Journal of Memory and Language **46,** 665–687 (2002)
doi:10.1006/jmla.2001.2830, available online at http://www.academicpress.com on IDEAL®

Object Naming, Vocabulary Growth, and the Development of Word Retrieval Abilities

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Previous research suggests that during a time of rapid growth in productive vocabulary, children are especially susceptible to errors of retrieval. These errors consist of words known to the child and often involve the incorrect selection of a previously said word. Two experiments investigated changes in lexical access and naming in the context of learning new words. Experiment 1 examined the rise and fall of children's naming errors for practiced and unpracticed words during the initial period of accelerated vocabulary growth. Findings indicated that as individual words were practiced in production, those words became stronger and more resistant to interference from lexical competitors. This result is consistent with the hypothesis that retrieval errors occur as a result of a general fragility of all words in the child's nascent lexicon. Experiment 2 investigated the related hypothesis that children's increased vulnerability to error is specific to the period of initial word learning. The results showed that older, more experienced word learners exhibited proportionately fewer errors when acquiring a set of novel words than novice word learners. However, the source of the error was similar, suggesting that common processing mechanisms may underlie the acquisition of a productive lexicon.

Key Words: word retrieval; language processing; naming errors; vocabulary development; acquisition of language.

One index of young children's linguistic knowledge is their ability to name everyday objects. By 18 months of age, children typically have productive vocabularies of 50 words or more and can be expected to demonstrate a major surge in naming as new words are acquired at a rapid rate. During this time, children begin in earnest to seek out names for things and to call attention to interesting objects and events by naming them. This period is sometimes referred to as the "naming explosion" or "vocabulary spurt" (Bates, Bretherton, & Synder, 1988; Benedict, 1979; Bloom, 1973; Dromi, 1987; Gershkoff-Stowe & Smith, 1997; Goldfield & Reznick, 1990; McCune-Nicolich, 1981; Nelson, 1973). It is thought by many developmentalists to mark important advances in children's semantic and conceptual knowledge (Bloom, 1973; Corrigan, 1978; Golinkoff, Mervis, & Hirsh-Pasek, 1994; Gopnik & Meltzoff, 1987; Lifter & Bloom, 1989; Mervis & Bertrand, 1994; Reznick & Goldfield, 1992).

Although the spurt is a time of impressive cognitive and linguistic gain, it is also a time of increased error. Several studies have documented instances of children's spontaneous naming errors in the initial period of rapid word acquisition (Anglin, 1983; Barrett, 1978; Bowerman, 1978; Clark, 1973; Dromi, 1987; Gershkoff-Stowe & Smith, 1997; Gruendel, 1977; Nelson, 1974; Rescorla, 1980). These errors most often appear to involve the overextension of a known word to a novel exemplar that shares some salient attribute, particularly when the child has not heard the object named before (Huttenlocher & Smiley, 1987; Naigles & Gelman, 1995). Thus a child who wants to

The original program used to generate the lag distribution analysis was developed by Stephen Gotts. I gratefully acknowledge his help and advice on the statistical analysis. Additionally, I thank Audrey Russo, Veronica Sansing, Erin Hahn, Rachel Whipple, and Jennifer Terry for assistance in data collection and analyses and Linda Smith for insightful comments on the manuscript. Extended thanks also go to the Cyert Center for Early Education at Carnegie Mellon University and the Carnegie Mellon University Children's School for their generous support in recruiting and testing children. Finally, I thank the parents and children who kindly participated in the study. This research was funded by a Faculty Development Fund award from Carnegie Mellon University and by NIH Grant RO1 HD39424-01.

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0749-596X/02 $35.00

refer to a cow but who does not know the name for that object might call the cow “doggie.”

Additionally, however, errors sometimes occur when the child “knows” the correct word but accesses the wrong word by mistake. These errors appear to be retrieval errors, reflecting momentary disruptions in retrieving a known word from the lexicon (Gershkoff-Stowe & Smith, 1997; Huttenlocher, 1974). For example, Elbers (1985) described an incident in which her 2-year-old son attempted to name a picture of a dolphin. Although the boy had learned the correct word and spoken it previously, in this instance, he called the dolphin “soldiers.” This misselected word, according to Elbers, was well known to the child and had been produced correctly on a recent prior occasion. Importantly, this type of error is not systematic; it does not result from consistencies in the child’s misperception of speech or an inability to articulate certain sounds (Elsen, 1994; Schwartz, Leonard, Loeb, & Swanson, 1987). Rather, retrieval errors are nonsystematic and transient.

The present study is concerned with these retrieval errors and with children’s apparent heightened sensitivity to them at the point when their rate of new word acquisitions begins to accelerate. The hypothesis is that children’s naming errors are due to a particular vulnerability of newly acquired words as those words experience greater competition among items in a rapidly expanding lexicon. That is, errors may occur at the time of accelerated vocabulary growth because of the absolute low levels of activation strength of lexical items that must occur as children learn their first words. As children repeatedly use those words in production, however, they may become stronger and more resistant to interference.

This hypothesis is suggested by previous developmental findings and also by studies of adult word retrieval. The key prior result concerns a rise and fall in children’s naming errors, with a brief and marked peak that is temporally coincident with the onset of accelerated vocabulary growth (Gershkoff-Stowe, 2001; Gershkoff-Stowe & Smith, 1997; see also Dapretto & Bjork, 2000). These naming errors, like those reported by Elbers (1985), seemed not to be simple overextensions, yet occurred with high frequency (nearly 30% of all naming in one study; Gershkoff-Stowe & Smith, 1997) just when children were acquiring many new words and were beginning to produce those words with greater frequency and in closer temporal proximity. Further, these errors sometimes involved misnaming objects that were perceptually and/or conceptually similar to the target object, or stimulus, for example, calling a zebra “horse.” More often, however, the errors involved the erroneous repetition of a previously retrieved word. The majority of the errors were words known to the children. Overall, the errors appeared to reflect interference from other words recently activated in the lexicon.

In these longitudinal studies, children’s naming errors did not continue to increase, even though new word acquisitions and the amount of talking did. Indeed, in both the Gershkoff-Stowe and Smith (1997) and Gershkoff-Stowe (2001) studies, naming errors peaked sharply at the point when new word acquisitions began to rise and dramatically fell in the weeks that followed. Thus the period of maximal error in word retrievals may be as brief as several weeks for some children. These facts suggest that for a transitory period, early in development but not later, newly acquired words are especially vulnerable to interference. The goal of the present research is to understand why this is so.

Several clues are suggested by the adult literature. In most models of mature speech production, accessing a word in the lexicon involves the activation and competition of multiple candidates; the stronger the activation of a word, the greater the probability of its selection will be (Dell, 1990; Marslen-Wilson, 1990; Stemberger, 1989). Additionally, words that are strong are more likely to resist interference than words that are weak. These results support the idea that the rise and fall of children’s errors reflect changes in the activation strength of individual words as they are retrieved for production.

The strength of a word, and hence its accessibility, derives from several sources. Principal among them is word frequency (Forster & Chambers, 1973). Word frequency exerts a strong influence on the likelihood of an error in adults; low-frequency words are more subject to error than high-frequency words (Dell, 1990; Stemberger & MacWhinney, 1985). In the case of the novice learner, the strength of a word will depend on its experienced frequency, that is, on the actual number of times children have the opportunity to hear and say the word (Schwartz & Terrell, 1983). Early in development, when children first begin to name objects, all of their words will be of low frequency. This is because, in an absolute sense, even the best-established words for children are likely to be orders of magnitude weaker than the very low frequency words for adults. These ideas thus suggest that children's first words are fragile and highly vulnerable to the effects of interference.

Two sources of interference appear most relevant to the occurrence of retrieval errors in young children: the effects of similarity and repetition (Gershkoff-Stowe, 2001; Gershkoff-Stowe & Smith, 1997). Both effects also have been noted in the adult literature. For example, in studies of lexical priming, Motley and Baars (1976) found that adults were slower to respond when presented with distractor items that were semantically similar to a target than items that were unrelated. Dell (1984) found that speakers could be induced to produce sound slips when presented with distractor words that shared a phoneme (see also MacKay, 1970). More recently, research on the effects of repetition priming has found that adults experience a higher incidence of lexical errors with repeated presentations of a word, particularly under speeded naming conditions (Campbell & Clark, 1989).

Less is known about the effects of priming on the word retrievals of young children. Although there is some evidence for similar influences in school-aged children (phonological: Brooks & MacWhinney, 2000; semantic: Lorsbach, Sodoro, & Brown, 1992; Rosinski, Golinkoff, & Kukish, 1975), virtually no studies have tested children below 3 years of age (for an exception, see Staley & Smith, 1999). Yet one might expect that the period of the vocabulary spurt, when the lexicon is rapidly expanding, is a time of major development in the processes associated with retrieving and saying words.

The present paper explores these ideas in two experiments. Experiment 1 investigated the hypothesis that, early in development, children's naming errors stem from a general fragility of word retrieval processes such that newly established words are subject to greater interference from lexical competitors than more well established words. If practice increases the strength of processes associated with successful retrieval and resistance to interference, such practice should reduce the likelihood of an error. To test this hypothesis, the experiment manipulated the amount of practice children received with individual words such that half the words on which they were trained were highly practiced, while the other half were only weakly practiced.

Experiment 2 tested the related hypothesis that children's vulnerability to error is developmentally specific to the initial word learner. That is, given a set of novel words to learn, children who are older and more experienced word learners will produce proportionately fewer errors and exhibit a different pattern of error than younger children. Such a finding would suggest the presence of systemwide changes in the strength of processes associated with successful word retrieval. Such changes might be expected given the simultaneous increase in the strength of many individual words (see Plunkett & Marchman, 1993).

EXPERIMENT 1

The central question addressed in Experiment 1 is whether the opportunity to practice hearing and saying individual words is related to the naming errors children produce. In this longitudinal study, there were two individual training sessions that all children received at each laboratory visit. In the Standard Practice training phase, children learned the names of 12 object words by looking at and naming objects in a picture book with their parent. In the Extra Practice training phase, children received extra training hearing and saying 6 of the 12 object words. Thus there were 6 low practice words and 6 high practice words on which to compare children's comprehension, production, and naming errors. Additionally, children's errors were compared at three developmental periods: just before, during, and just after the onset of the naming spurt.

Comparisons of the errors were made by aligning each child's data, using the rate of new object word acquisitions as the principal marker of change. The rate at which new words are added to productive vocabulary is considered by many investigators to be a reliable measure of accelerated vocabulary growth (e.g., Goldfield & Reznick, 1996). Additionally, Gershkoff-Stowe and Smith (1997) found that the period of errorful word retrieval was located near the shift from slow to fast new word acquisitions. In this experiment, the empirical definition of a rate-shift in productive vocabulary is based on this prior finding and on research conducted by several other investigators of early language. Gopnik and Meltzoff (1987) defined this shift in terms of the first 3-week period children added 10 new object words to their spoken vocabulary. Others have defined a spurt as 10 or more new words in a 14-day period (Mervis & Bertrand, 1994) or as the first 1-week period in which children added 3 new words after acquiring a base of at least 20 words (Bloom, Tinker, & Margulis, 1993). Still others have suggested that the transition in rate of growth occurs at about the time children have 50 words in their spoken vocabulary (Benedict, 1979; Huttenlocher, 1974; Nelson, 1973). All these methods converge on a similar region of the growth curve. Experiment 1 uses Gopnik and Meltzoff's definition of the rate-shift because their method counts object words and the procedure used here focuses specifically on the naming of objects.

For the purpose of examining children's naming errors just before, during, and just after the initial increase in productive vocabulary, each child's vocabulary growth curve was divided into three time regions, using the rate-shift as a benchmark. These three regions correspond to: (1) an Early phase, before productive vocabulary begins to accelerate, (2) a Transition phase, a 6-week window around the first sudden jump in the rate of productive vocabulary growth, and (3) a Late phase, after the initial jump but as children continue to add new words to their productive vocabulary at a rapid rate.

In sum, the goal of this experiment was to determine the effects of practice on the naming errors children produce at a time when they show a marked increase in the rate of new object name acquisitions.

Method

Participants

Fourteen children (8 girls and 6 boys) and their parents were recruited through birth announcements. All of the children were Caucasian, native speakers of English, and came from middle class families. The children's mean age at the time of initial contact was 14.7 months. At that time, children had an average of 20 words in their productive vocabulary. Experimental training began at approximately 16 months of age (range, 14.3–17.2), when children reached a mean vocabulary of 35 words (range, 25–47). Five additional children began the study but their data are not included. Two of the children ($M = 15$ months) reached the defined spurt in productive vocabulary growth before training began. Three other children ($M = 23$ months) failed to exhibit the spurt after several months of participating in the experiment. The fact that most but not all of the children exhibited a vocabulary spurt by 23 months is consistent with previous findings concerning the rate and timing of early lexical growth (Goldfield & Reznick, 1990).

Stimuli

Children were presented with a picture book designed specifically for the experiment. The book, which we referred to as the "Bunny book," consisted of 12 pictures of common objects (see Appendix A). The words for these objects were divided into two sets of six and matched for syllable length, phonological complexity, and age of acquisition (Dale & Fenson, 1993). One set of words was randomly selected for each child for use in the Extra Practice training phase. These were the high practice experimental words. The second set was selected for use in the Standard Practice training phase. These were the low practice experimental words. Half of the children received set one as the extra training, high practice words and half of the children received set two.

In the Extra Practice training phase, the six pictures were presented one at a time, on large pieces of poster board (20 × 25 cm). Each picture was isomorphic in shape and color to a real object. The pictures also were printed on fabric-covered "beanbags" filled with soft polyester. Two beanbags were present to the child at a time; each bag was inside one of two small lidded boxes (15 × 15 × 10 cm) that were distinct in pattern and color.

In the Standard Practice training phase, parents and children looked at and named objects in the experimental picture book containing the 6 Extra Practice items (pictures identical except in size to the 6 objects on poster boards and beanbags) and 6 new items (the low practice words). On each page of the book, a single object was presented in a predetermined random order. Additionally, on the last page, all 12 objects were presented together in the order in which they first appeared.

Procedure

Measures of productive vocabulary growth. Parents completed the Toddler version of the MacArthur Communicative Development Inventory (Fenson et al., 1993) as an initial measure of the number of words in their child's spoken vocabulary. Parents continued to record any new words or phrases their child spontaneously produced at home. Included in the list parents recorded were nonstandard words (e.g., "baba" for bottle) and onomatopoeia, suggesting pragmatic or referential meaning for the child (e.g., "choo-choo"). Additional information about the contexts in which the children used the words was obtained from parents in order to calculate children's nominal growth rate (e.g., bath as object rather than action).

To locate an initial shift in the rate of new word productions, the first 3-week interval in which children produced 10 new object names was identified (Gopnik & Meltzoff, 1987). Following this rate-shift in naming, children participated in the study for two additional 3-week sessions.

Laboratory tasks. Each laboratory session began with an Extra Practice training phase. During this 10-min period, parents and children first looked at, and parents named, six pictures on poster board. These were the pictures with which children had extra training over the course of the study (the high practice words). The same pictures were presented at each session and the same parent participated in the experiment each time (12 mothers, 2 fathers). During the Extra Practice training phase, parents and the experimenter provided the label for all six pictures a minimum of three times and usually more than six times. Repeating the names of each object was expected to increase the probability that the children would learn the correct name within a brief time (Schwartz & Terrell, 1983). After all the objects were named at least three times, the experimenter displayed all six poster boards together in random order. Parents were instructed to ask their child to point to each picture as it was named (e.g., "where's the apple?"). Performance on this task served as a measure of the children's understanding of individual words.

Also during the Extra Practice training phase, children were presented with two small boxes, each containing one beanbag randomly selected by the experimenter. The children were allowed to open the lid of each box and pull out the beanbag, one at a time. This activity prolonged interest in the naming task and gave children the opportunity to manipulate, rather than simply look at, each object. Parents again named the objects a minimum of three times and also encouraged their child to say the names of the objects (“what’s this?”). This task, together with the poster board pictures, provided a measure of which words were part of the children’s productive lexicon. Measures of comprehension and production, both self-generated and elicited, were obtained from the videotaped recording of each session. Agreement between two coders for six randomly selected children was 100% for comprehension testing in the poster board task and 92% for 122 naming responses in the poster board and beanbag tasks combined.

In the second training phase, the Standard Practice training phase, parents and children looked at a picture book together containing both sets of experimental words. Thus children received more training with one set of words (the six high practice words) than the other set (the six low practice words) by experimentally manipulating the number of times they had the opportunity to hear and say each set. Parents read the same book each time, following the simple text and providing the label for each object shown on the page.

Children’s responses were coded for the number of times they produced either a correct or incorrect object word. Although the majority of children’s responses took the form of single-word utterances, they sometimes reproduced a two-word utterance as it was given in the picture book. For example, the child might say “good dog” or “pretty house.” When this occurred, we counted the response as a single utterance unless there was a deliberate pause between items or the child used separate points to indicate reference to multiple objects. Two independent raters analyzed the naming responses for 6 of the 14 children. Agreement for the number of correct and incorrect naming attempts, based on 108 utterances, was 93%. Agreement for the actual content of the error (e.g., the child said “fish” instead of “chair”), based on 22 errors, was 100%.

Before parents began participation in the experiment, they were fully informed about the purpose of the research and asked not to give special attention to the words being tested in the study. This was done to reduce the possibility that parents might practice the low practice training words more than they would have had they not taken part in the study. Parents’ compliance was assessed informally at the start of each session and was found to match expectations concerning how often children typically are exposed to the experimental words outside the laboratory.

Results and Discussion

Productive Vocabulary

Over the course of the experiment, the number of new words children spoke at home increased from an average of 35 at the initial session of testing to approximately 100 at the eighth session, when most children had completed the study. These cumulative data were used to find the initial jump in the rate of new word acquisitions, defined as the first 3-week interval in which children produced 10 new object names. By these criteria, the 14 children participating in the study reached the rate-shift at the mean age of 19 months—a result close to those of other studies of children’s early vocabulary growth (Bloom, Tinker, & Margulin, 1993; Lieven, Pine, & Barnes, 1992; Nelson, 1973). Also, as in other studies, there was considerable between-subject variability, with the transition from a slow to a rapid rate of new word productions occurring between 15 and 24 months of age for individual children. Moreover, the cumulative number of words at that time varied widely across children, ranging from 51 to 140 (M = 76).

In the analyses that follow, each child’s data were aligned by the session in which the rate-shift occurred. This was then used to partition the vocabulary growth curve into the three developmental periods. The middle and defining Transition period includes the session of the rate-shift as well as the laboratory sessions just before and after that session. All laboratory sessions prior to the Transition period were designated the Early period, while those laboratory sessions after the Transition period were designated the Late period. The mean numbers of Early and Late sessions were 2.7

and 1.9, respectively. Because some children had more Early sessions and some children had more Late session, in analyses that make comparisons across vocabulary periods, the data are reported in terms of the frequency of behaviors per session.

Naming in the Extra Practice Training Phase

At each session, children were introduced to half of the object words during the poster board and beanbag tasks. In this first phase of training, children were given extra practice hearing and saying the names of the six high practice items. A measure of children's understanding of the high practice words was obtained in the poster board training task by asking them to point to the correct object as it was named. An additional measure of children's productive naming was obtained in the poster and beanbag tasks by counting the number of times they attempted to name the six stimulus objects.

With respect to the first measure—how well children were able to recognize an object upon hearing it labeled by the parent—Fig. 1 shows the mean numbers of correct and incorrect responding in the poster board task for the three vocabulary regions of the growth curve. In this measure, nonresponses are not included. The results indicate a significant increase in the number of correct responses from the Early period to the Transition period, $F(2,12) = 12.47$, $p = .001$, and a concurrent decrease in the number of incorrect responses, $F(2,12) = 4.85$, $p = .02$. No reliable change occurred from the Transition to the Late period (Tukey's hsd $= .05$). These findings suggest that the children's receptive vocabularies expanded early in the study to include the six stimulus objects.

With respect to the second measure, children also learned to say the names of the high practice training objects. The total number of times children named the high practiced items during the poster and beanbag tasks in the first phase of training increased markedly across the three vocabulary periods. Children in the Early period averaged 4.5 words (tokens) per

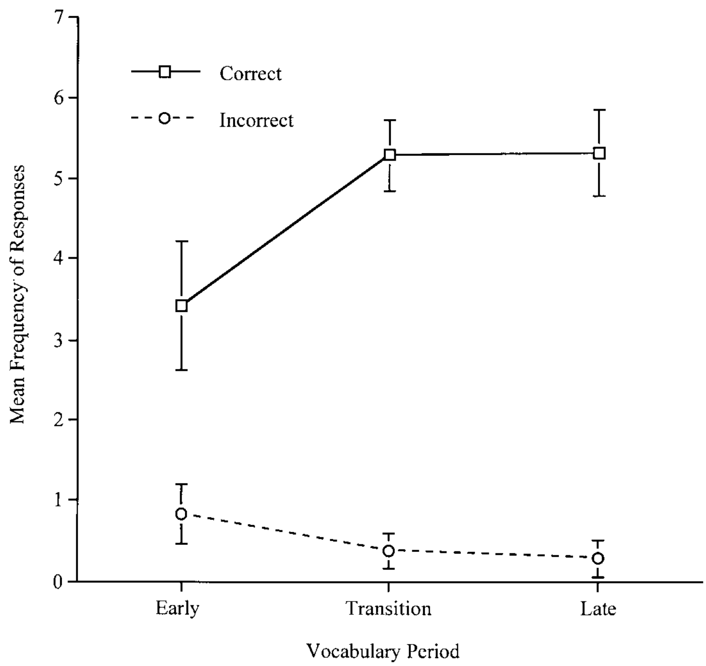

FIG. 1. Children's understanding of the high practice words in the Extra Practice training phase as a function of vocabulary period. Error bars indicate standard errors of the means.

session compared to 13 words in the Transition period and 21.5 words in the Late period, $F(2,12) = 21.83$, $p = .001$.

Naming in the Standard Practice Training Phase

After receiving extra training with the high practice words, children saw a picture book containing all 12 experimental items (the 6 high and 6 low practice objects). The same book was presented at each session. Figure 2 shows the number of times children said the names of the high and low practice objects as a function of vocabulary period. As is apparent, production increased for the high and low practice items across periods, $F(2,12) = 17.28$, $p = .001$. Further, there was a significant practice-by-vocabulary interaction effect, $F(2,12) = 5.65$, $p = .02$. While children named the two sets of words about equally often in the Early and Transition periods, the number of times they named the objects in the Late period was significantly greater for the low practice than for the high practice items. This suggests that with time, the relatively less familiar objects were more likely to capture the children's attention than the highly familiar, well-practiced stimulus objects. However, across both the Standard and Extra Practice training phases, the amount of total naming children experienced for the high practice words was more than twice as much at every period of vocabulary growth as that for the low practice words.

Effects of Practice on Children's Naming Errors

The principal question in this experiment is whether the frequency with which individual words are retrieved for production is related to changes in children's naming performance during the time of accelerated vocabulary growth. If practice producing a word increases the strength of processes associated with the successful retrieval of that word, then errors should be less frequent among the specially trained high practice words than among the low practice words. This is because high practice words will be less susceptible to interference from possible lexical competitors than low practice words.

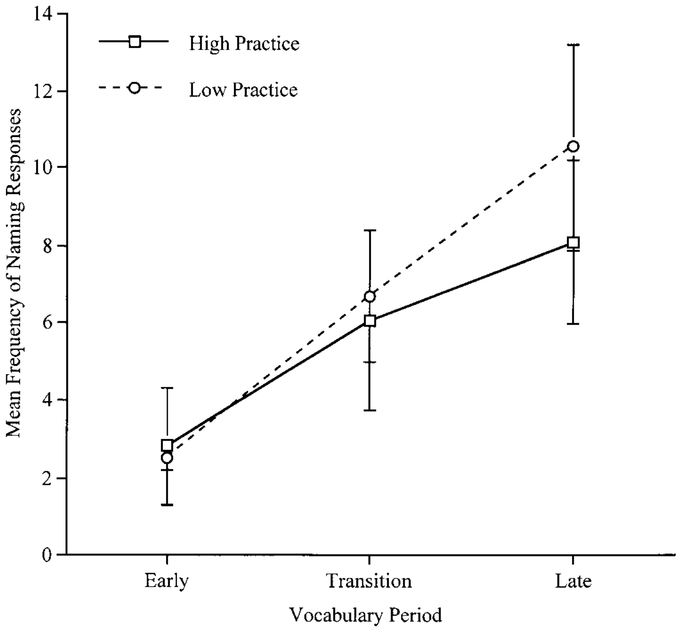

FIG. 2. Children's production of high practice and low practice words in the Standard Practice training phase as a function of vocabulary period. Error bars indicate standard errors of the means.

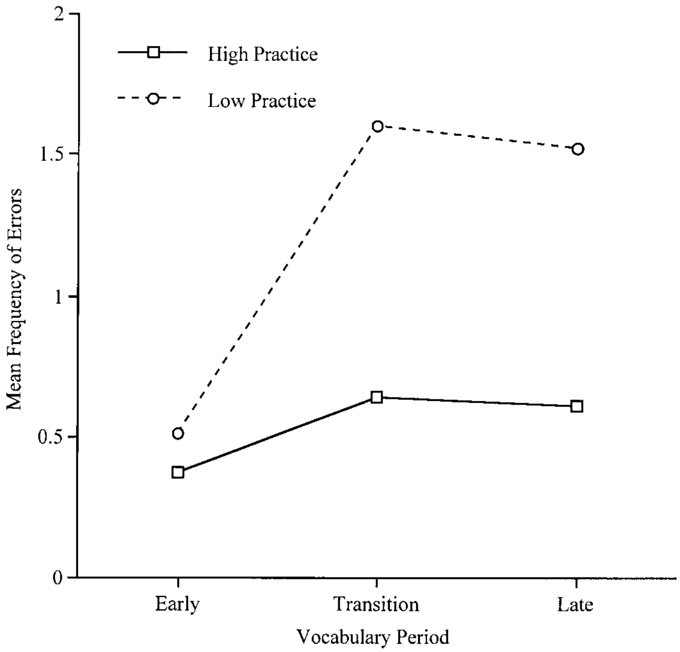

FIG. 3. Mean frequency of naming errors for high practice and low practice training words.

As shown in Fig. 3, the data support these predictions. Children consistently made more errors when words were low practiced than when they were high practiced. Errors of low practice words rose sharply from the Early period to the Transition period. Errors of high practice words also rose, but less dramatically. A 2×3 repeated measure analysis of variance revealed significant main effects for type of error (high/low practice), $F(1,13) = 8.27$, $p = .01$, and vocabulary period, $F(2,12) = 8.58$, $p = .005$.[1] The interaction was not significant, reflecting the fact that all errors rose in the Transition period, $F(2,12) = 1.88$, $p = .19$. However, the absolute frequency of these errors for the low practice words was substantial, whereas errors rarely occurred for the high practice words. This last fact fits the idea that it is the weak activation of newly acquired low practice words that makes them vulnerable to competition with other words.

Sources of Interference

What, then, is the source of this interference and how does it differ for the high and low practice words? Errors were examined first for their similarity to the target and next for evidence of perseveration.

Similarity effects. The following analyses are based on a total of 190 errors that children produced in the experimental sessions. Each error was classified as (1) phonologically related, (2) perceptually related, (3) semantically related, or (4) unrelated to the target.

An error was counted as phonologically related if the two words shared the same initial onset (e.g., bird and baby) or if they rhymed (e.g., moon and spoon). By these criteria, very few errors (3.6%) resulted from phonological confusion. An error was counted as perceptually related if the two objects were similar in overall shape but belonged to different taxonomic categories, for example, calling a centipede a "comb" (Rescorla, 1980). This type of error was

[1] Frequency data, rather than proportion of errors, provide the clearest presentation of the results. This is because the frequency of naming attempts was often too low to establish a reliable measure of error rate. However, additional analysis of the proportion of errors (using arc sine transformations) yielded a similar effect for vocabulary period, $F(2,12) = 4.05$, $p = .05$, though not for practice, $F(1,13) = 3.05$, $p = .11$.

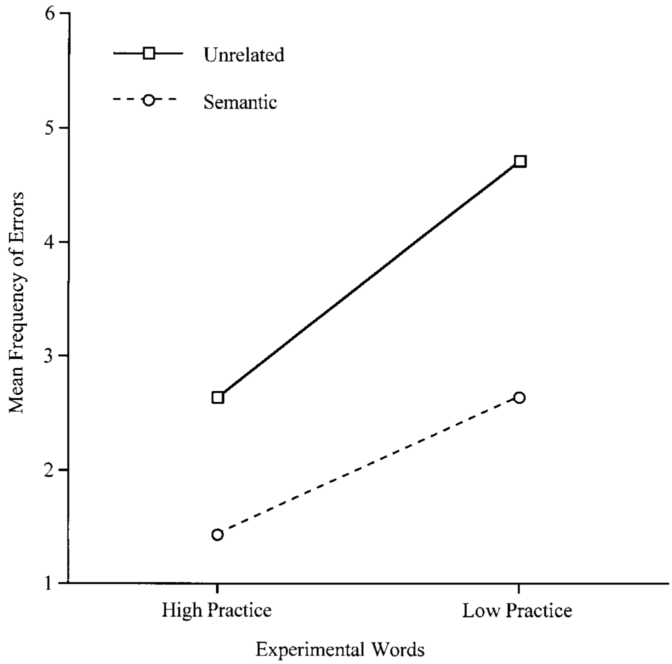

FIG. 4. Mean frequency of unrelated and semantically related errors for high and low practice words.

also infrequent, comprising only 11.4% of the total errors. Moreover, more than three quarters of the perceptual-only errors were made by one child, who repeatedly said "ball" when presented with pictures of apple and sun.

The remaining errors were either semantically related or unrelated. A semantically related error included objects that were both taxonomically and perceptually similar, for example, a bird and a duck, and only taxonomically but not perceptually similar, for example, a dog and a fish. Thirty-one percent of the total errors by this definition were semantically related. An unrelated error was one in which the interfering word was neither phonologically, perceptually, nor semantically similar to the target, for example, car and spoon.[2]

[2] It is possible that these "unrelated" errors might in reality be associatively or thematically related. For example, a child who sees a picture of a car and says "mommy" might be commenting on similarities related to the car his own mother drives. However, because it is not possible to determine what the child had in mind when providing a label, all responses that were not clearly related in the ways outlined above were classified as unrelated.

The majority of children's errors, or 53%, fell into this category.

A breakdown of the errors for high and low practice words is presented in Fig. 4. This analysis excludes perceptual-only errors, since they were predominantly the product of one child (who produced 17 of the 22 errors) and phonological errors, since they were too few in number to be interpreted reliably (7 in total). As indicated previously, the majority of errors consisted of failures to name the experimental low practice words. However, as shown in Fig. 4, the character of the errors appears to be the same for both low and high practice words. That is, most errors were unrelated to the target word, independently of the amount of practice received. One index of the relevant dominance of unrelated errors over semantic errors is the number of unrelated errors divided by the sum of unrelated plus semantic errors. This proportion was calculated for the low and high practice words for each participant. The mean proportions of semantic and unrelated errors that were unrelated did not differ reliably between low practice ($M = .61$) and high practice words

(M = .77), $t(13) = 1.22$, $p = .24$. Moreover, the mean proportion, collapsed over low and high practice words, was .69, which reliably exceeds the expected value (.50) if unrelated errors and semantic errors occurred equally often, $t(13) = 3.09$, $p = .01$.

The results suggest that the majority of errors involving both high and low practice words stem from factors not directly linked to the target itself. The source of the error, for both high and low practice words, may be related to prior productions of the child. That is, it may be that a previous word causes a momentary disruption in the ability to retrieve a current word. When this occurs, the outcome may be perseveration—the child persists in using the same word to name an object just previously spoken.

Repetition effects. Accordingly, for each error, an analysis was made of the time course of children's responses by working backward to locate a prior response that matched the interfering word. This analysis provided a measure of the number of perseverative errors children produced and, additionally, the number of trials, or lag, separating perseverations and earlier responses. The observed lag distribution was then compared to a control distribution, which was generated for each child by randomly scrambling the order of trials in the original set 100 times. This procedure enabled us to detect any nonrandom temporal structure in the data and thus to assess the existence and time course of perseverative phenomena for individual children (see Cohen & Dahaene, 1998; Gotts, Rocchetta, & Cipolotti, 2001; Neter, Kutner, Nachtsheim, & Wasserman, 1996).

Table 1 shows an example of the data used for this analysis. These data represent all 26 responses produced by one child in the fourth session of the experiment. At that time, the child had 73 words in his cumulative productive lexicon and his rate of new word acquisitions suggested the onset of the vocabulary spurt. In this session, the child produced four errors, all of which were produced correctly prior to the errors' occurrence. Three of the errors involved the perseveration of the immediately preceding word (a lag of 1). The fourth error occurred at a lag of 15 and was semantically related to the target (mommy–"baby"). In addition, note that the first occurrence of an error (house–"car") involved a word said by the child seven times previously (four of which immediately preceded the error), suggesting interference from perhaps considerable residual activity from the preceding produced word.

TABLE 1

Object Naming and Perseverative Errors (in Bold) Produced by One Child in a Single Experimental Session

	Target	Response
1.	car	car
2.	car	car
3.	fish	fish
4.	dog	dog
5.	dog	dog
6.	house	house
7.	chair	chair
8.	baby	baby
9.	mommy	mommy
10.	spoon	spoon
11.	spoon	spoon
12.	jacket	jacket
13.	car	car
14.	car	car
15.	spoon	spoon
16.	spoon	spoon
17.	car	car
18.	car	car
19.	car	car
20.	house	**car**
21.	house	house
22.	mommy	**house**
23.	mommy	**baby**
24.	chair	**baby**
25.	jacket	jacket
26.	sun	sun

An analysis conducted for all children on the proportion of errors matching a previous response revealed that over half of the total errors in the picture book naming task involved the repetition of a previously said word (105 of 190 responses). Figure 5 shows the time course of children's perseverations as a function of the number of trials (lag) separating the first response from the second. As shown, perseverative errors occurred most frequently at a lag of 1; 57% of the errors (60 of 105 re-

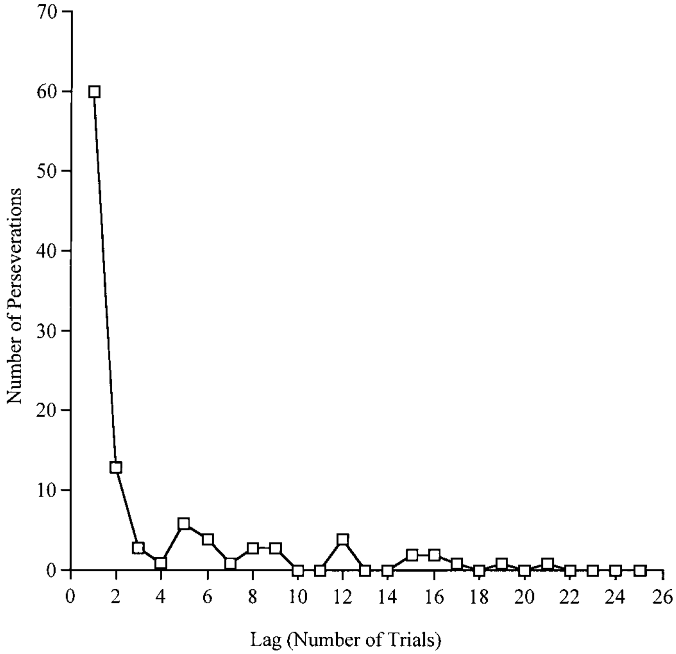

FIG. 5. Lag distribution analysis of children's perseverative errors.

sponses) involved the repetition of the immediately preceding word. This effect diminished rapidly, however, and perseveration occurred infrequently as the number of intervening trials continued to increase. Comparison of these data to the randomly generated distribution yielded rates of perseveration that reliably differed from those expected by chance at lags 1, 3, 4, and 12 ($\alpha = .05$). This pattern fits the idea of responding that is influenced by interference from a previously activated word—interfering activation that diminishes with time and/or intervening retrievals.

As these data show, perseverations are highly significant at lag 1 and decrease continuously with increasing lag, up until the 12th trial. Lag 12 thus represents the maximum point at which significant effects were found in the control distribution. Accordingly, subsequent analyses were conducted on the rate of perseverative errors up to and including lag 12.

Figures 6A and 6B, respectively, show separate lag distributions for high and low practice words. A one-tailed test was used to evaluate the hypothesis that low practice words are more susceptible to error than high practice words. Specifically, a paired *t* test was conducted for the high practice and low practice stimuli on the mean proportion of naming attempts that were perseverative through lag 12. The results indicated a marginal difference, $t(13) = 1.66$, $p = .06$, thus providing tentative support for the prediction of a heightened vulnerability for low practice words.

Additional support comes from examination of the high versus low practice responses children produced. If low practice target words are more susceptible to error than high practice target words, then we should also find that high practice responses are most often substituted for low practice targets. To test this prediction, separate *t* tests were conducted on the proportion of high practice and low practice naming attempts that involved either a high or low practice response. The results confirmed the prediction: although high practice targets were equally likely to have a high practice or a low practice response, low practice targets were significantly more likely to have a high practice response, $t(13) = 2.32$, $p = .01$ (one-tailed).

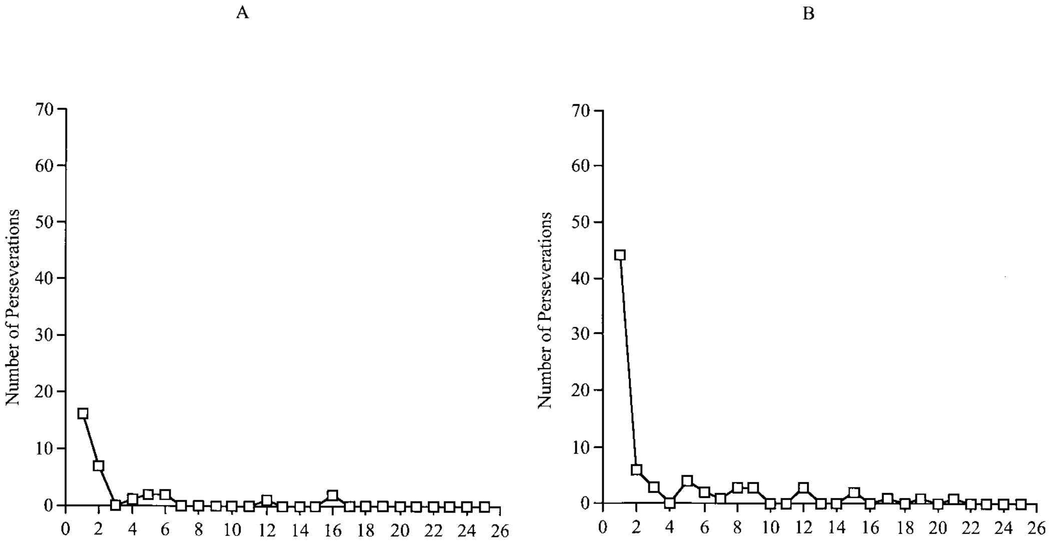

FIG. 6. Lag distribution analyses of children's perseverative errors for (A) high practice words and (B) low practice words.

In summary, the results of Experiment 1 indicate that children make many errors during the period when vocabulary growth first accelerates. Further, many of the errors during this time involve low practice target words, suggesting greater susceptibility to interference. The results also suggest that errors on both high and low practice words reflect similar sources of interference, mainly involving the repetition of a previously spoken word. However, this influence appears most potent for the more vulnerable, low practice words.

A question that arises from these findings is whether, for any newly learned word, there is an initial susceptibility to error, particularly under conditions where many new words are learned in a brief amount of time. Alternatively, it may be that naming errors are tied to a unique state of fragility, specific to the early word learner. Experiment 2 examines this issue.

EXPERIMENT 2

In this study, the developmental specificity of children's increased vulnerability to retrieval errors was investigated. Twenty-eight-month-old children were presented with a picture-naming task that involved learning a novel set of words. At this age, most children have become highly proficient word learners; they tend to have productive vocabularies of several hundred words and to speak in grammatically complex sentences (Bates & Goodman, 1997). Thus these children are well beyond the initial spurt in vocabulary, even though they may continue to add new words to their productive vocabularies at increasingly rapid rates (Bloom, 2000).

The set of words used in this experiment consisted of object names that are generally unfamiliar to children at this age. Additionally, the objects themselves were closely related in taxonomy and appearance. Because of this, it was expected that even experienced 28-month-old word learners would make many naming errors. The nature of the errors, rather than their frequency, is of most interest here. Previous studies of children's naming errors indicate that childern sometimes overgeneralize one word to name another unfamiliar object. These overgeneralizations are typically based on similarities of appearance and/or function (Clark, 1973; Dromi, 1987; Nelson, 1974; Rescorla, 1980). However, few reports indicate perseverative naming in the postspurt period—a characteristic that appears to be the hallmark of retrieval errors in the beginning word learner. Experiment 2 examines the pattern of naming errors produced by older children who have accumulated considerable experience learning new words.

Method

Participants

Twenty-one children, ranging in age from 27 to 30 months (M = 28.5 months) participated. Eleven of the children were girls and 10 were boys. An additional 4 boys were tested but eliminated from the sample due to failure to remain on task (n = 2), few intelligible utterances (n = 1), or experimental error (n = 1). Children were recruited from childcare centers in the Pittsburgh area and by word of mouth. Nineteen children were Caucasian, 1 Hispanic, and 1 Asian. All children came from middle class families and were native speakers of English. Two of the children had bilingual parents and were exposed to more than one language (Mandarin, 1; Arabic and Spanish, 1).

Stimuli

Children were presented with two picture books. The first book was *Polar Bear, Polar Bear, What Do You Hear?* by Bill Martin. The second book was the same as the one used in Experiment 1, the Bunny book. Both books were similar in design: on each page was a single, colorful picture of an object and a simple text in which the object was named twice in rhythmic fashion. On the last page, all the objects were shown together in the order in which they first appeared. There were 12 objects in the Bunny book and 11 objects in the Polar Bear book (see Appendix B).

There were several important differences between the two books. These differences were expected to increase the likelihood of naming errors in the Polar Bear book. The principal difference was the level of familiarity of the object names. Whereas the Bunny book contained objects that are very familiar to most 28-month-olds (e.g., dog, baby, apple), the Polar Bear book contained objects that are typically less familiar to children at this age (e.g., flamingo, walrus, leopard). Additionally, all of the objects in the Polar Bear book belonged to the same semantic category of animals. A final difference was that many of the words in Polar Bear were multisyllabic and phonologically complex.

Procedure

Children and their parents visited the laboratory for two individual sessions within a 1-week period (M interval = 2.2 days). Because many children this age tend to talk little in unfamiliar surroundings, the second visit was included to widen the opportunity for naming. At each session, children and their parents looked at and named the objects in the two experimental picture books. The books were presented in the same order across sessions to control for possible effects of priming. All children saw the Polar Bear book first and the Bunny book second.

In this experiment, no specific training was given to the children. Parents were instructed to read the books as they naturally would at home and to encourage their children to name the objects throughout the task. One consequence of this naturalistic design is that it allowed parents more control over the amount of talking children did in the laboratory. Accordingly, parents' behavior was analyzed for the number of times they queried their children and supplied the label of an object. Additionally, children's naming attempts, both correct and incorrect, were analyzed for whether they were spontaneously generated or elicited by parents' questions. Included as a correct response were children's partial productions of words, provided that the parent or experimenter accepted them as appropriate. For example, children sometimes said "hippo" or "potamus" for hippopotamus and "polar" or "bear" for "polar bear."

For purposes of reliability, three trained assistants independently coded 25% of the picture book reading episodes. Reliability was assessed both for children's talking in the laboratory and for parents' labeling and "what's this?" questions. The mean reliability score was .90 (range, .75–1.00) for 280 of the children's spontaneous responses and .88

(range, .80–1.00) for 146 elicited responses. The mean reliability score was .93 (range, .72–1.00) for 694 instances of parents' labeling and .89 (range, .80–.95) for 200 "what" questions asked by parents.

Parents completed the Toddler version of the MacArthur Communicative Development Inventory (CDI) (Fenson et al., 1993) at the beginning of the first testing session. At that time, parents also completed a separate checklist of all the experimental words not included in the MacArthur inventory.

Results and Discussion

Productive Vocabulary

Based on measures from the CDI, parents reported their children had an average productive vocabulary of 482 words. As expected, large individual differences were found, with vocabulary sizes ranging from 208 to 637 words. The supplementary checklist parents completed revealed that, prior to the study, children had productive use of 11.5 of the 12 possible words (96%) in the Bunny book (range, 7–12) and 5.5 of the 11 possible words (50%) in the Polar Bear book (range, 1–9). This difference was reliable, $t(20) = 2.08$, $p < .001$.

Naming in the Picture Book Task

Children's naming in this experiment occurred in naturalistic interaction with their parents. Thus the amount of talking they did in the laboratory reflected not only how familiar children were with the experimental words, but was also closely related to parents' behavior in the word learning task. Accordingly, I examined how often parents named the objects and asked their children questions as they looked at each of the experimental books. Parents appeared generally sensitive to their children's knowledge of the words in the books. As shown in Fig. 7, parents spent significantly more time naming the objects [$F(1,20) = 142.2$, $p < .001$] and asking their children "what's that?" questions [$F(1,20) = 32.9$, $p < .001$] in the Polar Bear book than they did with the more common objects in the Bunny book. This result corresponded to the amount of

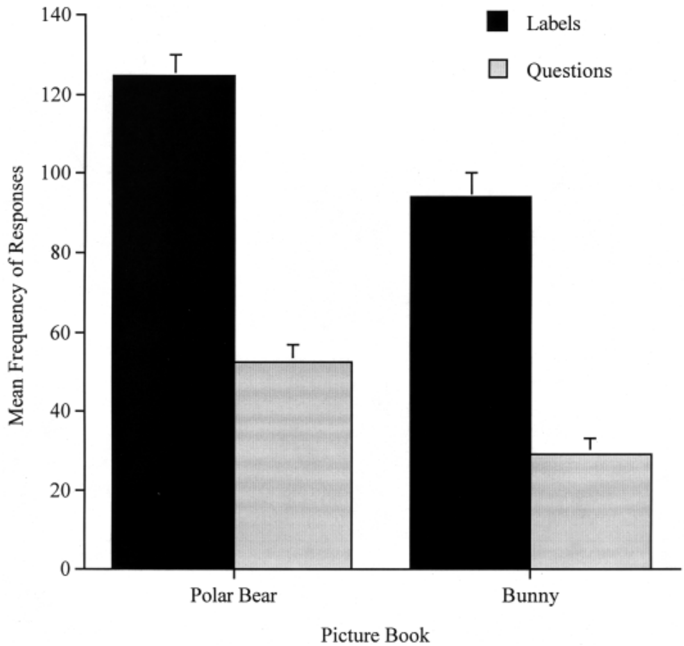

FIG. 7. Mean frequency of parents' object labeling and "what's that?" questions as a function of picture book. Error bars indicate standard errors of the means.

talking children did in the experiment. Children talked significantly more often across both sessions when looking at the pictures in the Polar Bear book ($M = 86.4$ words) than in the Bunny book ($M = 69.4$ words), $t(20) = 2.45$, $p < .02$. Additional analyses revealed that the proportion of utterances spontaneously generated by the child was reliably greater for the Bunny book, $t(20) = 3.43$, $p < .002$. Thus, although children spoke more overall while looking at the pictures in the Polar Bear book, this was largely due to queries made by the parent concerning the names of the experimental objects.

Children's Naming Errors

How did the frequency and pattern of children's naming errors differ as a function of the type of book? Given that all of the pictured objects in the Polar Bear book were similar in appearance and taxonomy, it was expected that children would generate more errors in the Polar Bear book than in the easier and more familiar Bunny book. Further, it was expected that children would produce more errors when naming was elicited by the parent rather than spontaneously generated by the child. Consistent with these predictions, children produced a total of 251 naming errors in the Polar Bear book, compared to 88 errors in the Bunny book. Additionally, 61% of the errors in the Polar Bear book, and 53% of the errors in the Bunny book, were in response to questions elicited by the parent. A two-way repeated measures analysis of variance conducted on the mean proportion of naming responses (spontaneous/elicited) that were errors yielded a significant book by type of error interaction, $F(1,20) = 11.43$, $p = .003$. Children produced reliably more elicited errors when attempting to name the unfamiliar objects in the Polar Bear book.

Sources of Interference

As in Experiment 1, individual errors were examined to assess their relation to the target in sound, concept, or appearance. Additionally, the errors were examined for possible repetition effects. Perseverative errors were then compared across books. Further, because children in Experiments 1 and 2 named objects from a common book (the Bunny book), comparisons were also made to assess the effects of general word learning experience on the types of errors they produced.

Similarity effects. The mean percentages of errors that were related to the target phonologically, perceptually, or semantically or that were unrelated were calculated for the Polar Bear and Bunny books. As in Experiment 1, phonological and perceptual-only errors were extremely rare (5% or less), regardless of the familiarity of the book. Nearly all of the errors in the Polar Bear book were semantically related to the target (96%), compared to approximately half of the errors in the Bunny book (56%). This result clearly stems from the nature of the books themselves; all of the objects in the Polar Bear book belonged to the semantic category of animal. However, in a previous study involving children's naming errors at the time of the vocabulary spurt, Gershkoff-Stowe and Smith (1997) found that semantically related errors occurred infrequently among beginning word learners, even when the children were presented with unfamiliar objects from the same taxonomic category (approximately 50% of the errors involved the names of animals). These findings, though speculative, suggest that the perceptual/conceptual cues that guide children's word retrievals may change with increased opportunities to name objects. We return to this possibility in the General Discussion.

Repetition effects. The key question in this experiment is to what extent 28-month-old word learners are influenced by the words they have previously retrieved and produced. As before, each error was examined for evidence of perseveration by matching the error to a prior repetition. Figures 8A and 8B show the frequency of perseveration as a function of response trial for the Polar Bear and Bunny books, respectively. As is evident, the two distributions follow a similar pattern: perseveration was greatest at a lag of 1, with a rapid decline in frequency beyond that point. This pattern closely resembles that seen in Experiment 1 (Fig. 5).

Analysis of the two distributions was made using a prediction interval for the mean ran-

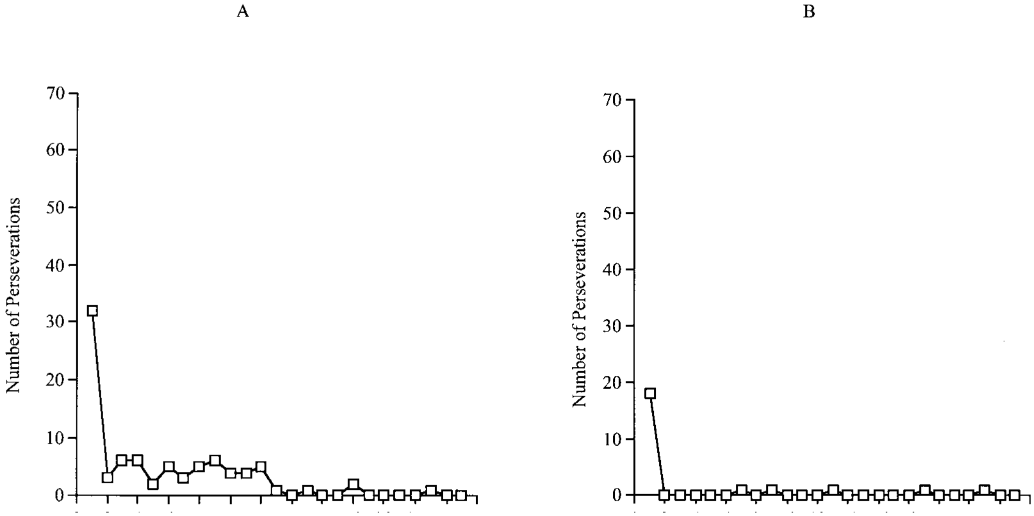

FIG. 8. Lag distribution analyses of children's perseverative errors in the (A) Polar Bear and (B) Bunny book.

dom frequency at each lag. A significant effect was found at lag 1, for both the Polar Bear and Bunny books ($\alpha = .05$), and at lag 12 for Polar Bear only. Significant effects also occurred at lags 32 and 34 for the Bunny book, suggesting that perseveration may be a long-lasting phenomenon for highly familiar words.

As in Experiment 1, a one-tailed, paired *t* test was used to compare the mean proportion of naming attempts that were perseverative in the Polar Bear and Bunny books through lag 12.[3] This analysis revealed that children made significantly more perseverative errors when naming the less well known objects in the Polar Bear book, $t(20) = 2.18$, $p = .02$. This finding suggests that older, more experienced word learners are also sensitive to the effects of familiarity when attempting to produce the names of pictured objects. A second analysis compared the perseverative errors of children in Experiment 2 to those of the younger children in Experiment 1. In this analysis only data from the Bunny book were included, since this book was presented to both groups of children. This comparison revealed a reliable effect of age, $t(33) = 3.83$, $p = .001$. Older children made fewer errors than younger children, suggesting a general effect of word learning experience on the perseverative errors that children produce.

In sum, the findings from Experiment 2 indicate that 28-month-olds produce fewer errors overall than the beginning word learners in Experiment 1. Moreover, the majority of the errors stem from target-related semantic effects rather than from the residual activity of a previously said word. When perseveration did occur, the latency was identical in most respects to perseverative naming in younger children, for both familiar and unfamiliar words. The results thus suggest that experience learning words makes children less vulnerable to the effects of lexical interference. However, the results also suggest that the processes that underlie the retrieval of a word are essentially constant across the two age groups. Both novice and more experienced word learners were influenced by the persistence of recently retrieved words. There were no obvious qualitative differences in the source of naming errors for older and younger children.

Methodological Issues

Experiment 2 was designed as a natural analog to the training study of Experiment 1. It

[3] Although we observed perseverations that were significantly greater than chance beyond lag 30 for the Bunny book in Experiment 1, the results do not change markedly if we include perseverations only out to lag 12. We thus use lag 12 in order to make subsequent comparisons on the rate of perseverative errors across experiments for the Bunny book.

thus provided an ecologically valid context for studying children's naming and susceptibility to error. However, the design also limited the ability to maintain tight control over the behavior of young children and their parents. Two issues, in particular, may have affected the outcome of Experiment 2. First, parents tended to speak frequently and to query their children often about the names of objects in the Polar Bear book. This is most likely because parents realized their children had little knowledge of the correct words. One effect of this change may have been to alter the temporal properties (i.e., speaking rate) associated with perseverative error. For example, in studies of normal adult speakers, perseverative errors can be increased or decreased by manipulating the time interval between naming responses (Dell, 1990; Vitkovitch & Humphreys, 1991). Dell (1990) has suggested that at faster speaking rates, previously activated words exert a greater influence on subsequent retrievals. In the present study, considerable time often passed between the child's first utterance and the next. One hypothesis, then, is that children's slow rates of speaking allowed more time for selected words to decay, resulting in fewer opportunities for perseverative naming.

A second issue concerns the character of the words presented in Experiment 2. The names of the objects in the Polar Bear book were generally longer and more difficult for children to pronounce than other words they usually encountered. In previous studies of adult aphasics, Silver and Halpern (1992) found that words with two or more syllables generated significantly more errors than one-syllable words. This finding would tend to favor an increase in the rate of perseverative naming for children while looking at pictures in the Polar Bear book. However, unlike the adult aphasics, word length did not appear to increase the likelihood of error for the 28-month-olds. One possibility, although not measured directly, is that when children encountered a difficult and unfamiliar word (e.g., boa constrictor), they decreased their speaking rate. This delay might again reduce the likelihood of perseverative error by increasing the time interval between responses. Together, these issues underscore the importance of taking speaking rate into account when investigating children's naming errors, since the time interval between words will vary widely, depending on the nature of the parent–child interactions and the length and complexity of the words themselves. Although naturalistic studies are an important component of research on children's naming, additional training experiments are needed to control the conditions under which children produce language.

GENERAL DISCUSSION

This research addressed the question of what changes in the accessibility of words in the growing lexicon of young children. Experiment 1 tested the idea that retrieval errors might increase when children are just beginning to produce many words because of the absolute low familiarity of individual words in a rapidly expanding lexicon. It was expected that errors might rise at the start of accelerated vocabulary growth because activation levels are too weak to resist interference that results from a more densely populated lexicon and from the succession of retrieval attempts that occurs as children more often attempt to name the things they see. This prediction was based on the idea that highly practiced words are more resistant to interference than less practiced words (Dell, 1990; Forster, 1990; Stemberger & MacWhinney, 1985).

The findings of Experiment 1 supported this prediction. Children showed an increased susceptibility to error at a particular developmental moment when they first began producing many new words. These errors mainly involved the experimental low practice training words in the context of naming objects in a picture book task. The experiment also replicated the previous finding of an increase in perseverative naming errors that was concomitant to the onset of rapid word acquisition (Gershkoff-Stowe & Smith, 1997). The findings thus suggest a general fragility of retrieval processes in the beginning word learner that causes words to be more vulnerable to the interfering effects of a previous production.

This vulnerability, however, may be the

same kind of vulnerability that one sees throughout development for all relatively unknown words. This conclusion is based on the findings of Experiment 2. Although the 28-month-olds in this experiment had many more high practice words and these words were less susceptible to error than the low practice words, the nature and source of the error did not differ from those of younger children near the time of the vocabulary spurt. For both groups of children, repetition effects emerged for both familiar as well as unfamiliar words, and this effect was nearly always local and short-lasting. Additionally, all children exhibited a sensitivity to similarity that seemed to be based on their past knowledge of objects and their names. Objects that were taxonomically similar to the target appeared most likely to influence the incorrect selection of a word. The results thus suggest that, while practice may play a significant role in the frequency of children's naming errors, it does not appear to transform the processes that give rise to them.

Semantically Mediated Errors

Bloom (1993) suggested that children develop the capacity for retrieving words, at first through physical cues from the immediate environment and eventually through "circumstances that are increasingly different and removed from their original experiences with words" (p. 10). What appears to change in development are the cues that children use in recalling words from memory. Additionally, Bloom suggested that, as the lexicon continues to expand, words themselves become cues for recall. For example, hearing the word "bone" may cue the word "dog" in much the same fashion that seeing a zebra may cue the word "horse." These associations may be conceptualized as semantic networks within lexical memory that depend on multiple connections to link words to concepts, as well as to other words (Anderson, 1976; Collins & Quillian, 1969). The strength of these connections, and thus their accessibility, is determined by frequency of experience.

These ideas fit well with the findings in Experiment 2, where 28-month-olds showed a stronger bias toward semantically related errors relative to younger children. Several developments appear to converge that might lead to a rise in semantic errors. First, children continue to add many new words to their productive lexicon, increasing the potential pool of taxonomically and associatively related competitors. This increase in semantically related words provides benefits as well. Now children are able to use semantic context to infer the meaning of a novel word (Goodman, McDonough, & Brown, 1998) and to name multiple objects that belong to the same taxonomic category (Shatz, Backsheider, Moore, & Goetz, 1999). Semantic errors might also increase in more experienced word learners because children are becoming sensitive to an increasingly broad range of stimuli that are capable of cueing the memory of a word (Bloom, 1993). Finally, semantic errors might increase in older children as they develop an increased capacity for utilizing available contextual cues (Dapretto & Bjork, 2000), possibly because of improvements in information processing (Case, Kurland, & Goldberg, 1982).

Beyond Individual Word Learning?

One question concerning the current findings is whether the processes that make children less vulnerable to error at 28 months of age reflect the increased activation strengths that accrue for individual words as children practice those words by talking more. Alternatively, there may be a systemwide increase in activation strength through the concentrated experience of having repeatedly retrieved and produced many different words (Marchman & Bates, 1994; Plunkett & Marchman, 1993). By this latter account, it is improvements in the general processing mechanisms of retrieval that make children more reliable speakers. One possibility, then, is that prior to some critical point of change, there may be a developmentally specific period of lexical growth in which interference from a previous production reflects the general fragility of all words in the nascent lexicon.

Consistent with the idea that general mechanisms might emerge in response to previous learning, Plaut, McClelland, Seidenberg, and Patterson (1996) found that exposing a connectionist network to a diverse sample of regular and exception words (e.g., gave, have) caused a gradual change in the system's sensitivity to the statistical structure of orthographic and phonological representations. This sensitivity took the form of changed connection weights in response to word frequency and spelling–sound consistency. Their results lend support to the hypothesis that experience with items at the local level also has consequences at the global level. With respect to children's early word learning, discovering what aspects of the language processing system change and how much experience is needed to make words less vulnerable to error are questions that remain open to future investigation.

General Implications for Models of Learning, Memory, and Retrieval

The developmental study of word retrieval operations offers a valuable perspective for testing current theories of adult lexical access and raises several new questions concerning how children build a productive vocabulary. Age-related improvements in word retrieval processes seem to support a model of production that emphasizes the strengthening of connection weights among lexical items (e.g., Dell, 1986). In particular, the finding that perseverative errors are frequent in younger children, but less so in older children, suggests that what changes with development is the relative activation strength of individual words. Naming errors may be less frequent with repeated experience retrieving and producing individual words because the strength of a current word becomes sufficient to override the residual activation from a recently retrieved word.

The results argue against the view that the decline in the number of perseverative errors from 16 to 28 months of age reflects changes in the development of inhibitory mechanisms that act to reduce the strength of past retrievals by increasing the rate at which words decay. This conclusion is based on the finding that perseverations were common both for the younger children when presented with the low practice training words and for the older children when presented with the less familiar words in the Polar Bear book. This interpretation is also consistent with findings reported by Dell, Burger, and Svec (1997a) that when normal adults practice saying difficult phrases (e.g., Bonnie's brown bread box), the errors they initially produce are most often perseverative, while the errors they later produce are most often anticipatory.

The findings from Experiments 1 and 2 show that mechanisms of learning, memory, and retrieval, long used in the adult verbal learning literature, also apply to the stages of primary language learning in young children. Such findings, although compatible with Dell's spreading-activation model, are not sufficient as yet to make strong claims about basic processes of activation and inhibition that underlie other models of cognitive functioning (Berg & Schade, 1992; Dempster, 1992; Diamond, 1989; Hasher & Zacks, 1988; Roediger, Neely, & Blaxton, 1983; Stemberger, 1989). Still, the present findings provide links to other subject populations that share similar disruptions in retrieval, in particular, verbal impairments associated with old age (Gerard, Zacks, Hasher, & Radvansky, 1991; MacKay & Burke, 1990) and aphasia (Dell, Schwartz, Martin, Saffran, & Gagnon, 1997b; Ellis, 1985; Plaut & Shallice, 1993). As such, the findings suggest that increased vulnerability to error reflects processing mechanisms that are common to all speakers, whether young or old, intact or damaged.

Conclusion

The present research shows that practice is a general agent of lexical development. This idea, of course, is not unique to object naming or to periods early in life (e.g., Anderson & Schooler, 1991; Lewicki, Hill, & Bizot, 1988; Logan, 1988; Newell & Rosenbloom, 1981; Spelke, Hirst, & Neisser, 1976). However, the findings strongly suggest that questions concerning what children know about categories of objects and how they learn the names for things cannot be separated from questions about memory retrieval processes and how conceptual representations are modified with use.

In this paper, children's naming errors were used as a guide to understanding the real-time processing mechanisms that underlie the retrieval of a word. Studying the processes that give rise to children's naming errors in the beginning and rapidly expanding lexicon—and how those processes change with development—may lead to a new understanding of large-scale changes that occur over developmental time.

APPENDIX A: OBJECTS PRESENTED IN THE BUNNY BOOK

1. apple
2. car
3. fish
4. jacket
5. dog
6. house
7. chair
8. bird
9. sun
10. spoon
11. baby
12. mommy

APPENDIX B: OBJECTS PRESENTED IN THE POLAR BEAR BOOK

1. polar bear
2. lion
3. hippopotamus
4. flamingo
5. zebra
6. boa constrictor
7. elephant
8. leopard
9. peacock
10. walrus
11. zookeeper

REFERENCES

Anderson, J. R. (1976). *Language, memory and thought*. Hillsdale, NJ: Erlbaum.

Anderson, J. R., & Schooler, L. J. (1991). Reflections of the environment in memory. *Psychological Science*, **2,** 396–408.

Anglin, J. M. (1977). *Word, object and conceptual development*. New York, NY: Norton.

Barrett, M. D. (1978). Lexical development and overextension in child language. *Journal of Child Language*, **5,** 205–219.

Bates, E., Bretherton, I., & Synder, L. (1988). *From first words to grammar: Individual differences and dissociable mechanisms*. New York, NY: Cambridge Univ. 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.

Benedict, H. (1979). Early lexical development: Comprehension and production. *Journal of Child Language*, **6,** 183–200.

Berg, T., & Schade, U. (1992). The role of inhibition in a spreading-activation model of language production: I. The psycholinguistic perspective. *Journal of Psycholinguistic Research*, **21,** 405–434.

Bloom, L. (1973). *One word at a time: The use of single-word utterances before syntax*. The Hague: Mouton.

Bloom, L. (1993). *The transition from infancy to language: Acquiring the power of expression*. New York, NY: Cambridge Univ. Press.

Bloom, L., Tinker, E., & Margulis, C. (1993). The words children learn: Evidence against a noun bias in early vocabularies. *Cognitive Development*, **8,** 431–450.

Bloom, P. (2000). *How children learn the meanings of words*. Cambridge, MA: MIT Press.

Bowerman, M. (1978). The acquisition of word meaning: An investigation into some current conflicts. In N. Waterson & C. Snow (Eds.), *The development of communication* (pp. 263–287). Chichester: Wiley.

Brooks, P. J., & MacWhinney, B. (2000). Phonological priming in children's picture naming. *Journal of Child Language*, **27,** 335–366.

Campbell, J. I. D., & Clark, J. M. (1989). Time course of error priming in number-fact retrieval: Evidence for excitatory and inhibitory mechanisms. *Journal of Experimental Psychology: Learning, Memory and Cognition*, **15,** 920–929.

Case, R., Kurland, D. M., & Goldberg, J. (1982). Operational efficiency and the growth of short-term memory span. *Journal of Experimental Child Psychology*, **33,** 386–404.

Clark, E. V. (1973). What's in a word? On the child's acquisition of semantics in his first language. In T. E. Moore (Ed.), *Cognitive development and the acquisition of language* (pp. 65–110). New York, NY: Academic Press.

Cohen, L., & Dehaene, S. (1998). Competition between past and present: Assessment and interpretation of verbal perseverations. *Brain*, **121,** 1641–1659.

Collins, A. M., & Quillian, M. R. (1969). Retrieval time from semantic memory. *Journal of Verbal Learning and Verbal Behavior*, **8,** 240–247.

Corrigan, R. (1978). Language development as related to Stage 6 object permanence development. *Journal of Child Language*, **5,** 173–189.

Dale, P. S., & Fenson, L. (1993). LEX: A lexical development norms database [computer program]. Seattle, WA: Univ. of Washington, Department of Psychology.

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. (1984). Representation of serial order in speech: Evidence from the repeated phoneme effect in speech errors. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **10,** 222–233.

Dell, G. S. (1990). Effects of frequency and vocabulary type on phonological speech errors. *Language and Cognitive Processes*, **5,** 313–349.

Dell, G. S., Burger, L. K., & Svec, W. R. (1997a). Language production and serial order: A functional analysis and a model. *Psychological Review*, **104,** 123–147.

Dell, G. S., Schwartz, M. F., Martin, N., Saffran, E. M., & Gagnon, D. A. (1997b). Lexical access in aphasic and nonaphasic speakers. *Psychological Review*, **104,** 801–838.

Dempster, F. N. (1992). The rise and fall of the inhibitory mechanism: Toward a unified theory of cognitive development and aging. *Developmental Review*, **12,** 45–75.

Diamond, A. (1989). Developmental time course in human infants and infant monkeys, and the neural bases of inhibitory control of reaching. In A. Diamond (Ed.), *The developmental and neural bases of higher cognitive functions. Annals of the New York Academy of Science* (Vol. 1., pp. 537–676). New York NY: N. Y. Acad. Sci.

Dromi, E. (1987). *Early lexical development*. Cambridge: Cambridge Univ. Press.

Elbers, L. (1985). A tip-of-the-tongue experience at age two? *Journal of Child Language*, **12,** 353–365.

Ellis, A. W. (1985). *Progress in the psychology of language* (Vol. 2). Hillsdale, NJ: Erlbaum.

Elsen, H. (1994). Phonological constraints and overextensions. *First Language*, **14,** 305–315.

Fenson, L., Dale, P., Reznick, J. S., Bates, E., Thal, D., & Pethick, S. (1993). Variability in early communicative development. *Monographs of the Society for Research in Child Development*, **59,** Serial No. 242, No. 5.

Forster, K. I. (1990). Lexical processing. In D. N. Osherson & H. Lasnik (Eds.), *Language: An invitation to cognitive science* (Vol. 1, pp. 95–131). Cambridge, MA: MIT Press.

Forster, K. I., & Chambers, S. M. (1973). Lexical access and naming time. *Journal of Verbal Learning and Verbal Behavior*, **12,** 627–635.

Gerard, L., Zacks, R. T., Hasher, L., & Radvansky, G. A. (1991). Age deficits in retrieval: The fan effect. *Journal of Gerontology: Psychological Sciences*, **46,** P131–P136.

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., & Smith, L. B. (1997). A curvilinear trend in naming errors as a function of early vocabulary growth. *Cognitive Psychology*, **34,** 37–71.

Goldfield, B. A., & Reznick, J. S. (1990). Early lexical acquisition: Rate, content and the vocabulary spurt. *Journal of Child Language*, **17,** 171–283.

Goldfield, B. A., & Reznick, J. S. (1996). Measuring the vocabulary spurt: A reply to Mervis & Bertrand. *Journal of Child Language*, **23,** 241–246.

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.

Goodman, J. C., McDonough, L., & Brown, N. B. (1998). The role of semantic context and memory in the acquisition of novel nouns. *Child Development*, **69,** 1330–1344.

Gotts, S. J., Rocchetta, A. I., & Cipolotti, L. Mechanisms underlying verbal perseverations in aphasia: Evidence from a single case study (submitted for publication).

Gruendel, J. M. (1977). Referential extension in early language development. *Child Development*, **48,** 1567–1576.

Hasher, L., & Zacks, R.T. (1988). Working memory, comprehension, and aging: A review and a new view. In G. H. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory* (Vol. 22, pp. 193–225). New York, NY: Academic Press.

Huttenlocher, J. (1974). The origin of language comprehension. In R. L. Solso (Ed.), *Theories in cognitive psychology—The Loyola Symposium* (pp. 331–368). Potomac, MD: Erlbaum.

Huttenlocher, J., & Smiley, P. (1987). Early word meanings: The case of object names. *Cognitive Psychology*, **19,** 63–89.

Lieven, E. V. M., Pine, J. M., & Barnes, H. (1992). Individual differences in early vocabulary development: Redefining the referential-expressive distinction. *Journal of Child Language*, **19,** 287–310.

Lewicki, Hill, & Bizot (1988). Acquisition of procedural knowledge about a pattern of stimuli that cannot be articulated. *Cognitive Psychology*, **20,** 24–37.

Logan, G. D. (1988). Toward an instance theory of automatication. *Psychological Review*, **95,** 492–527.

Lorsbach, T. C., Sodoro, J., & Brown, J. S. (1992). The dissociation of repetition priming and recognition memory in language/learning disabled children. *Journal of Experimental Child Psychology*, **54,** 121–146.

MacKay, D.G. (1970). Spoonerisms: The structure of errors in the serial order of speech. *Neuropsychologia*, **8,** 323–350.

MacKay, D. G., & Burke, D. M. (1990). Cognition and aging: A theory of new learning and the use of old connections. In T. M. Hess (Ed.), *Aging and cognition: Knowledge organization and utilization* (pp. 213–263). North-Holland: Elsevier Science.

Marchman, V., & Bates, E. (1994). Continuity in lexical and morphological development: A test of the critical mass hypothesis. *Journal of Child Language*, **21,** 339–366.

Marslen-Wilson, W. (1990). Activation, competition, and frequency in lexical access. In G. T. M. Altmann (Ed.), *Cognitive models of speech processing: Psycholinguistic and computational perspectives* (pp. 148–172). Cambridge, MA: MIT Press.

McCune-Nicolich, L. (1981). The cognitive bases of relational words in the single-word period. *Journal of Child Language*, **8,** 15–34.

Mervis, C. B., & Bertrand, J. (1994). Acquisition of the novel name—nameless category (N3C) principle. *Child Development*, **65,** 1646–1662.

Motley, M. T., & Baars, B. J. (1976). Semantic bias effects on the outcomes of verbal slips. *Cognition*, **4,** 177–187.

Naigles, L. & Gelman, S. (1995). Overextensions in comprehension and production revisited: Preferential-looking in a study of dog, cat, and cow. *Journal of Child Language*, **22,** 19–46.

Nelson, K. (1973). Structure and strategy in learning to talk. *Monographs of the Society for Research in Child Development*, **38,** Serial No. 149.

Nelson, K. (1974). Concept, word and sentence: Interrelations in development. *Psychological Review*, **81,** 267–285.

Neter, J., Kutner, M. H., Nachtsheim, C. J., & Wasserman, W. (1996). *Applied Linear Statistical Models* (4th ed., pp. 63–67). Chicago, IL: Irwin.

Newell, A., & Rosenbloom, P. (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.

Plaut, D. C., McClelland, J. L., Seidenberg, M. S., & Patterson, K. (1996). Understanding normal and impaired word reading: Computational principles in quasi-regular domains. *Psychological Review*, **103,** 56–115.

Plaut, D. C., & Shallice, T. (1993). Perseverative and semantic influences on visual object naming errors in optic aphasia: A connectionist account. *Journal of Cognitive Neuroscience*, **5,** 89–117.

Plunkett, K., & Marchman, V. (1993). From rote learning to system building: Acquiring verb morphology in children and connectionist nets. *Cognition*, **48,** 21–69.

Rescorla, L. A. (1980). Overextension in early language development. *Journal of Child Language*, **7,** 321–335.

Reznick, J. S., & Goldfield, B. A. (1992). Rapid change in lexical development in comprehension and production. *Developmental Psychology*, **28,** 406–413.

Roediger, H. L., Neely, J. H., & Blaxton, T. (1983). Inhibition from related primes in semantic memory retrieval: A reappraisal of Brown's (1979) paradigm. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **9,** 478–489.

Rosinski, R. R., Golinkoff, R. M., & Kukish, K. S. (1975). Automatic semantic processing in a picture-word interference task. *Child Development*, **46,** 247–253.

Schwartz, R. G., Leonard, L., Swanson, L., & Loeb, D. (1987). Some conditions that promote unusual phonological behavior in children. *Clinical Linguistics and Phonetics*, **1,** 23–34.

Schwartz, R. G., & Terrell, B. Y. (1983). The role of input frequency in lexical acquisition. *Journal of Child Language*, **10,** 57–66.

Shatz, M., Backsheider, A. G., Moore, T. S., & Goetz, M. J. (April, 1999). *Evidence of lexical categories in two-year-olds*. Poster presented at the biennial meeting of the Society for Research in Child Development, Albuquerque, New Mexico.

Silver, L. S., & Halpern, H. (1992). Word-finding abilities of three types of aphasic subjects. *Journal of Psycholinguistic Research*, **21,** 317–347.

Spelke, E., Hirst, W., & Neisser, U. (1976). Skills of divided attention. *Cognition*, **4,** 215–230.

Staley, B., & Smith, L. B. (April, 1999). *Priming overgeneralizations*. Poster presented at the biennial meeting of the Society for Research in Child Development, Albuquerque, New Mexico.

Stemberger, J. P. (1989). Speech errors in early child language production. *Journal of Memory and Language*, **28,** 164–188.

Stemberger, J. P., & MacWhinney, B. (1985). Frequency of the lexical storage of regularly inflected forms. *Memory and Cognition*, **14,** 17–26.

Vitkovitch, M., & Humphreys, G. W. (1991). Perseverant responding in speeded naming of pictures: It's in the links. *Journal of Experimental Psychology: Learning, Memory and Cognition*, **17,** 664–680.

(Received August 22, 2000)
(Revision received May 18, 2001)
(Published online January 18, 2002)