental words. Having a pre-established neighborhood in which to incorporate the new words thus appears to have a facilitating effect on rapid word learning. We interpret this finding within the context of a spreading activation model: Broadening the base of conceptually related links within a single neighborhood produces patterns of activation that support the accessibility of individual words.

These ideas have obvious relevance for developmental issues concerning the dynamics of vocabulary growth. However, there is evidence in the adult literature for facilitative as well as competitive effects of similarity neighborhoods on word retrieval. As Stemmerger (2004)

succinctly noted, a word’s neighbor is its potential competitor. Several recent studies suggest a complex interaction among lexical neighborhoods, word frequency, and levels of processing (Luce & Pisoni, 1998; Vitevitch & Sommers, 2003). The picture is further complicated in children, moreover, where multiple factors operate to influence retrieval on two time scales: (a) as it occurs online and (b) over ontogenetic development (Newman & German, 2002). In the present study, we found evidence that neighbors of target items provided a facilitative effect on children’s performance in the word comprehension task rather than acting as a source of interference. This effect, however, was not related to vocabulary development outside the laboratory.

Fast Mapping and Its Relation to Productive Vocabulary Growth

We anticipated that improvements in the ability to fast map words in the experimental task might translate to lexical gains outside the laboratory. This prediction was based on evidence from a 7-week training study by Smith et al. (2002). In that study, eight 17-month-olds were taught the names for four different novel object categories that were well organized by shape. At the conclusion of the study, these children acquired a shape bias that was associated with a 166% increase in the size of their productive vocabulary, compared with only a 73% increase in the vocabularies of 8 control children who did not participate in the training portion of the study.

In the present experiment, we found a modest increase in both receptive and productive vocabulary for children in the experimental group relative to their language-matched controls; however, these differences were not reliable. There are several possible reasons for this outcome. One possibility is the vocabulary instrument we selected. The CDI:WG provides useful information about receptive vocabulary for the beginning word learner. However, as suggested by Bates (1993) and others (Tomasello & Mervis, 1994), parents can keep track of word comprehension only up to about 100 words. Thus, the instrument may have become an insensitive measure of receptive vocabulary growth for children in the present study who amassed more than 250 words by the time of Session 12. Moreover, there was a clear ceiling effect in the size of productive vocabulary for our most lexically advanced children.

A second possibility is that the absence of a significant effect indicates a limitation in sample size. Insufficient power may have resulted from the small number of children who participated in the study, thus obscuring any real effect of word learning inside the laboratory on vocabulary growth outside the laboratory. A third

possibility concerns the nature of the underlying mechanisms of lexical access in the emerging lexicon. In particular, it may be that the activation of a single set or neighborhood of words is not sufficient to create across-the-board increases in the processing strength of items belonging to other lexical neighborhoods. Instead, qualitative changes may be found only after both the size of the lexicon and the number of different neighborhoods reaches a critical mass. In this regard, the present results are an important first step. The need for more research is clearly indicated, specifically with respect to how vocabulary growth and the process of fast mapping relate to word frequency and neighborhood density.

Clinical Implications

This research presents data that bear on the question of how to regard children who have difficulty accessing established words for expressive use. Such children are often diagnosed as having word finding deficits and typically require some form of language intervention. In most cases, children with word finding problems have difficulty naming objects despite intact comprehension (Dockrell, Messer, & George, 2001). We have suggested that both listening to words and producing words influence the lexical representations that children have previously stored in memory. Although they differ in that listening entails passive access, whereas speaking entails active retrieval, both processes are mutually influencing: Practice that strengthens the activation of units in one modality strengthens the activation of units in the other modality.

In the interactive model of language that we have proposed, lexical access is driven by both top-down and bottom-up processes. In the former case, words are strengthened in production by activation that is summed across multiple semantic connections. In the latter case, words are strengthened in comprehension by multiple opportunities to hear the sound and syllable structure of words. Both processes should contribute to long-term changes in the connection strength of pathways between the phonological and semantic levels.

We also have suggested that the number and density of lexical neighborhoods should affect the ease and accuracy with which words are retrieved for naming. Several recent studies have shown that children with word finding difficulties benefit from treatment at a variety of ages, but no single semantic or phonological approach is known to be effective for all children (McGregor, 1994; for a discussion, see Best, 2005). This may be due, in part, to the heterogeneous nature of the population identified with word finding difficulties, but differences in treatment outcome are also likely to reflect changes in the size and organization of the child's lexicon as it continually develops.

If problems in accessing words stem from the strength of semantic connections associated with neighborhood density, then one might expect differences in successful retrieval as a function of lexical category. Consistent with this idea, Dockrell et al. (2001) found that 6- and 7-year-old children with word finding difficulties performed less well than their age-matched peers on naming objects and actions but did not differ significantly in naming letters and numerals. These categories vary in semantic complexity, with actions and objects involving more complex representations than letters and numbers. In addition, Best (2005) noted that although there is a simple one-to-one mapping between word and concept for letters and numbers, there is a one-to-many mapping for objects and actions. Thus, for example, features such as "furry," "four-legged," and "pet" will activate *cat* in addition to *dog*. Dockrell et al. interpreted their findings as support for the hypothesis that children with word finding difficulties have impoverished semantic representations (see also McGregor et al., 2002). In the present theoretical framework, we find the results to be especially intriguing with regard to the unique properties associated with (a) individual neighborhoods and their relation to lexical frequency and (b) word retrieval. Future investigation is warranted.

Conclusion

As with many other acquisition tasks that adults and children perform, the transition from novice to expert word learner requires extensive practice. Word learning is more than the simple acquisition of information in memory; it also involves the fine-tuning of processes that enable increased accessibility to information (Rumelhart & Norman, 1978). One effect of these changes is to free children to focus their efforts on other linguistic tasks, such as the emergence of grammar (Anisfeld, Rosenberg, Hoberman, & Gasparini, 1998; Bates & Goodman, 1997) and the growth of pragmatic understanding (Baldwin, 1991). In this sense, the very activity of learning words may be the causal force behind fast mapping and related developments in language.

Acknowledgments

This work was supported by Grant RO1-HD39424 from the National Institutes of Health to the first author. Some data were collected while both authors were at Carnegie Mellon University. Portions of these data were presented at the April 2001 biennial meeting of the Society for Research in Child Development in Minneapolis, Minnesota.

We thank Rachel Whipple, Veronica Sansing, Audrey Russo, and Kimberly Massengill for their help with data collection. We are also grateful to Dana Courier, Elizabeth Carafiol, and Lisa Cantrell for their coding assistance and to the parents and children who participated in the study.

References

- Anderson, J. R., & Schooler, L. J.** (1991). Reflections of the environment in memory. *Psychological Science, 2*, 396–408.
- Anisfeld, M., Rosenberg, E. S., Hoberman, M. J., & Gasparini, D.** (1998). Lexical acceleration coincides with the onset of combinatorial speech. *First Language, 18*, 165–184.
- Baldwin, D. A.** (1991). Infants' contribution to the achievement of joint reference. *Child Development, 62*, 875–890.
- Baldwin, D. A.** (1992). Clarifying the role of shape in children's taxonomic assumption. *Journal of Experimental Child Psychology, 54*, 392–416.
- Barsalou, L. W.** (1983). Ad hoc categories. *Memory & Cognition, 11*, 211–227.
- Bates, E.** (1993). Comprehension and production in early language development. *Monographs of the Society for Research in Child Development, 58*, 222–242.
- Bates, E., Bretherton, I., & Synder, L.** (1988). *From first words to grammar: Individual differences and dissociable mechanisms*. Cambridge, MA: Cambridge University Press.
- Bates, E., & Goodman, J. C.** (1997). On the inseparability of grammar and the lexicon: Evidence from acquisition, aphasia and real-time processing. *Language and Cognitive Processes, 12*, 507–584.
- Best, W.** (2005). Investigation of a new intervention for children with word-finding problems. *International Journal of Language and Communication Disorders, 40*, 279–318.
- Bloom, L.** (1973). *One word at a time: The use of single-word utterances before syntax*. The Hague, The Netherlands: Mouton.
- Bloom, P.** (2000). *How children learn the meaning of words*. Cambridge, MA: MIT Press.
- Brown, R., & McNeill, D.** (1966). The "tip of the tongue" phenomenon. *Journal of Verbal Learning and Verbal Behavior, 5*, 325–337.
- Buchanan, L., Westbury, C., & Burgess, C.** (2001). Characterizing semantic space: Neighborhood effects in word recognition. *Psychonomic Bulletin & Review, 8*, 531–544.
- Capone, N. C., & McGregor, K. K.** (2005). The effect of semantic representation on toddlers' word retrieval. *Journal of Speech, Language, and Hearing Research, 48*, 1468–1480.
- Carey, S.** (1987). *Conceptual change in childhood*. Cambridge, MA: MIT Press.
- Carey, S., & Bartlett, E.** (1978). Acquiring a single new word. *Papers and Reports in Child Language Development, 15*, 17–29.
- Chapman, R. S., Kay-Raining Bird, E., & Schwartz, S. E.** (1990). Fast mapping of words in event contexts by children with Down syndrome. *Journal of Speech and Hearing Disorders, 55*, 761–770.
- Charles-Luce, J., & Luce, P. A.** (1990). Similarity neighborhoods of words in young children's lexicons. *Journal of Child Language, 17*, 205–215.
- Dale, P. S., & Fenson, L.** (1996). Lexical development norms for young children. *Behavior Research Methods, Instruments and Computers, 28*, 125–127.
- Dapretto, M., & Bjork, E. L.** (2000). The development of word retrieval abilities in the second year and its relation to early vocabulary growth. *Child Development, 71*, 635–648.
- Dell, G. S.** (1990). Effects of frequency and vocabulary type on phonological speech errors. *Language and Cognitive Processes, 5*, 313–349.
- Dockrell, J. E., Messer, D., & George, R.** (2001). Patterns of naming objects and actions in children with word finding difficulties. *Language and Cognitive Processes, 16*, 261–286.
- Dollaghan, C. A.** (1985). Child meets word: "Fast mapping" in preschool children. *Journal of Speech and Hearing Research, 28*, 449–454.
- Dollaghan, C. A.** (1987). Fast mapping in normal and language impaired children. *Journal of Speech and Hearing Disorders, 52*, 218–222.
- Dromi, E.** (1987). *Early lexical development*. Cambridge, England: Cambridge University Press.
- Elbers, L.** (1985). A tip-of-the-tongue experience at age two? *Journal of Child Language, 12*, 353–365.
- Ellis Weismer, S. E., & Hesketh, L. J.** (1996). Lexical learning by children with SLI. *Journal of Speech and Hearing Research, 39*, 177–190.
- Evey, J. A., & Merriman, W. E.** (1998). The prevalence and the weakness of an early name mapping preference. *Journal of Child Language, 25*, 121–147.
- Fenson, L., Dale, P. S., Reznick, J. S., Bates, E., Thal, D. J., & Pethick, S. J.** (1994). Variability in early communicative development. *Monographs of the Society for Research in Child Development, 59*(Serial No. 242).
- Fenson, L., Dale, P., Reznick, J. S., Thal, D., Bates, E., Hartung, J., et al.** (1993). *MacArthur Communicative Inventories: User's guide and technical manual*. San Diego: Singular Publishing Group.
- Fernald, A., Perfors, A., & Marchman, V. A.** (2006). Picking up speed in understanding: Speech processing efficiency and vocabulary growth across the 2nd year. *Developmental Psychology, 42*, 98–116.
- Fernald, A., Pinto, J. P., Swingle, D., Weinberg, A., & McRoberts, G. W.** (1998). Rapid gains in speed of verbal processing by infants in the second year. *Psychological Science, 9*, 228–231.
- Ganger, J., & Brent, M. R.** (2004). Reexamining the vocabulary spurt. *Developmental Psychology, 40*, 621–632.
- Gershkoff-Stowe, L.** (2001). The course of children's naming errors in early word learning. *Journal of Cognition and Development, 2*, 131–155.
- Gershkoff-Stowe, L.** (2002). Object naming, vocabulary growth, and the development of word retrieval abilities. *Journal of Memory and Language, 46*, 665–687.
- Gershkoff-Stowe, L.** (2007, June). *Lexical road jams: Eliciting tip-of-the-tongue states in children*. Poster presented at the 28th annual Symposium on Research in Child Language Disorders, Madison, WI.
- Gershkoff-Stowe, L., Connell, B., & Smith, L.** (2006). Priming overgeneralizations in 2- and 4-year-old children. *Journal of Child Language, 33*, 1–26.
- Gershkoff-Stowe, L., & Smith, L. B.** (1997). A curvilinear trend in naming errors as a function of early vocabulary growth. *Cognitive Psychology, 34*, 37–71.
- Gershkoff-Stowe, L., & Smith, L. B.** (2004). Shape and the first hundred words. *Child Development, 75*, 1–17.

- Gillette, J., Gleitman, H., Gleitman, L., & Lederer, A.** (1999). Human simulations of vocabulary learning. *Cognition*, *73*, 135–176.
- Goldfield, B. A., & Reznick, J. S.** (1990). Early lexical acquisition: Rate, content, and the vocabulary spurt. *Journal of Child Language*, *17*, 171–183.
- Golinkoff, R. M., Hirsh-Pasek, K., Bloom, L., Smith, L. B., Woodward, A. L., Akhtar, N., et al.** (2000). *Becoming a word learner: A debate on lexical acquisition*. New York: Oxford University Press.
- Golinkoff, R. M., Mervis, C. B., & Hirsh-Pasek, K.** (1994). Early object labels: The case for a developmental lexical principles framework. *Journal of Child Language*, *21*, 125–155.
- Gray, S.** (2003). Word-learning by preschoolers with specific language impairment: What predicts success? *Journal of Speech, Language, and Hearing Research*, *46*, 56–67.
- Harley, T. A., & Bown, H. E.** (1998). What causes a tip-of-the-tongue state? Evidence for lexical neighbourhood effects in speech production. *British Journal of Psychology*, *89*, 151–174.
- Heibeck, T., & Markman, E.** (1987). Word learning in children: An examination of fast mapping. *Child Development*, *58*, 1021–1034.
- Hollich, G. J., Hirsh-Pasek, K., & Golinkoff, R. M.** (2000). Breaking the language barrier: An emergentist coalition model for the origins of word learning. *Monographs of the Society for Research in Child Development*, *65*(Serial No. 262).
- Houston-Price, C., Plunkett, K., & Harris, P.** (2005). Word-learning wizardry at 1;6. *Journal of Child Language*, *32*, 175–189.
- Kay-Raining Bird, E., & Chapman, R. S.** (1998). Partial representations and phonological selectivity in the comprehension of 13- to 16-month-olds. *First Language*, *18*, 105–127.
- Lederberg, A. R., Preszbindowski, A. K., & Spencer, P. E.** (2000). Word learning skills of deaf preschoolers: The development of novel mapping and rapid word learning strategies. *Child Development*, *71*, 1571–1585.
- Levelt, W. J. M.** (1989). *Speaking: From intention to articulation*. Cambridge, MA: MIT Press.
- Lifter, K., & Bloom, L.** (1989). Object knowledge and the emergence of language. *Infant Behavior and Development*, *12*, 395–423.
- Luce, P. A., & Pisoni, D. B.** (1998). Recognizing spoken words: The neighborhood activation model. *Ear and Hearing*, *19*, 1–36.
- MacKay, D. G.** (1987). Asymmetries in the relationship between speech perception and production. In H. Heuer & A. F. Sanders (Eds.), *Perspectives on perception and action* (pp. 301–333). Hillsdale, NJ: Erlbaum.
- Marchman, V. A., & Bates, E.** (1994). Continuity in lexical and morphological development: A test of the critical mass hypothesis. *Journal of Child Language*, *21*, 339–366.
- Markson, L., & Bloom, P.** (1997, February 27). Evidence against a dedicated system for word learning in children. *Nature*, *385*, pp. 813–815.
- McGregor, K. K.** (1994). Use of phonological information in a word-finding treatment for children. *Journal of Speech and Hearing Research*, *37*, 1381–1393.
- McGregor, K. K., Newman, R. M., Reilly, R., & Capone, N. C.** (2002). Semantic representation and naming in children with specific language impairment. *Journal of Speech, Language, and Hearing Research*, *45*, 998–1014.
- Mervis, C. B., & Bertrand, J.** (1994). Acquisition of the novel name-nameless category (N3C) principle. *Child Development*, *65*, 1646–1662.
- Mervis, C. B., & Bertrand, J.** (1995). Acquisition of the novel name-nameless category (N3C) principle by young children who have Down syndrome. *American Journal of Retardation*, *100*, 231–243.
- Meyer, D. E., & Schvaneveldt, R. W.** (1971). Facilitation in recognizing pairs of words: Evidence of a dependence between retrieval operations. *Journal of Experimental Psychology*, *90*, 227–234.
- Mills, D. L., Coffey-Corina, S., & Neville, H. J.** (1997). Language comprehension and cerebral specialization from 13 to 20 months. *Developmental Neuropsychology*, *13*, 397–445.
- Mills, D. L., Plunkett, K., Prat, C., & Schafer, G.** (2005). Watching the infant brain learn words: Effects of vocabulary size and experience. *Cognitive Development*, *20*, 19–31.
- Mirman, D., & Magnuson, J. S.** (2006). The impact of semantic neighborhood density on semantic access. In *Proceedings of the 28th Annual Cognitive Science Society Meeting* (pp. 1823–1828). Mahwah, NJ: Erlbaum.
- Neely, J. H.** (1977). Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited-capacity attention. *Journal of Experimental Psychology: General*, *106*, 226–254.
- Nelson, K., Hampson, J., & Shaw, L. K.** (1993). Nouns in early lexicons: Evidence, explanations and implications. *Journal of Child Language*, *20*, 61–84.
- Nelson, D. L., McEvoy, C. L., & Pointer, L.** (2003). Spreading activation or spooky action at a distance? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *29*, 42–52.
- Newell, A., & Rosenbloom, P. S.** (1981). Mechanisms of skill acquisition and the law of practice. In J. R. Anderson (Ed.), *Cognitive skills and their acquisition* (pp. 1–55). Hillsdale, NJ: Erlbaum.
- Newman, R. S., & German, D. J.** (2002). Effects of lexical factors on lexical access among typical language-learning children and children with word-finding difficulties. *Language and Speech*, *45*, 285–317.
- Plaut, D. C., & Booth, J. R.** (2000). Individual and developmental differences in semantic priming: Empirical and computational support for a single-mechanism account of lexical processing. *Psychological Review*, *107*, 786–823.
- Plunkett, K., & Marchman, V.** (1993). From rote learning to system building: Acquiring verb morphology in children and connectionist nets. *Cognition*, *48*, 21–69.
- Reznick, J. S., & Goldfield, B. A.** (1992). Rapid change in lexical development in comprehension and production. *Developmental Psychology*, *28*, 406–413.
- Rice, M. L., Buhr, J. C., & Oetting, J. B.** (1992). Specific-language-impaired children's quick incidental learning of words: The effect of a pause. *Journal of Speech and Hearing Research*, *35*, 1040–1048.

- Rumelhart, D. E., & Norman, D. A.** (1978). Accretion, tuning, and restructuring: Three modes of learning. In J. W. Cotton & R. L. Klatzky (Eds.), *Semantic factors in cognition* (pp. 37–53). Hillsdale, NJ: Erlbaum.
- Schafer, G., & Plunkett, K.** (1998). Rapid word learning by 15-month-olds under tightly controlled conditions. *Child Development, 69*, 309–320.
- Schneider, W., & Chein, J. M.** (2003). Controlled and automatic processing: Behavior, theory, and biological mechanisms. *Cognitive Science, 27*, 525–559.
- Shiffrin, R. M., & Schneider, W.** (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending and a general theory. *Psychological Review, 84*, 127–190.
- Shiffrin, R. M., & Steyvers, M.** (1997). A model for recognition memory: REM—Retrieving effectively from memory. *Psychonomic Bulletin & Review, 4*, 145–166.
- Smith, L. B.** (2000). Learning how to learn words: An associative crane. In R. M. Golinkoff, K. Hirsh-Pasek, L. Bloom, L. B. Smith, A. L. Woodward, N. Akhtar, et al. (Eds.), *Becoming a word learner: A debate on lexical acquisition* (pp. 51–80). New York: Oxford University Press.
- Smith, L. B., Jones, S. S., Landau, B., Gershkoff-Stowe, L., & Samuelson, L.** (2002). Object name learning provides on-the-job training for attention. *Psychological Science, 13*, 13–19.
- Stemberger, J. P.** (1989). Speech errors in early child language production. *Journal of Memory and Language, 28*, 164–188.
- Stemberger, J. P.** (2004). Neighborhood effects on error rates in speech production. *Brain and Language, 90*, 413–422.
- Stemberger, J. P., & MacWhinney, B.** (1986). Frequency and the lexical storage of regularly inflected forms. *Memory & Cognition, 14*, 17–26.
- Stevens, T., & Karmiloff-Smith, A.** (1997). Word learning in a special population: Do individuals with Williams syndrome obey lexical constraints? *Journal of Child Language, 24*, 737–765.
- Storkel, H. L.** (2002). Restructuring of similarity neighbourhoods in the developing mental lexicon. *Journal of Child Language, 29*, 251–274.
- Stroop, J. R.** (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18*, 643–662.
- Tomasello, M., & Mervis, C. B.** (1994). The instrument is great, but measuring comprehension is still a problem. *Monographs of the Society for Research in Child Development, 59*, 174–179.
- Vitevitch, M. S., & Sommers, M. S.** (2003). The facilitative influence of phonological similarity and neighborhood frequency in speech production in younger and older adults. *Memory & Cognition, 31*, 491–504.
- Woodward, A. L., Markman, E. M., & Fitzsimmons, C. M.** (1994). Rapid word learning in 13- and 18-month-olds. *Developmental Psychology, 30*, 553–566.

Received September 18, 2005

Revision received April 18, 2006

Accepted August 11, 2006

DOI: 10.1044/1092-4388(2007/048)

Contact author: Lisa Gershkoff-Stowe, Department of Speech and Hearing Sciences, 200 South Jordan Avenue, Bloomington, IN 47405. E-mail: gershkof@indiana.edu.

Appendix. List of training words in the experimental and control conditions.

Experimental condition

High practice

bagpipe
bat (mammal)
clamp
crystal
dolphin
globe
grater
mask
mushroom
squid
toucan
zipper

Medium practice

beaker
crab
drill
feather
tadpole
trumpet

Low practice

backhoe
cobra
crown
kettle
pod
snail

Control condition

apple
baby
bird
car
chair
dog
fish
house
jacket
mother
spoon
sun

Copyright of *Journal of Speech, Language & Hearing Research* is the property of American Speech-Language-Hearing Association and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use.