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Complexities of Expressive Word Learning Over Time

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Abstract

Purpose—To examine semantic and lexical aspects of word learning over time.

Method—Thirty four 8-year-olds participated in vocabulary lessons for two weeks. Frequency of exposure and informativeness of semantic context were manipulated. A definition task assessed semantic learning and a naming task assessed lexical learning.

Results—Lexical and semantic knowledge accrued over time and were maintained after a one-month interval. Higher frequency of exposure had an immediate effect on semantic learning and a more gradual effect on lexical learning. Frequency of exposure coupled with informative context promoted semantic learning.

Clinical Implications—Clinicians should be mindful of the richness of the learning context and the redundancy of massed and distributed exposures. Learning at the semantic and lexical levels can dissociate so both should be addressed.

Children are typically viewed as word learning machines; without direct instruction they add an estimated eight to ten new words each day to their receptive vocabularies (Beck & McKeown, 1991; Nagy & Herman, 1987) with an accumulation of roughly 60,000 words by high school graduation (Aitchinson, 1994; Bloom, 2000). However, these impressive statistics belie the true nature and course of word learning. The task of word learning is multifaceted, involving at a minimum the mapping of the lexical form of the word (its phonemes, number of syllables, stress patterns), the semantics of the word (its referent), and a link between the two (see Gupta, 2005 for a relevant model). The initial memory trace of newly learned words will be fragile and unlikely to support production (Gershkoff-Stowe & Smith, 1997) or retention (Horst, McMurray, Samuelson, 2006). Only with additional exposures to the word in meaningful contexts over time does the child acquire a deep and lasting knowledge of any given word (Bloom, 2000; Carey, 1978).

Imagine a child experiencing his first birthday party. Mom says, “let me light the candle” and, a few seconds later Dad says, “Let’s blow out the candle.” The child has heard the lexical form twice while seeing the referent and witnessing some relevant events (lighting, blowing). What he has actually learned about the word candle at this point in time is minimal. Perhaps he will recognize the word or the object when he attends a friend’s birthday party and the memory trace will become more stable. Over time as he has more encounters with candles, he will learn to label them himself. He will come to know that they are hot, that they come in various colors and sizes, and that they are made of wax. In this sense, the learning of the word candle on his birthday is just the initial step in an extended process.

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[1]Because the stimuli were real words, neither naming accuracy nor number of definition units was at floor at time 1; therefore, time 1 was included in the statistical analyses.

Despite the importance of extended learning to the ultimate development of the lexicon, most investigations of word learning measure only fast mapping, the child's initial inference about the link between lexical form and referent. One goal of the present study was to begin to remedy this gap in the literature by exploring three phases of word learning in response to vocabulary lessons: initial mapping, operationalized as the learning that occurred after the first vocabulary lesson; extended mapping, or the learning that occurred after the second lesson; and maintenance, the retention of learned information after a period of one month that involved no additional lessons. These operational definitions are admittedly overly simplistic as they imply distinct rather than continuous, overlapping phases and a rather brief phase of extended mapping. Nevertheless, they allow a controlled examination of word learning beyond the fast mapping inference.

As the birthday candle scenario illustrates, word learning is highly dependent upon the word learning environment (Huttenlocher, Levine & Veva, 1998; Plomin and Dale, 2000); therefore, the second goal of this study was to explore the effects of two environmental variables, informativeness of context and frequency of exposure, on learning at the lexical and semantic levels. To do so, we varied the vocabulary lessons so that half of the words to be learned were presented in a more informative semantic context than the others. Also, half of the children received the vocabulary lessons twice per visit, the others only once. We were confident that frequent exposure to words in informative contexts would promote word learning; what was of greater interest was whether these manipulations would differentially influence word learning and whether such differential influences would interact with level of learning, be it lexical or semantic, or phase of learning, be it initial, extended, or maintenance.

Frequency of Exposure

Increasing exposure to any stimuli enhances learning; words are no exception. Words are typically learned in the context of their referents. For young children, adults tend to restrict noun input to here and now (Shatz & Gelman, 1973; Snow, 1972); for older children, referents may not be present but will be recoverable from linguistic and nonlinguistic context. Given the co-occurrence of words and their referents, frequent encounters will likely promote robust mapping at both the lexical and semantic levels. This has proven to be the case. For example, all other factors being equal, the frequency with which parents use a given word predicts when their child will acquire that word (Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991). In experimental settings, where all other factors *can* be equated, word learning does vary with frequency of word repetition. For example, Rice, Oetting, Marquis, Bode, and Pae (1994) examined five-year-olds' ability to comprehend eight new words that were embedded in an animated story. They found the children to learn and retain more words when ten, rather than three, repetitions of each word were massed within the story.

One can also construe frequency of exposure as the amount of relevant experience distributed over time. Learning words from exposures distributed over time is generally more effective than learning from exposures massed at a single point in time, even when the overall number of exposures is held constant (Childers & Tomasello, 2002; Riches, Tomasello, & Conti-Ramsden, 2005; Schwartz & Terrell). The benefits of distributed exposure hold for both initial phases of learning and for later retention (Bahrick & Phelps, 1987). Given the importance of massed and distributed exposure to word learning, we examined both. In this study there were between-subject differences in massed exposure per session and within-subject differences in distributed exposures as they accrued over time.

The effect of frequency of exposure on word learning is likely to vary with measures of learning outcome. Generally, but not always, expressive recall tasks require a higher frequency of exposure for success than do recognition tasks in part because recognition tasks usually recreate the encoding context more faithfully than do recall tasks (see Haberlandt, 1999 for a review and Gray 2003 for an example pertinent to word learning). Also, in some recognition tasks, a correct response may be obtained because the target is familiar, as opposed to known. Furthermore, guessing is always a possible basis for good performance on recognition tasks but is rarely an effective strategy on recall tasks. Therefore, to maximize sensitivity to effects of frequency of exposure on word learning, we used expressive recall as an outcome measure. To tap semantic learning, we asked children to state definitions of the target words; to tap lexical learning we asked them to state the name of each target as its pictured referent was presented.

Semantic Context

Children can learn words without direct tutelage; in fact, this is how most words are learned (Sternberg, 1987). Moreover, children can infer meaning from contexts that do not readily support recovery of the referent (Bloom, 2000). Nevertheless, reducing the poverty of the stimulus by ensuring a learning environment that is highly informative does facilitate word learning (Beck, McKeown, & McCaslin, 1983). In previous word teaching protocols, semantic information has been provided directly to the learner in the form of verbal definitions or semantic characteristics (e.g., Gray, 2005) or indirectly via sentences that contain syntactic, semantic, or prosodic cues to meaning (e.g., Rice et al., 1994). Both may be effective but there is evidence that direct instruction results in better performance on some measures of semantic learning (Nash & Donaldson, 2005). For this reason, we chose to use direct instruction in the current study.

Whereas it seems obvious that rich semantic contexts will facilitate semantic learning, whether mapping and retrieval at the lexical level would benefit from informative semantic information is an open question. In some models of the lexicon, semantic and lexical nodes are linked within a distributed neural network (e.g., McClelland & Rogers, 2003); in others, they are stored in separate networks but the semantic representations activate the lexical forms in a feed-forward fashion during production (e.g., Caramazza, 1997). Therefore, in either sort of model, one can expect some interaction between semantic and lexical knowledge. One example comes from the simulation work of McClelland and Rogers (2003) who found overextensions of lexical labels like “dog” to reflect an interaction between frequency of input of the lexical form “dog” and a lack of differentiation at the semantic level between the concepts of dog and other animals. Once deeper semantic knowledge was gained-- in this case, increased differentiation between dogs and other animals-- the overgeneralization of the form waned. Another example comes from Caramazza (2003) who made the case that semantic naming errors associated with aphasia arise from either damage to the semantic level or from damage in accessing lexical forms. This is a logical consequence of a model in which lexical activation is defined semantically. Deep (or in this case, intact) semantic knowledge will contribute a greater activation to lexical representations than will a weaker (or damaged) semantic representation.

Models that include semantic influences on lexical performance gain support from the finding that semantic knowledge and lexical retrieval are correlated such that children can typically supply a more complete definition for a word they can retrieve during picture naming than for a word they fail to retrieve (McGregor, Friedman, Newman, & Reilly, 2002). Nevertheless, knowledge of word meanings and lexical forms can dissociate. For example, in a minority of cases, preschoolers know a word perfectly well at the semantic level but are not able to name it (McGregor, Newman, Reilly, & Capone, 2002). Furthermore, Funnell and her colleagues (Funnell, Hughes, & Woodcock, 2006) have reported a developmental pattern such that children under roughly six years; six months are more likely to retrieve items they cannot define whereas older children are more likely to define words they cannot retrieve. In the current study we measured learning at both the semantic and lexical levels with the goal of determining associations and dissociations between the two.

Summary and Hypotheses

We examined the effect of frequency of exposure and informative context on expressive word learning. The primary goal was to capture some of the complexities of the word learning process by examining learning at both the semantic and lexical levels and by exploring three phases, initial mapping, extended mapping, and retention.

During sessions separated by one week, eight-year-olds received vocabulary lessons that included pictures and names of unfamiliar object referents. Half of the lessons included informative semantic context in the form of verbal definitions. Also, group assignment varied such that half of the children were exposed to the lesson once per session; the other children received the lesson twice per session, thereby doubling the number of exposures to the target words, pictures and, where relevant, definitions. All participants were tested on their ability to produce the word forms and meanings once prior to teaching to establish preexisting knowledge, once after the first teaching session to ascertain initial learning, once after the second teaching session to ascertain extended learning, and once again after a month-long retention interval to determine maintenance of learning. We measured the effects of frequency and informativeness of context using a definition recall task to assess semantic learning and a name recall task to assess lexical learning.

The experimental design allowed exploration of changes in learning and retention over time. Given the gaps in the current knowledge base, we asked basic descriptive questions: Within the parameters of the vocabulary lessons, how much of a 20 word set can an eight-year-old learn? Does learning proceed at a consistent rate across time? Do the children maintain their knowledge of the words after the lessons are withdrawn?

In addition to these exploratory questions, we made specific hypotheses about the influence of frequency and informativeness of input on learning at the semantic and lexical levels:

1. Semantic learning will be enhanced by frequent exposure to referents and by increased informativeness of the exposure context. On the definition task, we predicted better performance by the children in the high exposure group than the low exposure group and better performance for words presented in the more informative context (pictures plus definitions) than in the less informative control context (picture alone).
2. Lexical learning will be enhanced by frequent exposure to word forms and by increased informativeness of the exposure context. On the naming task, we predicted better performance by the children in the high exposure group than the low exposure group. Given the hypothesis that depth of learning at the semantic level aids retrieval at the lexical level, we predicted that performance would also be better for words presented in the semantically more informative context than in the less informative context.
3. Finally, we asked how semantic and lexical levels of learning change over time. It may be that the input variables of frequency and informativeness play a greater role during the initial mapping phase by serving to reduce the decay of fragile representations at either the level of word form or word meaning. On the other hand, it may be that the benefit of additional exposures and informative contexts accrues over time, only eventually resulting in representations that are more robust and less likely to decay. Our analyses tested these alternative hypotheses by tracing defining and naming behavior over time.

Method

Participants

Participants were thirty-four monolingual English-speaking eight-year-olds from the Midwestern region of the United States recruited via newspaper advertisements and posters. Eight-year-olds were targeted because they are experienced word learners who, given two or three years of experience at school, would be familiar with didactic vocabulary lessons of the sort used in this study.

Eight boys and 9 girls were randomly assigned to the low exposure group, 10 boys and 7 girls to the high exposure group. Within the low exposure group, 14 were Caucasian and 3 were of mixed ethnicity. Within the high exposure group, 11 were Caucasian, 3 were African American, one was Asian, one was of mixed ethnicity, and one did not report this information. The groups did not differ in age, $t(32) = 1.23$, $p = .23$; maternal education, $t(32) = -.76$, $p = .45$; raw scores on the *Expressive Vocabulary Test* (*EVT*, Williams, 1997), $t(32) = 1.34$, $p = .19$; raw scores on the Matrices subtest of the *Kaufman Brief Intelligence Test* (*K-BIT*, Kaufman & Kaufman, 2003), $t(30) = .47$, $p = .64$; and percentage of phonemes correctly repeated on the Nonword Repetition Test (Dollaghan & Campbell, 1998), a measure of phonological memory, $t(32) = 1.37$, $p = .18$. Though there were no significant differences between the groups on any of these background measures, Table 1 reveals a tendency for the mean scores of the low exposure group to be better than those of the high exposure group. Fortunately, this tendency presents no confound as it works against the prediction of better word learning on the part of the high exposure children.

Materials

So that realistic definitions and photographs could be readily constructed, items from foreign cultures rather than nonce items served as stimuli. Because artifacts and natural kinds vary more with culture and geographic location, respectively, than do actions, stimuli were limited to nouns with object referents. An initial search of the web and the *Encyclopedia Britannica* resulted in reasonably large pools of items from the Egyptian and the Japanese cultures. A list of 67 nouns (36 Egyptian, 31 Japanese) was distributed to 15 adults to collect information about the likely familiarity of these words to a typical 8-year-old child from the United States. The raters, all native speakers of American English who had experience working with children, were instructed to classify the nouns as unfamiliar, possibly familiar, or familiar. The final stimuli consisted of 10 foreign words (e.g., cartouche) or English translations (e.g., sandgrouse) that labeled Egyptian items and 10 that labeled Japanese items. According to the adult raters, these were low in familiarity and equivalent in familiarity between Egyptian and Japanese sets. To control for any differences in phonotactic probability that may affect word learning (Storkel, 2001), the assignment of Japanese and Egyptian sets to the informative and control contextual conditions was counterbalanced across children.

A female speaker recorded the words and sentence frames using standard American English pronunciations, that is, none of the stimuli included non-English phonemes. Digital recording was made using Praat 4.2.05 (Boersma, 2002) with a sampling rate of 22 KHz. The sentence frames were kept constant across stimuli in the control context by substituting only the target noun (e.g., A *kimono* is pictured here. A *kimono* is what you see now. A *kimono* is on the screen). The sentence frames in the informative context always presented the target noun in a sentence-initial noun phrase followed by a semantic attribute (Appendix A).

The auditory stimuli, together with three color photographs of each referent, were imported into Kai's Power Show version 1.5. Two slide shows were created, each presenting 10 Egyptian nouns and 10 Japanese nouns in random order. In one show the Egyptian nouns were in definitional sentence frames and the Japanese nouns were in the uninformative sentence frames, the reverse was true in the other show. These two shows allowed counterbalanced assignment of noun sets to informative or control contexts across children.

Procedures

Children were seen individually at a university laboratory for four sessions, with the first three scheduled weekly and the fourth scheduled one month later than the third. The format of the first and second sessions was (1) naming probe, (2) definition probe, (3) teaching slide show. Also, children in the high exposure group received an additional exposure to the word teaching slide show. The naming probe preceded the defining probe so that the examiner did not prime the naming response when requesting the definition. Both probes preceded the teaching interval because we were interested in long-term, rather than short-term, memory for the target words. The format of the third and fourth sessions was (1) naming probe (2) definition probe, (3) standardized testing. The *EVT* and the *Nonword Repetition Test* were administered at the end of the third session; the Matrices subtest of the *K-BIT* at the end of the fourth.

Naming probe—One of the three stimulus pictures was randomly selected for each of the 20 target nouns and presented via SuperLab 2.0 on a 21-inch LCD monitor with advancement controlled by a voice detection key. The child named the pictures as quickly as possible and the examiner recorded the naming responses for later coding. Ten practice trials involving non-target items were administered before the 20 target trials to familiarize the child with the task and calibrate the voice key device.

Defining probe—To begin the definition probe, the examiner defined *dog* as an example and then presented each of the 20 target nouns in random order asking, "what's a ___" and prompting once with, "what else can you tell me about ___." Children's definitions were audio-recorded for later coding.

Teaching slide show—Children were seated in front of a computer screen and instructed to pay attention to the slide show and to imitate each word when prompted. Prompted word production was meant to ensure that the child was paying attention and that seemed to be the case as the children's prompted imitations were always accurate.

The format of the slide show is illustrated in Appendix B. As can be seen there, the show included three exposures to each pictured referent and seven exposures to each target noun with an eighth exposure occurring as a result of the child's prompted imitation. Because the slide show was presented during sessions one and two, the children in the low exposure group received a total of 16 exposures to each noun and six exposures to each referent during teaching. Children in the high exposure group viewed the slide show twice during session one and twice during session two for a total of 32 exposures per noun and 12 exposures per referent during teaching.

Coding

Naming Responses—Correct productions of lexical forms were tallied. These were completely accurate pronunciations of the target words. Because we were interested in the emergence of word knowledge, we also coded target substitution errors. Target substitutions were labels for other targets in the training set (e.g., *koto* for *tatami*); as such, they suggest partial knowledge (e.g., mapping of a lexical form but not a semantic referent or form-to-referent link).

Definitions—Correct definitions were tallied. These were definitions that included at least one accurate unit of information. In addition, each accurate information unit was classified by type as superordinate category or attribute. To illustrate, the child who defined *cartouche* as "made of metal and thought to bring good luck" was credited with two information units; both were attributes. The child who defined *scarab* as "a bug" was credited with one information unit, a superordinate category. Finally, as in the naming responses, we also tallied any incorrect definitions that represented a target substitution. A target substitution involved accurate information for another target in the training set (e.g., *an Egyptian beetle* [the definition for the target *scarab*] for *sandgrouse*).

Reliability—A trained research assistant coded the naming and definition responses for all 34 children. A second rater independently coded all naming responses across the four sessions for a random sample of 9 children (for a total of 720 responses). Point-by-point agreement on response types was 99.03% between the two raters. Similarly, a second rater coded all definitions across the four sessions for a random sample of 11 children. Point-by-point agreement levels on number of correct definitions, number of accurate information units, type of accurate information units, and occurrence of substitution errors were 98%, 90.09%, 94.5%, and 94.5%, respectively.

Results

Accuracy of Naming

The children accurately named an average of 0.97 words in session 1 (*SD* = 1.11), 4.29 words in session 2 (*SD* = 2.79), 7.18 words in sessions 3 (*SD* = 3.90) and 8.15 words in session 4 (*SD* = 3.86). The rate of learning was fairly consistent over time in that roughly the same numbers of new words were added after session 1 and session 2. Learning was maintained during the month-long retention interval. To determine whether this general pattern was influenced by frequency of exposure and informative context we graphed the data (see Figure 1) then conducted a 2 x 2 x 4 ANOVA with the number of correct naming responses as the dependent variable. Results were interpreted as small effects ($\eta^2 < .05$), moderate effects ($\eta^2 = .05$ to .10), or large effects ($\eta^2 > .10$), where η^2 refers to the proportion of total variance in the dependent variable accounted for by variation in the independent variable (Cohen, 1988;Levine & Hullet, 2002).

There was support for the prediction that frequency of exposure affects learning of lexical forms. Though there was no main effect of exposure group, $F(1, 32) = 2.44$, $p = .13$, there was a significant effect of session, $F(3, 96) = 100$, $p < .001$, $\eta^2 = .76$, qualified by an interaction between group and session, $F(3, 96) = 3.01$, $p = .03$(see Table 2). This interaction reflects a significant gain in performance from sessions 1 to 2, and again from sessions 2 to 3 (session 1 < session 2 < session 3 = session 4, $p < .001$ for the significant comparisons) together with the gradual emergence of a high-exposure advantage (high exposure group = low exposure group at sessions 1 and 2; high exposure group > low exposure group at sessions 3 and 4).

There was no main effect of learning context, $F(1,32) = 0.08$, $p = .78$. Therefore, the prediction that naming performance would be better for words presented in semantically more informative contexts than in less informative contexts was not supported.

Accuracy of Defining

The children accurately defined an average of 3.94 words in session 1 (*SD* = 2.72), 9.50 words in session 2 (*SD* = 3.86), 12.88 words in session 3 (*SD* = 3.17) and 12.97 words in session 4 (*SD* = 3.70). Clearly the largest gain occurred after the first teaching session. Cumulative semantic learning was maintained during the month-long retention interval.

An ANOVA with the dependent variable being the mean number of accurate information units per subject revealed variations in this overall pattern (see Figure 2). There was a main effect of group, F (1, 32) = 5.75, p = .02, η^2 = .15; a main effect of learning context, F (1, 32) = 26.22, p < .001, η^2 = .45; and a main effect of session, F (3, 96) = 101.96, p < .001, η^2 = .76. These effects were respectively due to better performance by the high exposure group than the low exposure group, better performance in the informative than the control context, and a significant gain in performance from session 1 to session 2, and again from session 2 to session 3 (session 1 < session 2 < session 3 = session 4, p < .001 for the significant comparisons).

The main effects were qualified by an interaction between group and learning context, F (1, 32) = 4.38, p = .04, η^2 = .12. Children in the high exposure group performed better on words learned in the informative context (mean = 15.71; SD = 7.26) than those learned in the control context (mean = 11.34; SD = 6.38), p < .001; but children in the low exposure group performed similarly regardless of learning context (mean for the informative context = 10.38, SD = 3.27; mean for the control context = 8.54, SD = 2.39; p = .16). Increased exposure coupled with informative input facilitated mapping of semantic information.

As one of the goals of the study was to explore how the effects of increased exposure and informative semantic context changed over time, cases where these main effects were qualified by interactions with session were critical. The main effects on definition performance were qualified by two-way interactions between group and session, F (3, 96) = 7.26, p < .001, η^2 = .18, and learning context and session, F (3, 96) = 11.08, p < .001, η^2 = .26. In part, the interactions reflected equivalent pre-training performance. Performance by high and low exposure groups did not differ at session 1 (Table 3), nor did performance on words assigned to the informative or control contexts (Table 4). More importantly, the interactions reveal differences in the time course of exposure and informativeness effects. The effect of high exposure on semantic learning was immediate: the high exposure group was superior to the low exposure group by session 2 and they maintained that advantage in sessions 3 and 4 (Table 3). The effect of informativeness was more gradual to accrue, emerging by session 3 (Table 4).

Content of Definitions

To further evaluate the effect of informative context, we compared the types of accurate information units included in definitions of items learned in the informative and control conditions. The percentages of accurate definitions that included superordinate category information did not differ: 77% (SD = 27) in the informative condition and 87% (SD = 14) in the control condition, t = −1.9, df = 33, p > .05. Instead, the advantage of informativeness was reflected in the children's use of attributes. Sixty percent (SD = 27) of accurate definitions of items learned in the informative condition included attributes compared to 26% (SD = 16) in the control condition, t = 6.7, df = 33, p < .00001.

Relationship between Defining and Naming

Figure 3 depicts the progression of the children's knowledge of the trained words over time. After initial exposure, most of the words could be neither named nor defined (−name−define). This response type dropped with additional exposure while the number of words that could be both named and defined (+name+define) increased. Critical here are those words that elicited correct performance on one task but not another. These dissociations rarely involved knowledge of lexical forms without knowledge of semantics (+name−define). Instead, words involving partial knowledge were more likely to be defined but not named (−name+define).

Errors

Target substitution errors, collapsed across exposure groups and learning contexts,[2] are plotted in Figure 4. Given the main effect of session in the accuracy data reported above, it is clear that overall error rates dropped across sessions. However, this was not the case with target substitution errors. These emerged in both defining and naming after the first session. Consistently, target substitutions were more common during defining than naming. These errors suggest mapping of some target information for a given word, especially semantic information, but not other information, especially lexical forms or form-to-meaning links.

Discussion

Eight-year-olds participated in vocabulary lessons designed to teach them 20 words and referents from foreign cultures. This study involved analysis of the resulting word learning during initial mapping, extended mapping, and maintenance. A naming probe tapped lexical learning; a definition probe tapped semantic learning.

The challenge of learning many new words at once was obvious. Notwithstanding the high ability evident in their standardized test scores and despite repeated lessons designed specifically to teach them words, these eight-year-olds learned, on average, only eight words well enough to name and 13 words well enough to define.

One likely reason for the limited number of words learned was the large learning problem the children faced. In other studies involving large sets of target words, learning has also been limited. For example, Schwartz and Terrell (1983) found toddlers to learn, on average, only 5 or 6 of 16 novel words presented multiple times over the course of 10 weeks. Here 20 words were presented and, judging by their performance in session 1, the children were unfamiliar with the majority of them. By asking them to learn this many new words, we put the children in a situation that required simultaneous storage of much new information. These new and fragile representations were vulnerable to retrieval failure as other representations competed for activation during naming and defining tasks (Gershkoff-Stowe & Smith, 1997). The interference of competing entries was most evident in the defining task where, after the initial exposure to the new words, the children demonstrated a spike in target substitution errors. For example, when asked to define *sphinx*, one child gave an accurate definition of *pharaoh*. Clearly some new meanings had been mapped but the lexical forms or the links between forms and meanings were not yet secure. The clinician should be aware of the challenge presented by introducing many new word learning targets at once.

In addition, the children's low performance likely reflected the high standard of learning set for them. Knowledge of both lexical forms and meanings was tapped with expressive recall tasks. In contrast, impressive estimates of children's rate of word learning (e.g., Beck & McKeown, 1991; Nagy & Herman, 1987) and cumulative word leaning (e.g., Aitchinson, 1994; Bloom, 2000) are typically based on their recognition performance. One would expect fewer words to be learned to a degree sufficient to support performance on production recall tasks. Indeed, that the children maintained newly learned words over a one month period suggests that the words learned, though small in number, were robustly represented in the long-term store. This overall pattern of significant but somewhat limited learning varied with manipulations in the learning environment. We interpret these differential effects below.

[2]Error profiles between groups and between learning contexts were very similar.

Frequency of Exposure

As expected in any task involving declarative learning and memory, frequency of exposure affected success. Though our study examined the word learning of typical 8-year-olds, frequency effects have been reported for learners of other ages and abilities as well. Frequency predicts preschoolers' word learning when assessed in forced-choice recognition formats (Storkel, 2001; Rice et al., 1994) or picture naming tasks (Storkel, 2001). In addition, preschoolers with specific language impairment require more frequent exposure to learn words than do their unaffected age-mates (Gray, 2003). Moreover, their word learning is more frequency dependent than that of their younger vocabulary-matched peers (Riches et al., 2005). Finally, in young adults, cumulative frequency of exposure predicts age of acquisition judgments as well as the speed with which familiar words are recognized in reading aloud tasks (Zevin & Seidenberg, 2004).

In this study there were two means by which frequency of exposure was manipulated, between-subject differences in massed exposure per session and within-subject differences in numbers of distributed exposures over time. Both massed and distributed exposure affected learning. In the definition probe, the high exposure group performed better than the low exposure group (with the exception of pretest) and performance in both groups improved with exposure over sessions, more so after the first session than the second. In contrast, distributed exposure played a larger role than massed exposure in naming performance. The main effect of session on naming was large with steady growth from sessions 1 to 2 and sessions 2 to 3. The effect of massed exposure on naming was later to emerge, only after the second session did the naming performance of the high exposure group benefit. We conclude that increases in frequency of exposure, whether massed or distributed, promoted word learning and we hypothesize that distributed exposure may be particularly important for learning at the lexical, as opposed to the semantic, level.

The value of distributed practice is best tested in studies that directly pit massed exposures against distributed exposures and subsequently measure effects on learning at the lexical and semantic levels. In one existing study of this type, distributed exposure was superior to massed exposure in facilitating two-year-olds' expression of new lexical forms but equal to massed exposure in facilitating expression of new meanings (Childers & Tomasello, 2002). Our results concur exactly. However, studies of young adults' word learning demonstrate the superiority of distributed exposure on learning at the semantic as well as the lexical levels. For example, Dempster (1987) found undergraduates to recall 50% more word meanings when three exposures to words and definitions took place every 4 minutes than when the three exposures took place in immediate succession. Exploration of the optimal combination of massed and distributed practice for promoting word learning throughout childhood at both the lexical and semantic levels is an important avenue for future research.

Semantic Context

Both the pictures in the control context and the pictures plus verbal definitions in the informative context provided semantic information for the learner. Children's ability to define words learned in either context increased over time and children were equally likely to learn superordinate category information in the two contexts. This suggests that pictures alone are a rich source of semantic information. An object's category as well as some of its defining physical features are readily available in picture stimuli. Nevertheless, an advantage of the informative context over the control context was manifested as a higher overall number of accurate information units and a higher rate of semantic attributes in the children's responses to the definition probe. Not only did the informative context make available details about attributes that could not be gleaned from the pictures (e.g., a cartouche *is thought to bring good luck*), it also provided a verbal script during encoding that was much like that expected at test.

Though here the effect of informative context was obtained in a contrived laboratory setting, similar results have been reported in real-world learning environments. When Beals (1997) examined mealtime conversations between preschoolers, ages three- to five years, and their parents, she found that parents frequently introduced their preschoolers to “rare” words in informative contexts. Roughly two-thirds of these informative contexts involved direct verbal semantic information in the form of definitions or synonyms. Furthermore, there was a positive correlation between the frequency of the parents’ informative introductions of rare words and the children’s receptive vocabulary scores at the ages of five and seven years. This leads to a second aspect of the current findings: the interaction between informativeness and frequency of exposure.

Importantly, informativeness facilitated semantic learning only when coupled with high exposure of either the massed or distributed type. Children in the high (massed) exposure group benefited from informative context but children in the low exposure group did not. Furthermore, the effect of informativeness on semantic learning accrued gradually. There was no effect when measured in session two but the advantage of highly informative context emerged at session three and this advantage was maintained after the lessons were discontinued.

The Relationship between Lexical and Semantic Learning

Cases where children could define a word but not name it far outnumbered cases where they could name but not define. This suggests that semantic mapping led lexical mapping to some extent. However, contrary to prediction, enhancement of semantic knowledge yielded no effect on learning at the lexical level, not even for the high exposure group, indicating that the semantic and lexical aspects of word learning may develop independently. These findings accord with those of Funnell and colleagues (2006): though they obtained a high correlation between semantic knowledge, as revealed by five-question definitional probes for each item, and lexical retrieval, as revealed by a picture naming probe for the same set of items, they also found a relative independence between semantic and lexical word knowledge such that younger children (those below six years; six months) evinced a lexical advantage and older children evinced a semantic advantage. They conclude that the tight relationship between semantic and lexical knowledge (as reported in McGregor et al., 2002) does not reflect a reliance of naming upon levels of knowing, but rather reflects increases in performance levels in both tasks as experience accrues. We agree in that here we found that both semantic knowledge and lexical knowledge increased with experience but enhanced semantic knowledge did not lead to enhancements in lexical retrieval.

That said, Capone and McGregor (2006), found semantic enhancement in the form of gestured input to facilitate lexical retrieval among toddlers. This exception suggests a complex relationship between word knowledge at the lexical and semantic levels that merits additional research efforts. One hypothesis to pursue is that for novice word learners (toddlers in Capone & McGregor, 2005) the semantic and lexical levels of word storage and retrieval are less modular than for more expert word learners (3- to 11-year-olds in Funnell et al., 2006; 8-year-olds in the current study) (see the neuroconstructivist approach of Karmiloff-Smith, 1998). Another hypothesis is that gesture is unique in enhancing both semantic learning and lexical retrieval. This may be the case as gesture, being visual, supports semantic learning without competing for verbal processing resources, resources that are then available for encoding the lexical form (see Goldin-Meadow & Wagner, 2005).

Conclusions and Clinical Implications

Frequent exposure to words and their referents facilitated later phases of lexical learning when massed exposures had accrued over a distributed interval of time. Frequency of exposure had a more immediate effect on semantic learning with the high exposure group showing an advantage over the low exposure group during initial and subsequent phases of learning. Frequency of exposure coupled with informative contexts of the type used here—definitional sentences plus pictured referents—promoted semantic mapping during later phases of word learning.

Though a protracted process, word learning is highly amenable to environmental manipulations. This is a hopeful message for clinicians in the schools and for the children they serve. In planning these manipulations, the clinician should aim to create rich, informative environments that include massed and distributed redundancies. Distributed exposures might be organized around a cycles approach, a clinical strategy with attested value, albeit for the teaching of sounds, not words (Hodson & Paden, 1983; also see review in Gierut, 1998). Learning at the semantic and lexical levels may dissociate so both levels should be considered when selecting goals and planning lessons. Likewise, when measuring learning outcomes, clinicians should include tests of both lexical and semantic knowledge (see suggestions in Brackenbury & Pye, 2005). Tests involving a recognition format are likely to reveal whether or not the child has any knowledge of a given word whereas those involving expressive recall generally hold the child to a higher standard and thereby better reveal the robustness of that knowledge.

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Appendix A

Definitions Used in the Informative Condition

Egyptian	Japanese
A cartouche is a piece of gold or silver jewelry. A cartouche has words and pictures on it. A cartouche is believed to bring good luck.	An armlet is a decorative band. An armlet is worn around the upper arm. An armlet is made out of cloth or metal.
An equestrian is a person who rides a horse. An equestrian wears a special uniform. An equestrian competes in riding competitions.	A bonsai is a miniature tree. A bonsai is kept small by trimming the roots and branches. A bonsai may live for 100 years or more.
A chisel is a sharp tool. A chisel has a metal blade. A chisel is used for shaping wood, stone, or metal.	A futon is a mattress on a wooden frame. A futon is used as a bed. A futon can be folded up and stored in a closet when not in use.
Henna is a decoration on the body. Henna is made from a red-brown dye from plant leaves. Henna is used for weddings and big celebrations.	A kimono is an ankle length robe. A kimono has wide sleeves and a V-neckline. A kimono is worn on special occasions.
Papyrus is a grass-like plant. Papyrus grows up high in water. Papyrus is used to make paper.	Kokeshi are wooden toys. Kokeshi are carved and hand painted. Kokeshi have been made for over 150 years.
A pharaoh is a king of Egypt. A pharaoh was believed to have magical powers. A pharaoh was buried in a pyramid when he died.	A koto is a musical instrument. A koto has 13 silk strings. A koto is played by plucking and pressing on the strings
A sandgrouse is a desert bird. A sandgrouse is hard to kill because of its tough skin and thick feathers. A sandgrouse lays long dark-colored eggs in a hole in the ground.	A macaque is a type of monkey. A macaque has a hairless red face. A macaque likes to eat fruit and plants.
A scarab is a large insect. A scarab has unusual antenna. A scarab used to be placed in the bandages of mummies.	Origami is the art of making objects by folding paper. Origami is made without cutting or pasting. Origami is made out of colorful, square-shaped pieces of paper.
A sphinx is a make-believe creature. A sphinx has a lion’s body and human head. A sphinx is typically carved out of stone.	A tatami is a mat used as a floor covering. A tatami is made of straw with cloth borders. A tatami stays cool in summer and warm in winter.
A tunic is a loose-fitting shirt. A tunic may or may not have sleeves. A tunic reaches to the knees or lower.	A warbler is a small songbird. A warbler eats insects. A warbler makes dome shaped nests with green leaves sewn in.

Appendix B

Slide Show Parameters Illustrated with the Item “bonsai”

Visual Input	Timing	Informative Sound File	Control Sound File
Picture 1 of bonsai	5 sec	bonsai A bonsai is a miniature tree	bonsai A bonsai is on the screen
Picture dissolves	2.5 sec		
Picture 2 of bonsai	5 sec	bonsai A bonsai is kept small by trimming the roots and branches	bonsai A bonsai is what you see here
Picture dissolves	2.5 sec		
Picture 3 of bonsai	5 sec	bonsai A bonsai may live for 100 years or more	bonsai A bonsai is pictured here
Picture dissolves	2.5 sec		
Picture 3 of bonsai	5 sec	Now you say bonsai	Now you say bonsai

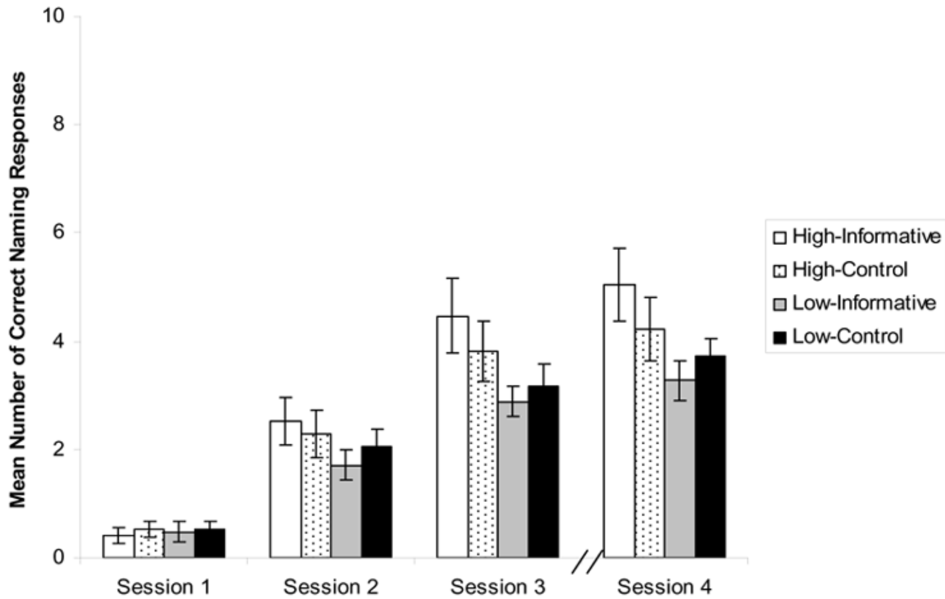

Figure 1.
Naming performance as a function of exposure group, and session.

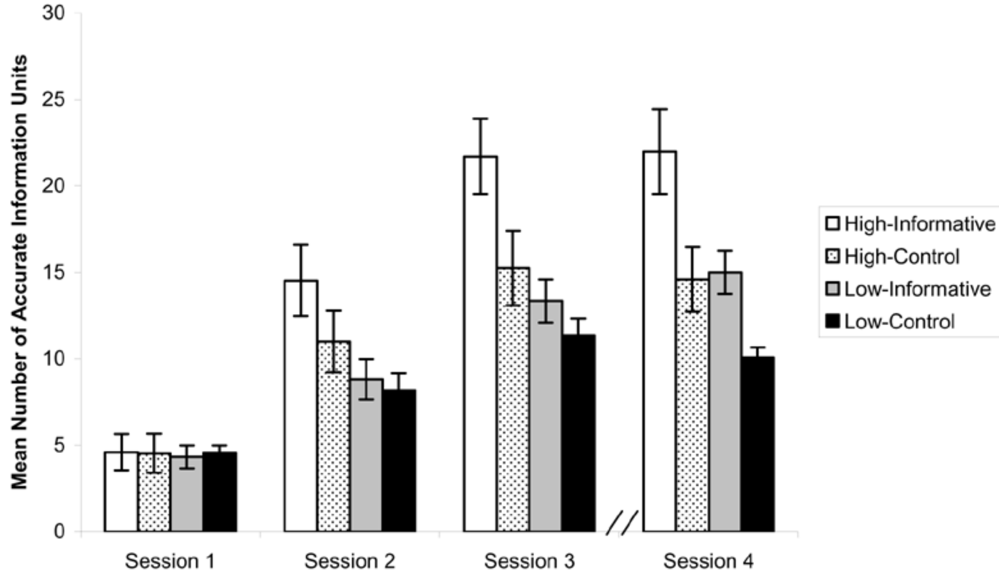

Figure 2.
Definition performance as a function of exposure group, learning context, and session.

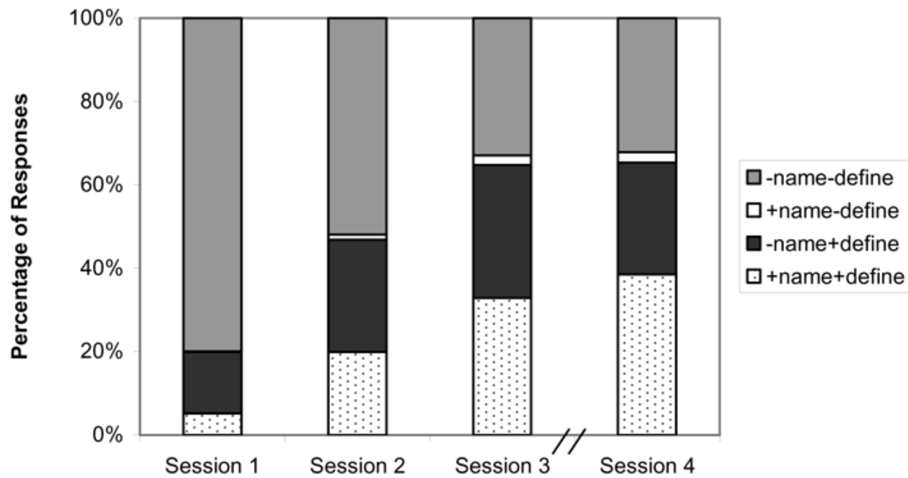

Figure 3.
Associations and dissociations between naming and defining performance.

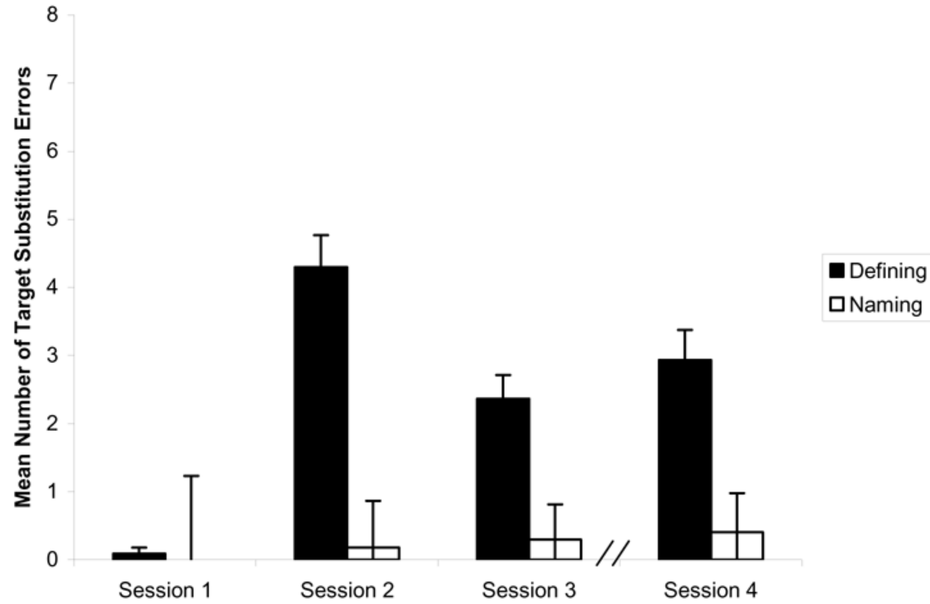

Figure 4.
Number of target substitution errors by task and session.

Table 1

Characteristics of the subjects by group

	Exposure Group			
	Low		High	
	Mean	SD	Mean	SD
Age in months	102.18	3.63	100.47	4.42
Maternal Education (in yrs)	16.41	3.00	17.06	1.78
EVT-standard	107.71	6.98	105.29	5.88
EVT-raw	93.24	9.71	88.94	8.91
Nonword Repetition	89.10	4.42	86.89	4.94
KBIT-standard	116.87	17.71	116.00	18.82
KBIT-raw	29.40	5.84	28.35	6.57

Note. EVT = *Expressive Vocabulary Test* (Williams, 1997). KBIT = Matrices subtest of the *Kaufman Brief Intelligence Test* (Kaufman & Kaufman, 2003).

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Table 2

Naming performance (mean number accurate names) as a function of session and group.

Session		Exposure Group: High	Low
1	M =	0.94_a	1.00_a
	SD =	1.03	1.22
2	M =	4.82_b	3.76_b
	SD =	3.24	2.19
3	M =	8.29_c	6.09_d
	SD =	4.77	2.61
4	M =	9.29_c	7.00_d
	SD =	4.71	2.35

Note. M = mean per subject. Means in the same row or column that do not share subscripts differ at $p < .03$ in the Tukey honestly significant difference comparison.

Table 3

Definition performance (mean accurate information units) as a function of session and group.

Session		High Exposure	Low Exposure
1	M =	9.12_a	8.92_a
	SD =	(8.02)	(4.16)
2	M =	25.53_b	17.00_c
	SD =	(14.90)	(7.08)
3	M =	36.94_d	24.71_e
	SD =	(16.07)	(7.64)
4	M =	36.59_d	25.07_e
	SD =	(16.65)	(6.77)

Note. M = mean per subject. Means in the same row or column that do not share subscripts differ at $p < .001$ in the Tukey honestly significant difference comparison.

Table 4

Definition performance (mean accurate information units) as a function of session and learning context

Session		Informative	Control
1	M=	4.46_a	4.56_a
	SD=	(3.53)	(3.42)
2	M=	11.68_b	9.59_b
	SD=	(7.38)	(6.04)
3	M=	17.53_c	13.29_d
	SD=	(8.36)	(7.09)
4	M=	18.50_c	12.33_d
	SD=	(8.68)	(6.09)

Note. M = mean per subject. Means in the same row or column that do not share subscripts differ at $p < .001$ in the Tukey honestly significant difference comparison.