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CHILDREN'S LEXICAL EXPERTISE

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ABSTRACT

There are several indications that the process of children's word-learning and the development of expertise are similar. These clues are found in both theoretical contentions and in prior intervention work. However several pieces of evidence were needed to make the link between lexical acquisition and expertise development explicit. The present research study provides that evidence. In a microgenetic study 4-year-old children were taught 450 new lexical items from three animal domains. Across 3 months children showed patterns of lexical learning that are similar to longer-term patterns of learning displayed by experts. Children also showed show evidence of increasing memory, perception, attention and abstraction- cognitive abilities that evidence advanced performance in experts and that are associated with increased domain knowledge. Finally the children showed evidence of characteristic patterns of behavior previously documented in experts. It is argued that children who are learning words can be thought of as developing lexical expertise or "lexpertise".

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INTRODUCTION

Children's Lexical Expertise

Learning words is a complex task. However, most children indeed master this task relatively early in life. Numerous theories have been proposed to account for children's word learning. Current thinking about lexical learning focuses on an item-based, or usage-based, approach (Tomasello, 2000), that specifies the emergence of linguistic abilities based on initially encoded input properties (MacWhinney, 1987). That is, characteristics inherent in the learner-- cognitive abilities such as attention, perception, abstraction, and memory-- allow individuals to attend to, recognize, and remember associative and probabilistic patterns in the environment, setting the stage for learning to occur (Kelly & Martin, 1994; Keil, 1986; Seidenberg, 1997; Samuelson & Smith, 1998). As lexical items are encountered they are stored in the lexicon as whole or partial representations. These representations contain information about the meaning of the word, along with phonological and syntactic information (MacWhinney, 1987; Pisoni, 1996). Furthermore, information about the situation in which the word was learned, including information about the learner's present emotional state (Bloom & Tinker, 2001), and about the speaker (Clark, 1997) is recorded. Thus, learners encode lexical elements of the word-learning situation, as well as elements of the context that are not traditionally viewed as lexical elements but that apply to aspects of language such as connotation-denotation distinctions and code-switching.

Repeated exposure to the lexical items and their inherent aspects results in filling the gaps in the lexical representation and the expansion of associative connections with related concepts. In addition, as individuals gain experience with a language they learn its phonological, syntactic, and pragmatic rules, and subsequently abstract and apply those rules, allowing for the productive generation of new constructions seen in more experienced users of a language (Tomasello, 2000). Furthermore, as individuals accumulate knowledge about the words of their language, they are more able to use other processes to support lexical learning, such as semantic and syntactic bootstrapping, rather than having to rely on phonological bootstrapping alone (Bushnell & Maratsos, 1984; Deak & Maratsos, 1998; Nelson, Rescorla, Gruendel, & Benedict, 1978; Rice, Oetting, Marquis, Bode, & Pae, 1994).

In sum, lexical entries exist in an associative network, with each entry specifying information about the lexical item obtained from the learning episode. Information about meaning and use, as well as intricacies of the social message, perceptual nuances, and contextual properties, are encoded each time a word is recalled or a new lexical item is encountered. Learning proceeds through the continual linking of past and current associations, resulting in the emergence of new conceptions about how elements of lexical items work and in connectionist models involves gradual changes to connection weights between units that determine patterns of activation in the network (MacWhinney, 1998; Roelofs, 1999, 2003; Snow, 1999; Samuelson & Smith, 1998).

This conception of the lexicon allows for consideration of the interplay among features of the lexicon and how relations among features change with linguistic experience. Furthermore, because item-based emergence theories specify the strength and interconnectivity of lexical elements they can account for effects of changes on the lexicon due to word learning (Charles-Luce & Luce, 1990; Jared & Kroll, 2001) and can account for effects that must be explained by multiple models in other contentions. In particular, this notion explains findings such as language-independent-activation and cross-language effects (Colome, 2001; Jared & Kroll, 2001; Miller & Kroll, 2002), and is consistent with neurological research evincing shared semantic processing for bilinguals' developmental reorganization in the lexicon (Cheour et al., 1998; Illes et al., 1999; Mills, Coffey-Corina, & Neville, 1997; Naatanen et al., 1997).

Summarized, word learning occurs through changes that emerge from initial experiences. Characteristics inherent in the learner allow for the current acquisition of new words and the reorganization of the lexicon itself and impact on the levels of basic cognitive abilities, all of which affects future word learning. That is, word-learning appears to contain two parts-- one that directs the processing of input, and one that changes as the result of it. This idea of a two-process model is widespread in the word-learning literature- theories ranging from constraints suppositions, to dynamic-systems models to connectionism suggest elementary processes are needed for the emergence of more complex lexical principles to develop. For example, Hollich, Hirsh-Pasek, & Golinkoff (2000), Samuelson and Smith (1998), MacWhinney (1998), and Hulstijn (2002) all suggest ontogeny is reliant upon certain basic processes, processes such as attention, perception, abstraction, and memory. In addition, although these theories differ in terms of what they contend children then do with the knowledge acquired though these basic processes, they do not dispute the claims that evolving basic domain-general processes contribute to development, and contribute in a way that serves as the skeleton for further growth.

For example, in their emergentist coalition model of word learning, Hollich et al. (2000) contend that the learning of words is a product of attentional, social, and linguistic cues. For them, associative elementary cues are important in providing a framework for later learning in younger children. As children's age and experience and maturation increase, however, skills that at first provided information about words, become information that directs children to salient aspects of social situations. Furthermore, children gain the ability to abstract cues from the language framework itself. Thus children move from immature to mature states of language learning that are differentiated by the type of information that guides their word learning- associative, social, and then linguistic. In sum, in these constraints approaches basic properties of the cognitive system are needed to stimulate the appearance of more refined processing capacities.

While the critical elements of dynamic-systems approaches vary dramatically from those of constraints approaches to language learning, the idea that elementary cognitive processes serve as the basis for future learning is apparent. Dynamic-systems applications portray an ontological system that results from continually reorganizing networks of abilities that integrate sensory input, current internal activity, and the developmental and evolutionary history of an organism (Thelen, 1989; Thelen & Smith, 1994). At different points in time this network necessarily differs because perceptual input, internal state, and the organism's history differ (Smith & Katz, 1996). Thus, developmental change results from the self-organization of initial perceptions, contexts, learning, and histories continually coupled with each other. What is important to keep in mind for this theory is that early cognitive abilities are vital for any lexical development and that as development proceeds there are mutual dynamic influences of cognitive advances generally and advancing lexical knowledge.

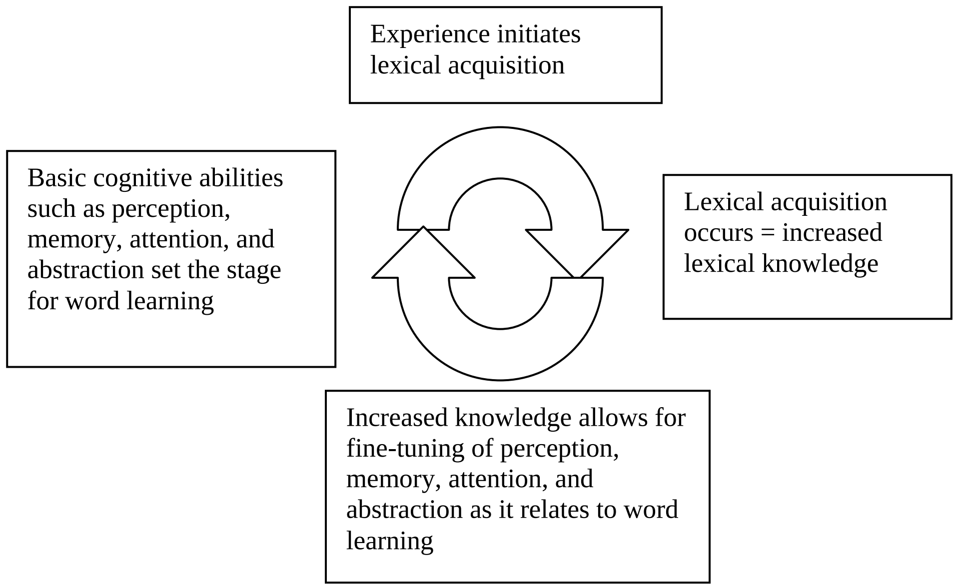
Nelson and colleagues (Nelson, 2001; Nelson & Welsh, 1998) also place domain-general abilities at the center of language learning. In Rare-Event learning and Dynamic Tricky Mix theory domain-general abilities such as attention and engagement serve as catalysts for optimal language acquisition. Furthermore, learners bring certain levels of capabilities, such as memory, to the table. These readiness abilities buttress word learning by providing knowns in a world of unknowns. That is, they allow children to use these skills during the acquisition of language by scaffolding current learning. Thus, attention, perception, and memory all serve as elements that may either aid in, or serve as a detriment to the learning situation. Additional conditions for learning words or any new structures are social interactive patterns and the ways challenges are embedded in interaction. For optimal learning to occur, all elements of the learning situation must merge in a precise, but rarely achieved way.

Connectionist architectures similarly support the emergence of high-level systems from low-level systems. For example, MacWhinney (1998) suggests that low-level attentional and perceptual mechanisms aid in focusing children’s attention on relevant input. Learning results from pressure within the child to both integrate and disentangle social and cognitive properties implicit in the input she receives. Experiences are stored as episodes containing information about each situation. Learning proceeds through the continual linking of past and current associations, the result of which is the emergence of new concepts, techniques, and strategies. Learning involves gradual changes to connection weights between units that determine patterns of activation in the network.

Hulstijn (2002) also suggests that the most comprehensive account of language learning may be a hybrid theory of acquisition that includes elements of both symbolic models and connectionist models-- specifically parallel-distributed-processing models. Subsymbolic information acquired through certain non-domain-specific capabilities such as the capability to perceive and remember rudimentary stimuli comprises implicit knowledge that is represented in hidden units. Symbolic units, such as words, comprise explicit knowledge resulting from practice with subsymbolic units and higher-order cognitive skills. Furthermore, implicit learning resulting from elementary information-processing abilities that accompany and interact with later cognitive processes that are involved in explicit learning, allows for the "construction of adjustment of knowledge representation in a distributed form." (p. 9). That is, the combination of elementary processes, combined with higher-order processes that emerge out of early ones, results in learning.

In sum, across these theories we see a trend towards the recognition of two-process models of word-learning that suggest there may be two categories of factors responsible for word learning, elementary properties such as basic attention, perception, abstraction and memory, that serve to direct processing and learning of language input and higher-level abilities that reflect refinement that occurs as the result of experience and maturation. Furthermore, lower-level abilities dovetail with higher-level processes to result in the proficient word-learning seen in experienced users of a particular language. See Figure 1.

Figure 1. Two-Process Model of Lexical Acquisition



The extent to which children's knowledge base of lexical items is currently established reflects the degree of expertise children may have in that domain. This expertise may be apparent not only in the amount and kind of knowledge children have about an area, but also in the way newly encountered information is processed.

Children's Word Learning.

Theories of word learning stress the role of perception, attention, memory, and abstraction processes as important variables in the attainment of new information. Empirical evidence is suggestive that these variables do contribute to word learning. In addition, there are clues in the current literature that hint at changes in these initial abilities may result from lexical acquisition.

Working Memory

Just and Carpenter (1992) characterize working memory as a resource limited capacity system that is involved in the preservation and processing of information. For children difficulties in cognitive processing may be the result of the inability to retain or maintain information in working memory while also further processing that or related information (Case, 1995). Several researchers contend that memory is an important variable in language learning (Braine, 1994; Gathercole & Baddeley, 1990b). According to Slobin (1973), because spoken language is temporal in nature, memory is a critical prerequisite for its development. Thus, the ability to perceive and remember under challenging temporal conditions is central to a child's ability to comprehend and produce language (Kirchner & Klatzky, 1985). Children must have adequate working memory systems in order to most efficiently attend to speech input, construct mental representations of this input, recall phonological information stored in long-term memory, and assimilate new phonological information (Gillam, 1997; Gillam, Cowan, & Marler, 1998), tasks imperative for novel word learning (Baddeley, Gathercole, & Papagno, 1998; Gathercole & Baddeley, 1989; 1990b; Gathercole, Hitch, Service, & Martin, 1997; Gathercole, Service, Hitch, Adams, & Martin, 1999).

Baddeley (1986) has suggested that the human memory system is ideally constructed for dealing with phonological information in working memory. In his theory, working memory is constructed of three main components: a central executive that performs all mental operations, a visuospatial sketchpad that holds short term iconic information, and a phonological loop, consisting of a phonological store that keeps phonological information in queue, together with a rehearsal mechanism that keeps this phonological information active. Baddeley et al. (1998) have suggested that the phonological loop evolved for language learning, specifically the learning of novel words. As phonological information enters working memory, a memory trace of this information is stored in the phonological loop. The phonological loop performs both the task of recruiting previously stored phonological information from long-term memory that is used to supplement decoding of novel material, and the task of holding novel phonological information until that information can be incorporated into one's current plans and existing long-term store. Word learning is thought to be dependent on the child's ability to hold phonologically intact information until that information can be assimilated into the child's lexicon.

It has been suggested that variability in word learning may result from differences in children's capacity to hold information in the phonological loop. Gathercole and Baddeley and colleagues (Baddeley et al., 1998; Gathercole & Baddeley, 1990a, 1990b; Gathercole et al., 1997) suggest that differences in children's rate of vocabulary development can be explained, in part, by differences in their working memory capacity, specifically in the capacity of the phonological loop. To illustrate, Adams and Gathercole (1995) examined the association between phonological memory and spontaneous spoken language in normal 3-year-old children. They found that children who produced higher scores on auditory digit span and nonword repetition indices produced significantly more and varied speech output than did preschoolers with lower memory scores. In particular, higher-scoring children tended to have larger expressive lexicons and tended to produce a greater number of words per utterance. The authors suggested that these results clearly indicated an association between phonological memory and expressive vocabulary.

In another study Gathercole et al. (1997) examined the association between phonological loop capacity and the rate of learning unfamiliar phonological material in 5-year-olds. In this research, digit-span and nonword repetition scores were obtained, and were correlated with the rates of word-word and word-nonword pair learning. A large degree of association was found between scores on the short-term memory tasks and the rate of learning word-nonword pairs. This relationship was not found for word-word pairs, suggesting that the learning of new words is independent of learning of familiar word pairs, and that this learning is constrained by the capacity of the phonological loop. Children make use of both new information held in the phonological loop and any existing information stored in long-term memory (Snowling, Goulandris, Bowlby, & Howell, 1986). When existing knowledge is not available to aid in new word learning, then children must rely on the phonological loop alone. Long-term storage of unfamiliar sound structures (phonologically unfamiliar words) is dependent on the representations of these sound structures in the phonological loop. The phonological loop, then, is critical in maintaining intact phonological information for the construction of more permanent mental representations (Baddeley, Gathercole & Papagno, 1998). This theory implies that the ability to learn new words is constrained by the ability to hold intact phonological information in the phonological loop until that information is ready for long-term storage. Decay or degradation of this phonological information can inhibit word learning because information stored in long-term memory will consist of inaccurate representations

(Adams & Gathercole, 1996). Furthermore, if novel information exceeds capacity of the phonological loop, some information pertinent to forming accurate phonological representations will be unavailable, thus hampering the acquisition of new lexical items (Gathercole & Baddeley, 1990b). These findings, then, suggest that the rate of vocabulary acquisition is dependent on one's phonological loop capacity.

The ability to encode and retrieve information about past events is integral to word learning. Baddeley et al. (1998) suggest the ability to accurately store phonological material is essential for word learning in children learning their native language and adult learners of a second language. In fact, most researchers contend that memory is an important variable in language learning (e.g. Braine, 1994; Gathercole & Baddeley, 1990b).

For example, Rice, Buhr, & Oetting (1992) showed that both 5-year-olds with specific-language impairments and younger normally developing children who were matched on mean length of utterance required a greater number of exposures to retain new words than did language normal 5-year-olds, suggesting the process of encoding new words may dictate the propensity to learn new words quickly. In a similar investigation, Gathercole and Baddeley (1990a) looked at the ability to learn familiar or unfamiliar names of toys in children with differing nonword repetition scores, an index of working memory. Children who scored lower on the nonword repetition task learned significantly fewer unfamiliar toy names than did children with higher nonword repetition scores. These children did not, however, vary in their ability to learn toys with familiar names, suggesting children with poor memory may be unable to store transient phonological representations of unfamiliar words. Thus, they may have difficulty constructing stable representations of these words to store in long-term memory (Gathercole, Willis, & Baddeley, 1991).

These results plus findings from Adams and Gathercole (1995) implying a relation between memory and language production, suggest the process of learning new words requires children to make use of both new information held in the working memory and any existing information stored in long-term memory (Snowling, Chiat, & Hulme, 1986). Thus, it appears that the ability to encode, store, and remember is vital for new word-learning.

Memory has also been implicated in the learning of a second language. Cheung (1996) found nonword repetition was predictive of the number of trials needed to learn new words in a second-language. This result, however, held only for individuals with smaller vocabularies in that language. This finding mirrors that found by Arkenberg and Ryalls (submitted) which shows that memory plays a role early in lexical learning but falls off as vocabulary increases in size. Neurological findings support the contention that working memory plays an essential role in word learning as well. Ceponiene, Service, Kurjenluoma, Cheour, and Naatanen (1999) have shown that individuals who differ in their ability to repeat nonwords also show differential mismatch negativity amplitude patterns to speech stimuli. Event –related potentials were measured in response to frequent versus infrequent phonetic contrasts in 7- to 9-year-old children. They found that the larger the difference between P3 amplitudes for the different stimuli, the higher the score on the psuedoword repetition test. In the context of this experiment a difference between the P3 components for the two stimuli is thought to represent acknowledgement of, or attention to the difference between similar sounding stimuli. This result suggests that the accuracy of one's ability to discriminate phonological information may affect phonological memory and subsequently word-learning.

Effects of Language Acquisition: Advances in Working Memory

Experience with a language allows for changes to take place in terms of memory systems as well. Thus, while initial word-learning relies heavily on working memory, later-learning relies more on previously stored lexical items in long-term memory. To illustrate, Gathercole, Willis, Emslie, and Baddeley (1992) investigated the relations among the ability to learn new lexical items, their previous vocabulary knowledge, and their working memory ability in 4-, 5-, 6-, and 8-year-olds. They found that for 4- and 5-year-olds working memory best predicted the learning of new vocabulary items, while for 6- and 8-year-olds previous vocabulary knowledge was a better predictor of new word learning. Thus, with experience there is a decreasing need to rely solely on working memory for the learning of new words as the ability to use previously stored lexical items in long-term memory to buttress vocabulary acquisition increases. This research differs from previous results on working memory—instead of phonological memory, it appears that older children may be relying on their acquired vocabulary knowledge to support the acquisition of new words. This suggests that as children gain lexical experience, there is a change in lexical processing such that vocabulary itself starts to serve as a more important scaffold for children's learning of new lexical items.

As individuals gain experience with their native language other changes happen as well-- both the number of connections and the strength of connections between lexical items increase, resulting in the elaboration of the structure of the lexicon. These changes result in increases in the type and number of cues that can be used to recall a word, allowing for quicker recall of stored information. Ericsson and Kintsch (1995) suggest that an additional process ensues as well. Strategic retrieval structures, structures that contain both cues used for retrieval as well as the to-be-retrieved item, are stored as a separate entry- allowing for information to be recalled rapidly during instances where time constraints are present. In terms of word learning this means that frequently retrieved lexical items are represented in two ways- both as elaborations of retrieval cues and in terms of retrieval structures. When time is not a factor, using retrieval cues to detect a word may be a more beneficial strategy because it allows for consideration of related lexical elements and thus may allow for the selection of a less-frequently used, but more accurate term for the situation at hand. However, retrieval structures may allow for quick selection of good-enough terms that may not be as precise, but that get the message across in a short amount of time. Furthermore, as lexical learning proceeds, less frequently recalled terms may be routinized into retrieval structures allowing individuals the benefits of being fast and accurate. This process is similar to the idea of entrenchment proposed by Tomasello (2000).

There is some evidence for this idea. For example, Fernald, Pinto, Swingley, Weinberg, and McRoberts (1998) showed that 24-month-old children can identify familiar words presented in fluent speech based on partial phonetic information. Fifteenand 24-month-olds' eye movements were recorded as they looked at pictures of familiar items and listened to speech repeatedly labeling one of those items. The critical trial occurred when the label switched from the previously labeled object to the target object. The investigators found that children's latency to shift their gaze from the distracter to the target object was significantly less for phonetically distinct items (doggie versus tree) than for words with phonetic overlap (doggie versus doll). For phonetically distinct labels, 24-month-old children shifted their gaze by the second consonant- about 300ms into the word. Time to shift gaze for the phonetically similar items was twice that. This difference was not seen for 15-month-olds, suggesting that experience may in fact allow for the development of retrieval structures. Furthermore, Fernald, Swingley, and Pinto (2001) divided 18- and 24-month-olds into groups representing high- and low expressive vocabulary for their age. Children heard sentences containing one of four target words. Both accuracy and latency to look at the picture corresponding to the target word contained in the sentence were recorded. Results showed that infants who spoke more words were also more accurate in their picture selection and were faster to select those pictures than were children with smaller expressive vocabularies. This result was found for both 18- and 24-month-olds. These results suggest that experience may lead to more efficient encoding and retrieval strategies.

Retrieval structures may represent a type of forward-working strategy that emerges with experience. A common finding in the expertise literature is that experts are more likely to use initial information to make preliminary hypotheses about problems in their domain of expertise rather than considering an end-state (Larkin, McDermott, Simon, & Simon, 1980). This forward-working strategy is also seen in word-learning. The success of this strategy, however, depends on knowledge of phonology of one's native language and the development of the lexicon. For example, Vihman (1981) showed that both children and adults used forward-working strategies to determine a word after hearing degraded phonetic information, but that children were more likely to incorrectly guess at what a heard word might be. Charles-Luce & Luce (1990) suggest that findings such as these reflect the fact that because children's lexicons are steadily expanding, premature commitment based on partial information could lead to errors and thus interfere with word learning.

In sum, memory appears to play an important role in lexical acquisition and manifests itself, at least implicitly, from very early on. For later word-learning, memory is vital for encoding, storing, and retrieving of new words. As the lexicon increases, individuals can use information stored in memory as the basis for learning new words. When this basis is not sufficient new word learning suffers. Thus, the effect of memory on word-learning not only provides the initial foundation for word-learning, it also sets the stages for the emergence of the reliance on the lexicon as more important for determining word-learning later on.

What is missing from the literature however is the critical test of whether this process really does occur. That is, what is missing is the investigation of the effects of working memory prior to and during the acquisition of new lexical items. If phonological memory is important for word learning then a child's initial level of phonological memory should predict how many new words a child can acquire. Furthermore, this predictive relationship should change as a child acquires more knowledge such that the more words a child learns, the better current levels of vocabulary predict learning compared to initial levels.

Perception

Several investigators contend that phonological sensitivity, often referred to as phonological awareness, also plays a major role in lexical acquisition (Bowey, 1996, 2001, 2002; Snowling, et al., 1986, 1991). Stanovich (1992) defines phonological sensitivity as sensitivity to speech sounds. This ability is thought to arise from perceiving the speech of one's native language (Fowler, 1991). That is, knowledge of the sound patterns used in one's language is gained through linguistic experience. Sensitivity to such phonological structure gained through perceiving the speech of one's native language supports word learning (Werker & Tees, 1999). Word learning is thought to require the ability to identify and store the sounds, and units of sound, important in one's language.

Myers et al. (1996) suggest that the ability to segment words from fluent speech depends on children's knowledge of the sounds and sound structure important in one's language. Based on this work, Jusczyk (1993) developed a model, called the Word Recognition and Phonemic Structure Acquisition Model, to account for these tasks. In this model it is proposed that as speech enters the auditory system, children perform a preliminary analysis on this input to extract basic properties from the signal. These properties are weighted in terms of their importance in determining meaningful distinctions in the child's native language, where weighting amounts to directing attention to certain properties in the speech signal. The resulting weighting scheme that develops is appropriate only for that language for which that scheme was derived. The weight assigned to different acoustic properties changes as children gain experience with their native language (Eilers & Oller, 1976; Nittrouer, Manning, & Meyer, 1993), moving from initial emphasis on dynamic properties, to emphasis on the acoustic features of the signal that are most informative for making phonemic discriminations. The result of this refinement of phonemic categories is increased phonemic sensitivity. In other words, featural refinement affords the ability to make more accurate discriminations between phonemes with similar, but distinct sound units (Archangeli, 1988; Bird & Bishop, 1992; Gierut, 1996).

It has been posited that the ability to accurately discriminate phonological units may play a role in word learning (Snowling et al., 1986). As children gain experience with their native language, they are developing a database of frequently occurring and acceptable sounds and phonetic combinations for that language (Jusczyk & Hohne, 1997). This knowledge is thought to enable children to construct stable representations of new words by allowing them to infer whether an unfamiliar sound pattern can be a word in their language (Gathercole et al., 1997). Jusczyk, Luce, and Charles-Luce (1994) have shown that sensitivity to the phonological structure of one’s native language is, in fact, an important factor in word learning. These authors demonstrated that young children favor listening to phonological combinations familiar in one’s native language over phonological combinations that are unfamiliar. In their study, 9-month-old children were presented with either nonwords with phonological combinations familiar in their native language, or nonwords with unfamiliar phonological combinations. Using a head turn preference procedure, it was shown that infants clearly preferred listening to nonwords with familiar phonological combinations, as evidenced by significantly longer fixation times for nonwords with familiar phonology compared to nonwords with unfamiliar phonological combinations. The authors concluded that even young children appear to prefer speech that contains phonologically familiar information, that infants have learned that some sounds and sound combinations are more important in one's native language than are others, and that this phonological information can serve as a basis for what children will consider as possible words in their language (Jusczyk, et al., 1993). Gathercole, Frankison, Pickery, and Peake (1999) extended this work by investigating the recall of unfamiliar lexical items with either high frequency or low-frequency phonological combinations in 7- and 8-year-olds. They found significantly better recall for nonwords containing high-frequency phonological combinations compared to nonwords with low-frequency combinations. In sum, phonological knowledge appears to plays an important role in the learning of new lexical items.

Researchers have also suggested that individual differences in vocabulary acquisition may arise due to differences in the underlying representations of phonologically familiar lexical units (Gathercole, et al., 1991; Gathercole, Willis, Emslie, & Baddeley, 1992; Snowling, et al., 1991). Unfortunately, while this suggestion has been proposed, it has not been fully tested. Preliminary work is suggestive that this contention may be a plausible one however. To illustrate, Bowey (1996) has performed some research investigating the role of phonological sensitivity on individual differences in vocabulary. In her research, Bowey investigated the relation between phonological memory and already learned vocabulary, and phonological sensitivity and vocabulary in normally developing 5-year-olds. Using the traditional nonword repetition task to assess phonological memory capacity, and a rhyming task to measure phonological sensitivity, she found that both phonological sensitivity and phonological memory contributed a significant proportion of the variance in receptive vocabulary. That is, each factor added additional explained variance above and beyond age. These results suggest that phonological sensitivity can explain some of the variance in school-age children's vocabularies. Gathercole et al. (1991), however, found conflicting evidence in their study of 7- and 8-year-old children; in their investigation phonological sensitivity did not account for a significant proportion of the variance in the learning of nonwords. One possibility for the discrepancy between these studies is that phonological sensitivity may exert the majority of its influence on vocabulary learning at an earlier point in development. That is, the discrepancy between these studies could be the result of having used children of different ages, and hence different linguistic abilities. Jusczyk and colleagues' work described above suggests that phonological sensitivity is an important factor in word learning in very young children, implying that differences in phonological sensitivity may serve to account for a significant proportion of the variance between young children's lexicons. Much remains for future work to sort out concerning which types of words and which kinds of learning contexts are sensitive to effects of phonological sensitivity and phonological memory for 3 to 8 year-old children.

Effects of Language Acquisition: Advances in Perception

This field also includes research on how perception of the units of speech changes with linguistic experience. For example, Meyers et al. (1996) suggest the ability to segment speech depends on children's learning of the sounds and sound structure important in one's native language. Nittrouer, Manning, and Meyer (1993) contend that children weigh the acoustic cues contained within the speech stream and that the weightings associated with different aspects of the speech signal change as children gain experience with their native language. This process, termed the Developmental Weighting Shift, has been examined with a variety of speech stimuli and using a multitude of methods (see Nittrouer, 1992 and Nittrouer & Studdert-Kennedy, 1987 for example). In general, children weight dynamic cues in the speech signal more heavily than other cues. As children gain experience with their language the cues used to determine word boundaries change, from reliance on dynamic cues to the incorporation of more reliable cues for determining word boundaries.

Furthermore, this experience changes the way in which individuals perceive their environment. For example, Werker & Tees (1984) have shown that increases in individuals' linguistic experience result in decreases in the ability to perceive phonetic contrasts found in languages other than their own. Furthermore, experience with more than one language does not increase the ability to make discriminations in languages that individuals do not know (Werker, 1986). While the ability to make fine-grained phonetic distinctions is never lost, perception of linguistic elements becomes biased toward phonetic elements that identify meaningful distinctions in one's native language (Stager & Werker, 1997).

Similar findings are seen in terms of the repetition effect in bilingual individuals. Pallier (2002) investigated the repetition effect in individuals whose native language did and did not contain a critical phonetic feature. For individuals whose language contained that crucial feature, the repetition effect was observed. This result was not observed in individuals whose language did not contain the phonemic contrast, suggesting that the repetition effect was modulated by the phonemic systems of one's native language and that "the perceptual system builds a language-specific representation" (p. 2) that can be used for future processing. For example, in Study 3, Japanese speakers heard stimuli that either did or did not conform to the typical consonant clusters found in their language. In an ABX task listeners showed significant difficulties in discriminating VCCV stimuli from the typical VCuCV structure found in their language. In other words, perception was biased according to linguistic experience, leading listeners to 'hear' acoustic parameters that were not actually present. Pallier suggests that the consequence of experience on the cognitive system is the prediction of future phonological input. A system such as this affords individuals the increased processing time and/or space needed for ongoing language processing.

Perceptual refinement, however, does not imply the loss of the ability to learn to perceive non-native contrasts with experiences. Logan, Lively, and Pisoni (1991) and Lively, Logan and Pisoni (1993) showed that individuals whose first language did not contain a particular phonetic contrast could learn to discriminate that contrast as they gained linguistic experience. For example, Japanese speakers learning English were able to learn to discriminate /r/ vs. /l/, a phonetic contrast not apparent in their native language, after a 15-day training period. Each day learners heard two repetitions of sets of words containing the critical contrast and were required to perform a discrimination task. As listeners gained experience with that contrast their ability to discriminate it increased. In addition, their discrimination abilities expanded to include speech by multiple speakers. Thus, not only did these second-language-learners learn to discriminate phonetic contrasts not found in their first language, they also developed the ability to make this distinction across speakers of English, in essence overcoming the effects of talker variability. Ryalls and Pisoni (1997) have shown similar increases in the ability to overcome differences in speaker characteristics as the result of linguistic experience. This suggests that language experience allows individuals to learn the cues important for making fine-grained distinctions between phonological elements as well as learning which cues are static and which are variable in these discriminations. This perceptual reworking as the result of experience shows that elementary abilities such as perception do in fact aid in initial learning, guiding attention to important aspects of the learning situation in order to increase successful learning.

Further evidence suggests a relation between the ability to perceive speech and learn words. For example, Werker, Fennell, Corcoran, and Stager (2002) showed that 14-month-old children with higher vocabularies were better able to learn new words than their peers whose productive vocabularies were smaller. In addition, a correlation existed between 17-month-olds' receptive vocabulary and word-learning, indicating that the ability to attend to relevant characteristics of the speech signal may be the mechanism that enables change in word learning (p. 20). Thus, a sufficient vocabulary may more exactly specify phonetic details in the words of a language (Metsala, 1999).

The ability to learn words, then, is reliant on the early ability to perceive relevant linguistic units as well as the perceptual reorganization that occurs as the result of experience. These perceptual abilities are present early in life, providing the foundation for learning the words of a language. Experience with a language shapes these perceptual abilities, however, biasing future perception towards the known language. The ability to perceive contrasts pertinent for other languages is by no means lost, but the learning of a new language must entail the reallocation of perceptional abilities for the purpose of learning the elements of the new language. That is, components of speech perception interact, so that the perception of phonemes necessarily affects perception of words and vice versa. Furthermore, this is a dynamic, ever-evolving process that depends on experience with a language and on novelty, familiarity, complexity and other parameters of perceiving and learning new words.

In sum, phonological sensitivity is an important component of learning words. Furthermore, this ability is predictive of the ability to learn words and it appears that experience does alter this ability. However, again, the specific hypothesis that phonological sensitivity both contributes to word learning and changes as of the result of the word learning such that it become more fine-tuned for the learning of ones particular language has not been comprehensively tested in one study.

Attention

Posner and Petersen (1990) argue that attention is a two-part system consisting of both processing routines and a central executive controller that sets up and coordinates priorities and goals. Translated for lexical learning this means that the two aspects of attention needed to learn words are the ability to identify what aspects of a word one needs to attend to and the process of allocating resources for the purpose of learning a word. Individual differences in attention, then, may be the result of differences between children in terms of their vigilance, or in terms of their identification of relevant (and inhibition of irrelevant) parameters of a word. That is, an additional component of word learning is the ability to attend to relevant parameters of a to-be-learned word for the purpose of assimilating or accommodating that new information into one's existing lexicon. Children must be able to detect the relevant parameters used to predict the category to which a word may belong, and disregard parameters that are not predictive. Smith (2000) suggests that children must learn to identify which characteristics of an object or action to pay attention to so that similar elements can be grouped together.

Words do not exist in isolation, but rather, are meaningful only in terms of the item or items that they represent. This representation is stored, not as a single entity, but as an element of an architecture of previously encountered elements (represented objects and their corresponding words) and their meanings (Mandler, 1997). For learning to occur, children must categorize new objects or actions in order to fit them into their existing conceptual organization. How concepts are arranged in the lexicon remains unknown. Classical theories, or feature theories, of conceptual organization suggest that categories are defined by specific features that are individually necessary and collectively sufficient Others suggest the features are detected through association and concepts represent correlations between features and concepts reflected in the real world, this representing a probability view of conceptual organization. Further, researchers such as Rosch and Mervis (1975), and Medin and Smith (1981) suggest that concepts are more ill-defined than suggested by probabilistic views and that a more accurate way to think of categories is as representations comprised of exemplars, differentially weighted features, and combinations of dimensions. This family-resemblance approach specifies that concepts that are generally related to one-another, but there is no set of defining features that all category members share.

The concepts-in theories view (Murphy & Medin, 1985) specifies that categorization is related not only to specific features, or even goodness of fit, but to things not easily observable such as mechanisms, functionality, and causality. That is, in order to accurately describe how concepts are arranged, both implicit and explicit conceptual and categorical elements must be considered. Further, concepts are arranged according to an individual's reality, thus concepts may or may not map onto conventional real-world structure. However, knowledge aids in the discovery of the way concepts are arranged, and aids in the induction of properties that can help to constrain properties that were initially used for categorization, resulting in refinement and reorganization of what is already known (Keil, 1994) and aiding in future categorization.

Research by Keil (1989) supports the idea of reorganization with increasing knowledge. As individuals gain knowledge, explanations of relations between concepts play an increasingly important role. For example, Keil examined reported defining features for tools, meals, kinship, cooking, and morality in kindergarteners, 2nd graders, 4th graders and adults. He found that with age, individuals were more likely to identify implicit features, such as functionality, as defining characteristics, and use this information as a basis for their categorizations. The youngest children were more likely to include surface features as defining features for category membership. However, the extent to which explicit features were used depended on the domain being studied—understanding of implicit relations was stronger for domains such as tools, where a shift from explicit to implicit features occurred between kindergarten and 2nd grade, compared to moral terms, which was still not well-defined by adulthood. Keil (1992, 1994) suggests that when little is known about a concept associative information is the best predictor of category inclusion. However, with increasing exposure, an individual learns that, while some external features are useful for determining category membership, others are not. When the cues predictive of category membership are ambiguous or absent, individuals are left to search for an explanation that can be used to best predict categorization, resulting in the examination of possible causes for differentiation and the implicit features associated with that cause. Developmental changes in learning words may result from the awareness that different explanations may be used for the determination of category membership, allowing for insight into possible predictive features.

It may be, however, that simply examining possible explanations may not be enough for accurate classifications; variability may also be an important factor (Keil, 1994; Rips, 1989). For example, Gruberth and Keil (as cited in Keil, 1994) examined the tendency to provide a new name to a class of entities (artifacts, plants, animals) that differed from normal members by shape, size, pattern, or color. They found a relation between property change and class: variability in shape was an important consideration for a new name when animals and artifacts were being examined, but was less important when plants were being considered. In addition, for living things, individuals considered the extent of variability in all properties. Keil (1994) suggests that variability is important for making determinations about features but not about function. That is, variability may aid in the ability to initially form categories, while explanation may play a larger role in the reorganization of categories. In the Words of Waxman and Booth (2003), a growing lexicon can serve as the foundation upon which children “begin to notice correlations between particular *types* of words and particular *types* of relations among objects” (italics in original).

Eimas, Quinn, and colleagues (Behl-Chadha, 1996; Eimas & Quinn, 1994, 1996; Eimas, Quinn, & Cowan, 1994; Quinn, Eimas, & Rosenkrantz, 1993) have shown that even very young children (3-month-olds) form categories based on object properties. Using the familiarization-novelty-preference paradigm, children were familiarized to animal silhouettes (a cat or a dog) and were then shown a test stimulus-- either a novel silhouette from the same category, or a silhouette from the opposite category. They found that even 3-month-olds were able to form categories of objects based on perceptual properties- children who were familiarized with cats looked longer at the dog silhouette than the novel cat silhouette and vice versa, indicating that not only could infants discriminate the categories, they also showed a novelty preference. Furthermore, 4-

month-old children were able to ignore irrelevant perceptual attribute information during categorization. For these children, information from the head region, but not from the body was used for categorization. Quinn and Eimas (1996) suggest that children form categories based on static object properties that can be used to determine the category that object (and thus that word) belongs. Furthermore, perceptually based surface feature information used for initial categorization is thought to set the stage for later conceptually based categorization (Quinn & Eimas, 1997). Thus early systems that are not specific to language learning allow for the emergence of specific language learning abilities.

Waxman and Markow (1995) have shown that naming enhances children's ability to categorize their world. They sequentially presented 13-month-olds with category exemplars (animals, vehicles and tools) at either the basic or superordinate level. The exemplars were paired with their familiar label or were not labeled during presentation. They found that when objects were labeled, infants paid attention to those labels, as evidenced by more quickly habituating to the exemplar category and by better recognition of new exemplars of that category. This was especially pronounced at the superordinate level, when perceptually based similarities are not as apparent, suggesting that labeling allows infants to use names for the formation of categories. It is important to note however, that the categories used were categories that were likely familiar to the infants (animals, vehicles, tools) and thus naming might be important only for known objects.

Effects of Language Acquisition: Advances in Attention

Infants may be able to use naming information as a tool for the formation of new categories as well. For example, Nazzi and Gopnik (2001) looked at 16- and 20-month-olds abilities to form new object categories when two types of cues were presented: visual clues or naming information in an object manipulation task. Infants were provided with object triads that included two identical objects and a third different object and told to play with the items. In the naming condition the similar objects were labeled with the same name and the third object with a different name. One of the similar items was then picked up and set aside and the child was asked to give the investigator the object that went with the one that had been set aside. Results showed that 20-month-olds were more likely to give the investigator the matching item when it had been named compared to the 16-month-olds, and were more likely to give the investigator the similar object when it had been labeled compared to when no label was presented. Sixteen-month-olds responded at chance. Of further interest was the positive correlation between children's performance on the selection task and their productive vocabulary (as measured by the CDI) suggesting that children who had used naming information during categorization were those children who also had higher vocabulary scores than children who did not use names.

Yoshida and Smith (2003) showed similar results for the influence of naming on categorization. They presented children with an object and labeled the object. They then showed children three additional objects and asked children to choose which one of the objects was called by the same name as the first object. In the first experiment objects were labeled with known names that corresponded to some object property (shape, color, or texture). They found that children were more likely to select the shape-matched object when the nouns referred to shape, the similar color when the object matched on color and texture with texture. Thus, children were using names as a guide for how the novel object could be classified. In the words of Yoshida and Smith, “names of things by themselves activate attention to the perceptual properties relevant to that category.” When nouns were unfamiliar nouns, children were more likely to fall back on the shape bias—the bias that is generally most relevant across categories.

This is implicit in ideas about the restructuring of the lexicon as children gain knowledge. Emergent perspectives suggest that word-learning emerges from general learning mechanisms that are not specific to language learning but that nevertheless contribute to it. This contribution results in initial word learning which then in turn assists later word learning. Thus, general learning accounts can explain different aspects of lexical acquisition and early word learning. Learning that arises from general mechanisms then assists in future learning by directing perceptual experience and attention and inferring semantic patterns, allowing for a universal account of word-learning (Reiger, 2003). For example, associative learning has been shown to guide generalization about category membership, even when categories may not be mutually exclusive, by enabling children to develop general expectations that can then guide future word learning at an accelerated rate (MacWhinney, 1999; Merriman, 1999). Reiger (2003) suggests that words and their multiple meanings are housed in separate similarity spaces that are reciprocally linked by associations. At first, words would be similarly linked. However, through repeated exposures memory inference forms. This inference affords children the ability to detect the differences they can use to determine how to link future items and how to reorganize their initial links. Thus, experience drives the development of selective attention towards dimensions that are relevant and can thus be used to best predict categorization (Reiger & Carlson, 2001). This selective attention both increases attention to variables that are most predictive and decreases attention to dimensions that are less predictive. Learning proceeds rapidly because as more words are learned, the more predictive different dimensions become. This phenomenon is seen in the development of expertise as well. Compared to novices, experts are more likely to use forward-working strategies when attempting to solve problems. These strategies are riskier because they use assumptions that are based on previous knowledge, rather than deductive reasoning. The advantage to forward-working strategies is speed. As knowledge increases the chance of being correct on any given problem increases, allowing experts to infer certain dimensions of the problem without testing them directly. At first, this strategy results in more incorrect answers; however, with enough experience, knowledge is gained that increases the probability of being correct by tailoring the kinds of assumptions with which the expert approaches the problem (Vihman, 1981).

Children must pay attention to relevant attributes, and disregard irrelevant attributes of the to-be-learned word (Smith & Medin, 1981). Furthermore, expertise literature suggests that as children gain expertise, their propensity to access categorical information about words changes in terms of the level of categorization (Johnson & Mervis, 1997). Often learners may either ignore relevant cues or attend to irrelevant cues.

What is required to learn an association between a word and its meaning may be the learning of inattention (Kruschke, 2003). Some children may be slow to learn words due to their inability to shift between cues that represent different dimensions and which are predictive of category membership for some words but not others. For example shape may be predictive for the addition of a new dog into the superordinate category of dogs, however, function may be more predictive for subordinate classifications. The inability to identify and switch cues for the purpose of word learning may result in individual differences in word learning.

During the process of learning a word children rely on two pieces of information: the distinction between previously learned associations between words and object properties and the current association between properties of a to-be-learned word and that word, and an understanding about the extent to which different attributes matter for the type of word that is being assimilated into the lexicon (Keil, 1994). This information guides attention to different parts of novel objects. For example, when children are learning names of animals or plants they use the best predictor for determining what kind of animal this new animal might be based on what they know about animals- that shape rather than color or texture is generally the best predictor of kind (Smith, 1995, 2000).

Smith (1995, 2000) has suggested the Attentional Learning account. She suggests novel nouns are generalized according to shape and that this bias is the result of attentional learning. As children learn words they generalize that different things have different names, and that objects with the same name have the same shape. Furthermore, as continued learning occurs they further generalize that shape can be used as a predictor for future encounters with novel objects. Associations between object names and object properties direct attention to specific properties relevant to the category to which the object belongs. Perception then is the product of learning words and categories (Goldstone & Barsalou, 1998; Smith & Heise, 1992; Yoshida & Smith., 2003, 2005) - and thus the more words a child knows the more her attention is tailored to the properties of the words she has learned previously.

In sum, lexical learning involves the formation of categories. This ability involves the discovery of the cues that can be used to best structure the lexicon. This discovery leads to the allocation of attention to properties that are most predictive of category membership. Children who are slow to learn words may lag behind their peers in their ability to identify which aspects of a word are most predictive for word learning, thus failing to allocate attention to those properties and inhibiting their rate of lexical acquisition. Although some attempt has been made to examine the effects of different types of clues on attention for categorization, there is no well-established experimental or correlational link among attention, categorization, and word-learning. An additional goal of this study was to examine the role of attention to predictive classification clues on word-learning. As with the other cognitive abilities, this study examined whether extensive word learning across several months would impact attention levels.

Abstraction

Certainly perception, memory, and attention are important for word learning. However, for optimal learning to occur, each aspect of word learning that has been discussed must support abstraction processes. The ability to abstract information has been defined in a number of ways. Abstraction is going beyond perception to the formation of a ‘gist-like’ idea of a concept, complete with fuzzy boundaries. Posner and Keele (1968) in ‘On the genesis of abstract ideas’ state “When a man correctly recognizes an animal he has never seen before as a dog, he has manifested the ability to generalize from previous experience.” That is, to abstract is to generalize from previously encountered information for the purpose of applying that information to novel instances (pp. 353).

Markman and Gentner (2001) further specify abstraction as the process of comparison, which includes structural alignment and inference projection. Structural alignment includes matching of semantically similar relations within and between categories. To derive structural alignment children must identify commonalities, which emerge through comparison, and differences, that are salient to the similarity comparisons. Noting both similarities and differences influences new inferences that can be drawn from comparison (Markman, 1997), providing the mechanism for constraining inferences. Comparison allows for abstraction by determining local matches and promoting a focus on common relational systems that can be used for abstraction, highlighting differences, inviting likely inferences, and reorganizing the representational system. When not much is known about a domain, comparison between similar concepts is limited because few instances exist in the representational network.

As an illustration of this phenomenon, Nelson, Denninger, Olewiz, and Kovac (as discussed in Nelson and Nelson, 1978 and Nelson, 1987) showed 3- and 5-year olds four similar objects labeled with novel names and presented children 500 exemplars- some of which could be generalized well to the same category and others that could not. They found that the rate of generalization for ‘good’ matches was 97%, while the rate of non-matching for poor category matches was 77%. At both ages increased numbers of defining features not satisfied by the exemplars was related to decreased extension of the category name to an exemplar. Further, older children were more likely to allow extension to objects with more wrong-features than were 3-year-olds, suggesting that with increasing age children are more likely to extend their generalizations to nonevent matches. In sum, older children have learned that defining features can vary from exemplar to exemplar and that these features may be compiled across exemplars such that a general rule about extension can be formed.

Effects of Language Acquisition: Advances in Abstraction

Gentner and Markman (1997) and Gentner and Holyoak (1997) suggest comparison between exemplars is the mechanism for abstraction-based findings. Comparison changes knowledge by highlighting commonalities, by inviting inferences from more to less familiar exemplars, particularly when presented with common labels, and by initiating re-representations of the concepts- that is by attempting to understand a novel situation in terms of one that is familiar. They suggest that common labels may allow children to notice more abstract commonalities between objects and then, once noticed, use those deeper traits to determine other category members. As stated by Gentner and Namy (1999, pp. 40), “Even if initial extensions are perceptually based, later comparisons among instances may give rise to deeper insights into category structure.” Further, Markman and Gentner (2001) claim that comparison allows for matching of semantically similar representations both within and between categories-- it allows for structural alignment. Inferences can be drawn by comparing new information to similar information from known domains.

Words may invite children to discover meaningful categories (Waxman & Markow, 1995) by providing a core for learning a more general category. Even very young children appear to apply what they know about words for the purpose of assimilating information. Waxman and Booth (2001) suggest that 14-month-olds use word types such as nouns and adjectives to determine whether to classify objects at the basic or superordinate level. They found that when objects were labeled with adjectives (purple) children were more likely to select a superordinate category match (animal). However, when objects had been labeled with a noun (horse), children selected the basic level category match more often. They argue that word types allow children to direct their attention to the property that they know best describes either as basic or superordinate match. That is, they know that adjectives can refer to properties across categories, while nouns refer to within category properties. They further suggest that children appear to learn this as they gain linguistic experience—when 11-month-olds were tested they did not use word types as a clue to category membership (Waxman & Booth, 2003).

Imai et al. (1994) provide additional evidence of the abstraction abilities of young children. In their study they showed 3- and 5-year-old children a series of target objects. Each target was presented with three additional objects- a similar item from a category match, a thematic match, or perceptual match. A second condition was employed as well, where children were taught new words in a ‘dinosaur language’ and then asked to choose items with similar names. Overall, they found that 3-year-olds shifted their choice away from the thematic match to the perceptual match (based on shape), and this finding was stronger when children were taught new names, rather than in the no-name condition. Five-year-olds, however, chose the category match more often than did 3-year-olds in both conditions, suggesting an age-related trend in the propensity to choose a category match. Imai et al. suggested that with age, children experience a “shape-to-category shift” that is based on naming. Early grouping strategies are based on thematic relations; however, as children learn words they learn that items that are similarly shaped are often of the same kind and share the same name. Moreover, as children learn names they learn that although shape may be a good predictor of categories initially, in some cases naming offers a better clue to category membership than does shape.

Gentner and Namy (1999) further suggest that young children may choose perceptually based items in instances where multiple comparisons cannot be made, and that provided with the opportunity to compare across instances insight into category structure may occur. Gentner and Namy investigated 4-year-olds’ categorization in a word-extension task. Children were taught a new word for a familiar object (an apple) and were then asked to select a match to the target from two pictures- one that was perceptually similar but out-of category (a balloon), and one that was a perceptually different category match (a banana). In this condition children were just as likely to choose the perceptual match as the category match. However, when children were provided with multiple target exemplars (an apple, a pear, a watermelon slice, grapes), they were more likely to select the category match (the banana), even when the other (the balloon) was more perceptually similar, suggesting that multiple instances of a category can help to delineate category for the purpose of extending words. What may be going on as children gain experience is the ability to draw analogies.

Moreover, Waxman and Namy (1997) have shown that preschoolers can use known information to classify novel objects. They presented children with toys that corresponded to well-known categories. They named a familiar object with a novel name and then presented two additional objects, one that matched the category to which the object belonged and one that did not. They were then asked which object best went with the first object. Children were more likely to choose the taxonomically related object. Landau, Smith, and Jones (1998) extended these findings by using the same methodology, but with novel objects as well as novel names. Objects differed by shape, texture, or color. In this case children were more likely to choose objects that matched in shape. Landau, Smith, and Jones (1998) suggest a number of different characteristics of words can be used to highlight rules about how children might best fit those words into their knowledge base—as children are learning words they are learning rules for how to assimilate new lexical items into their knowledge base.

Johnson and Mervis (1994) have shown that acquiring knowledge about a domain does in fact result in reorganization of one’s conceptual hierarchy and that this reorganization results in abstracting rule-based information that can be applied to new category exemplars. In their study, Johnson and Mervis induced shorebird expertise in school-age children. They found that as children acquired more and more information about shorebirds, the connections between different elements of the bird families both merged, in terms of bird attributes, and diverged, in terms of shorebird families, suggesting that increases in knowledge allow for generalization in conceptual knowledge as well as refinement in category knowledge. Further, child experts who knew a lot about songbirds learned shorebird exemplars more quickly than did children who did not know about songbirds, suggesting that learning not only about exemplar, but also about category membership was occurring.

Deak, Ray and Pick (2002) have also shown convincing evidence of abstraction in older children, and that a relation may exist between children's short-term memory and their ability to apply a rule they have learned. They showed 3- and 4-year-old children three objects. One of these objects could be matched to another of the objects by shape and another by function. Children were then provided with a rule instructing children to match objects by either shape or function. They found that while 4-year-olds could successfully match by either shape or function, 3-year-olds could not—3-year-olds consistently matched by shape. When children were not provided a rule both 3-and 4-year-olds tended to match the intermediate object by shape. Interestingly, however, when prompted about the function of the objects, both 3-and 4-year-olds were able to specify the use of the objects, as well as the object name. The authors suggest that 3-year-olds tendency to match by perception, despite knowing about function, is the result of taxing of their short-term memory. To categorize information using perceptual clues does not require children to hold much in mind during the process of categorization because the information that forms the basis for categorization is readily apparent and requires minimal working memory. However, conceptual bases for categorization, like function, are based on abstracted rules. To successfully categorize based on function children must not only identify the parameters important for categorization, but then remember this information while categorization is occurring. Young children may fail to categorize on the basis of function not because of an inherent lack of understanding, but because of a failure to both maintain an abstract rule and categorize at the same time.

In sum, as children are learning about concepts they learn which elements of a concept can be best used to infer category membership. With increasing knowledge comes increasingly connected concepts. The more knowledge a child gains about a domain, the more their lexicon becomes interconnected and the better able they are to make the structural alignments needed to infer new rules for assimilating or accommodating information into their lexicon. Repeated exposures to relative information increasingly connects the lexicon, allowing for increasingly efficient abstraction process to occur.

Effects of Language Acquisition: the Development of Lexical 'Expertise'

Increasing lexical experience allows for the development of increasingly elaborated lexicons. In addition, lexical experience may be aiding in the refinement of the cognitive abilities that initially served in the onset of lexical learning. There are clues from the literature that suggest that children are becoming more and more efficient at word learning as they learn more words. In fact, children are often characterized as experts at learning words. The similarities between theories of children's lexical development, and the theories of development of any area of specialized skill, or expertise, are quite striking. Expertise can be defined as highly proficient performance that results from increasing experience in an area, or domain, and that results in changes in the way information about that domain is processed. By this definition lexical acquisition can be thought of as the development of an area expertise.

The claim that children are expert word learners is generally used in a figurative sense. However, should we take this claim more seriously? In fact, up to this point no studies have attempted to equate the processes of lexical learning and the development of expertise, despite similarities in the theoretical underpinnings of both literatures, and despite the evidence that currently exists that provides clues about this similarity. Using the analogy of children as budding lexical experts provides a number of benefits to the field of word learning. First, the expertise literature, mostly on adults, provides a framework for placing the pieces of the lexical acquisition puzzle. Adopting the view that the process of word learning is similar to the acquisition of expertise allows us to adopt a similar theoretical framework. In fact, there are many implicit similarities between theories of how word learning proceeds and the development of expertise. Providing a theory of lexical learning based on the theoretical underpinning of expertise development would make the link between word learning and the development of expertise explicit. An additional benefit is the inspection of variables that might contribute to learning, and those variables that might contribute to individual differences in learning. Knowing how children gain knowledge in a domain of expertise, and the factors associated with variability in this gain can contribute to our knowledge about lexical acquisition by allowing investigators to draw an analogy between these two fields. Finally, both the characteristics and the benefits of being an expert are well-documented. Thus, if children truly are expert word learners, or are on their way to becoming experts, then they should show the same characteristics, reap the same benefits, and exhibit the same detriments as individuals who are acquiring knowledge in any domain.

What does it mean to be an expert?

Expertise is defined as skill or knowledge in a particular area that arises from experience and is identified by performance. Expertise can apply even to skills in which many individuals exhibit a high level of performance. The progression from a lower or simpler to more advanced or complex form or stage, as in the case of lexical learning, can be thought of developing expertise. Bedard and Chi (1992) suggest a number of characteristics that define experts in any domain. By definition, experts are individuals who know more about some domain than do others. However, while amassing information is necessary, expertise is not just accumulation of knowledge—the way that knowledge is structured is an additional characteristic of expertise. To illustrate, Johnson and Mervis (1994) induced shore-bird expertise in school-age children. They found that as children acquired more information about shorebirds, the connections between different elements of the bird families both merged, in terms of bird attributes, and diverged, in terms of shorebird families, suggesting that increases in knowledge allow for generalization as well as refinement in category knowledge. In a similar study Chi and Koeske (1983) detailed a child dinosaur expert's knowledge base for well-known and lesser-known dinosaurs. As noted above, they found that well-known dinosaurs generated more links to other concepts and were recalled faster than elements of lesser-known dinosaurs, suggesting that both the number of connections and strength of connections were greater for the dinosaurs for which the child knew a lot. Similarly, Johnson and Mervis (1998) found that novices use featural perceptual similarity to categorize classes of objects while experts use their background knowledge for categorization. These results imply that the way domain knowledge is structured for experts differs from that of novices, and that as individuals gain expertise, cognitive restructuring of domain-related information may be occurring.

Acquisition of domain related information may be beneficial in a number of other ways, allowing for some additional characteristics seen by individuals with domain expertise. For example, a well-documented benefit of learning about a domain is increased memory for domain information. In their classic study, Gobet and Simon (1966) presented novices and experts with either legal or illegal chessboard configurations and measured their recall of the arrangements. When the chessboard configuration was a configuration that was possible in the game of chess experts' recall of the configurations surpassed the recall of novices. However, when the configurations were unnatural chessboard configurations, the recall for the configurations for experts and novices did not differ. Chase and Simon (1973) suggest that the learning of domain-information results in the development of perceptual structures- chunks of information, in this case familiar chess-board patters, that can be quickly recalled that correspond to natural and familiar events in that domain. Memory for domain material depends on the organized long-term memory of specific information about chessboard patterns. Whereas novices must abstract from what they see on the board in order to encode a position, experts can rely on the contents of their memory to recognize and to encode rapidly the position. That is, knowledge structures from LTM seem to be involved in expertise (Gobet and Simon, 1996). According to Ericsson and Kintsch (1995) exceptional memory performance is possible because experts acquire the ability to quickly and effectively store the products of varying stages of processing, and their corresponding retrieval cues, as structures in long-term memory.

Experts differ from novices in their ability to recognize important domain-related features as well (Newell & Simon, 1972). To illustrate, Reingold et al. (2001) measured the visual span and eye movements of novice, intermediate, and expert chess players for typical chess configurations and random ones. Experts showed dramatically larger visual spans for structured chess positions. However, this pattern was not observed for random configurations. Furthermore, compared to intermediate players and novices, experts made fewer fixations between individual chess pieces when viewing chess configurations. Theses results illustrate that experts show a perceptual advantage for domain related information that cannot be attributed to more global abilities in attention, perception, or memory, but rather to the garnering of relevant information to their domain of expertise.

Further, Chastrette (2002) investigated the classification systems of perfumery experts during odor discrimination of different chemical compounds. He found that compared to novice classification systems, those of experts included descriptions for odors and different vocabulary that were not included in categorization schemes of novices. Chastrette concluded that experts in perfumery tune into chemical properties not used by novices during their discrimination of odors. That is, developing expertise results in the recognition of relevant, perceptually-based, domain-related information needed for precise discrimination. Experts key into aspects of domain information that are not employed by novices, information that they have acquired through specific experiences with that domain.

Any perceptual advantage seen in experts necessarily goes hand in hand with the related ability of attention (Gibson, 1991). She suggests the development of expertise can be thought of as the education of attention. In his specificity theory he states that learning about a domain is, in effect, perceptual learning that results from recognizing the strategy that is most economical for a domain-related task. This focuses attention to the minimal number of distinctive features that can be used to successfully discriminate among the features. The development of expertise, then, consists of changing what one attends to, with the goal of being able to identify discriminatory, high-order information. Vicente and Wang (1998) further suggest in addition, that an outcome also plays a role in the development of expertise. In their Constraint Attunement Hypothesis they suggest that the more relevant a goal-state is, the more attention will be allocated to the attainment of that goal and the defining properties of that goal in order to maximize the probability of attaining that goal. For example, Weber and Brewer (2003) compared recall for sequences of field hockey plays by experts and novices when individuals were and were not attending to the sequences. They found that experts better recalled the sequences than did novices and that for all participants recall systematically decreased as attention to the sequences decreased. Furthermore, they found a significant interaction between attention and expertise where attention enhanced recall of the field hockey sequences. Weber and Brewer suggest that attention allows experts to recognize the constraints associated with the goal in order to identify the characteristics needed to attain that goal. In other words, being able to pay attention to the sequences allowed experts to use what they knew about the domain to identify the moves important for accurate recall of the sequences.

Rassmussen (1985) suggests that the development of expertise in any domain results in several layers of understanding and discovery, or abstraction, of the rules that apply to that hierarchy. First, individuals must recognize that a domain can be divided hierarchically, but that while there may exist different levels of the domain, one can draw similarities across those levels. Each level deals with the very same system; the only difference is that different level provides different descriptions, or different models, for observing the system. Different levels of the hierarchy consist of their own unique set of terms, concepts, and principles. By moving up the hierarchy, one obtains a deeper understanding of significance with regard to the goals that are to be achieved, whereas in moving down the hierarchy, one obtains a more detailed explanation of functioning in terms of how those goals can be carried out. For example, learning about dinosaurs allows individuals to recognize that different types of dinosaurs exist, thus recognizing the need for classification and that dinosaurs can be classified according to nonperceptually-based characteristics, like function, for the most accurate distinctions.

The development of these different levels of understanding has three benefits: it allows for problem-solving within a domain by allowing individuals to structure information, it allows them to start their problem-solving activities at a higher hierarchical level to simplify the problem, and it allows for focusing on different levels to selectively attend to only those parts of the domain that are relevant to the function of interest (Vicente & Wang, 1998). Research on chess experts also shows that their background knowledge can be used to buttress learning. For example, Reingold, Charness, Schultetus, and Stampe (2001) taught good and fair chess players new chess moves. They found good players learned the moves more quickly than did the average players.

In sum, experts show a number of characteristic traits: they have more knowledge, and that knowledge is structured differently than that of novices, and as a result they show perceptual advantages compared to novices, they show differential allocation of attentional resources, and they show the development of a complex, orderly hierarchical understanding that results from the abstraction of general and specific information in the domain of expertise. That is, there appears to be cognitive restructuring of several sorts as individuals gain knowledge.

Can word learning be described as the acquisition of expertise?

Suggesting children are on their way to becoming experts in word learning, requires that children show evidence of emergence the same traits as individuals who display expert performance in any domain. Experts are characterized by a number of different traits, including increased domain knowledge, quicker learning, and increased proficiency in terms of their memory, perception, attention, and abstraction of information related to their area of expertise. The literature to date on children who are learning words suggests that children also display these same traits.

With an increase in the number of words one knows comes a number of possible benefits. One such benefit is the restructuring of the lexicon. Restructuring of the lexicon includes increases in strength and number of connections between words and word elements (Gobbo & Chi, 1986). This is implied repeatedly in theories of lexical learning (MacWhinney, 1998). Detailing the lexicon is an immense project even when young children are being considered. Charles-Luce and Luce (1990) however, have attempted to detail the database of categories of words in 5- and 7-year-olds', and adults' lexicons. Their general findings suggest that the words in children's lexicons have fewer similarity neighbors than do the same words for adults, and further, that 7-year-olds have more similarity neighbors than do 5-year-olds, suggesting the structure of the lexicon increases with increasing lexical items. Similarly Charles-Luce and Luce (1995) measured the similarity neighborhoods of 3-, 4-, and 5-year-olds' lexicons. As before, they found that similarity neighbors increase as individuals acquire new lexical items, again demonstrating that one consequence of lexical acquisition is growing complexity of relations in the semantic network. These results imply that cognitive restructuring is occurring with the acquisition of knowledge—in this case words. Furthermore, they support the contention that word learning and the development of expertise are comparable processes.

The cognitive restructuring that occurs with lexical learning also appears to contribute to the rate at which individuals learn words. In short, children and adults who know more words also learn new words more quickly. Recall that Rice et al. (1990) showed when children are of normal age and language ability they require fewer presentations of a novel word to learn that word than do language delayed and younger children. Furthermore, the rate of learning appears directly related to children's current receptive vocabulary levels—the more words a child knew, the fewer repetitions that child needed for novel word learning to occur, suggesting that developing expertise in word-learning is related to, and may contribute to, quicker lexical learning.

Word-learning appears to result in memory advantages as well. For example, Fernald, Pinto, Swingley, Weinberg and McRoberts (1998) showed that 24-month-old children can identify familiar words presented in fluent speech based on partial phonetic information. Fifteen- and 24-month-olds' eye movements were recorded as they looked at pictures of familiar items and listened to speech repeatedly labeling one of those items. The critical trial occurred when the label switched from the previously labeled object to the target object. The investigators found that children's latency to shift their gaze from the distracter to the target object was significantly less for phonetically distinct items (doggie versus tree) than for words with phonetic overlap (doggie versus doll). For phonetically distinct labels, 24-month-old children shifted their gaze by the second consonant- about 300ms into the word. Time to shift gaze for the phonetically similar items was twice that. This difference was not seen for 15-month-olds, suggesting that experience may in fact allow for the development of retrieval structures. Furthermore, Fernald, Swingley, and Pinto (2001) divided 18- and 24-months olds into groups representing high- and low expressive vocabulary for their age. Children heard sentences containing one of four target words. Both accuracy and latency to look at the picture corresponding to the target word contained in the sentence were recorded. Results showed that infants who spoke more words were also more accurate in their picture selection and were faster to select those pictures than were children with smaller expressive vocabularies. This result was found for both 18- and 24-month-olds. These results suggest that experience may lead to more efficient encoding and retrieval strategies. Metsala (1999) has also illustrated that older children and adults needed less phonetic information to recognize a word with fewer similarity neighbors than do younger children. Furthermore, adults were able to recognize more high frequency words with fewer similarity neighbors than were either 5- or 7-year-olds. These results suggest that experience with words allows for more efficient recall.

A burgeoning lexicon also results in attention and perceptual advantages during the process of word learning in a language. For example, Smith, Jones, Landau, Gershkoff-Stowe, and Samuelson (2002) showed that making an object property salient simply by highlighting that property through labeling of objects with similar properties allows children to generalize more abstract conceptions about word-learning situations and subsequently increase their propensity to learn new words. They suggest that as children learn words they first learn to make first-order generalizations such as cups are cup-shaped. With word-learning experience they learn higher-order generalizations regarding a general principle such as x’s are x-shaped. Children, then, learn that reliable properties across objects can be used to for novel name learning, thus leading to rapid naming acquisition.

Similarly, learning more than one language results in these same kinds of benefits. For example, bilingual children routinely outperform monolingual children on tasks measuring the control of attention and inhibition in word learning. For example, when children are provided with sentences that violate grammar but are semantically plausible, bilingual and monolingual children do not differ in their ability to identify the sentences as ungrammatical. However, when sentences are grammatical but semantically meaningless, bilingual children are more accurate at identifying sentences as grammatical than were monolingual children, suggesting that bilingual children are more able to separate parameters of grammar and meaning (Bialystok, 1986; 1988b). Bialystok asserts that this ability results from the need to be aware of abstract dimensions of language such as when to use a particular language. Learning about one's languages, then, results in learning when to pay attention to particular characteristics of the situation.

Bilingual children show advantages over monolingual children in tasks that would appear to be more domain-general as well. For example, Bialystok (1999) showed that the performance of bilingual children exceeded that of monolingual children in the dimensional card task and the moving words task- tasks that required attentional control and the control of inhibition. Bialystok suggests that one of the consequences of learning two or more languages simultaneously is the early development of attentional control ability to inhibit nonrelevant characteristics. In this case experience directs attention. In general, then, experts in a domain do show attentional and executive function benefits resulting from experience with domain related information.

The learning of domain related knowledge results in changes in strategy use regarding that domain as well. For example, lexical development allows a learner to use previously acquired lexical knowledge as a foundation for making generalizations about new information. Fernald et al.'s (1998) results that children use partial phonetic information to identify a spoken word, and that this ability emerges with lexical experience, suggests that individuals with lexical knowledge can use that information to make decisions about future word-learning. Research comparing strategy use in experts and novices shows that experts are more likely to use initial information to make preliminary hypotheses about a problem solution while novices prefer to have a goal-state in mind prior to attempting a problem (Larkin et al., 1980). Thus, novices are more likely to use backward-working strategies while experts typically make use of forward-working strategies. While forward-working strategies are riskier, they are also more cognitively efficient because they rely on previously stored knowledge. Experts save both time and effort making educated guesses about the way to best approach an unfamiliar problem based on their knowledge of previously encountered problems.

The younger a child is, or the less experience she has with a language, the more she must rely on input alone to recognize a word for the determination of whether that word is known, which would be reflected in the amount of time needed to process that word. In fact, Vihman (1981) has shown that young children use forward-working strategies to recognize the words they know, but that because both their knowledge of the phonology of their native language and their lexical content is limited, these strategies often result in incorrect guesses of what a word might be. As children learn more words the use of this strategy dramatically improves. In general, parallels can be drawn in terms of the way novices and experts approach problems and how individuals at different stages of language development access lexical items. The use of different strategies evolves as the result of gaining knowledge in a domain. This aids in the acquisition and compilation of new information, including lexical learning- words, by allowing cognitive resources that would be taken up by resource-intensive backward-working strategies to be allocated to the purpose of acquiring new knowledge. Thus, the acquisition of knowledge, including lexical items, results in changes in the way individuals go about using that information. Novices do not have the skills or the knowledge necessary to make preliminary hypotheses about information based on input alone. They must perform resource-intensive searches of their acquired knowledge to gain enough information to adequately solve a problem. Experts, on the other hand, can use their previously acquired knowledge as a bridge for gaining access to possible solutions, saving time and energy.

In sum, experts know more about a domain, their domain knowledge is better structured, they show quicker learning of domain-related material, they show clear memory advantages for information in their domain of expertise, they show clear attentional and perceptual advantages for material related to their expertise, and they use different strategies for obtaining information about their domain of expertise than do novices. Individuals learning the words of a language show increasing proficiencies in these same aspects.

In realms where most people reach a high level of proficiency, as in vocabulary, individuals are not routinely characterized as experts when they espouse high levels of skill. However, although most individuals are able to learn the words of their language this does not mean that individuals are not experts in lexical acquisition or that variability in word learning does not exist. The processes seen in lexical development and the development of expertise appear too similar to deny that comparable processes are at work. Overall, the evidence so far reviewed tentatively suggests that word-learning can be thought of as budding expertise in lexical acquisition.

With this reconceptualization comes many benefits. Expanding the view of lexical development to include elements of development of expertise forces researchers and theorists to think about other factors that contribute to the development of the lexicon. For example, experts show a great deal of metacognition concerning their domain of expertise (Barnett & Koslowski, 2002; Voss et al., 1986). While some work has been performed looking at the effects of language learning on metacognitive skills (see Bialystok, 1998, Snow, Cancino, DeTemple, and Schley, 1998, and Malakoff and Hakuta, 1998 for examples), investigations have not been applied to lexical learning *per se*.

A further benefit concerns the increase in methods traditionally used to study the effect of expertise. For example, microgenetic studies are often performed to investigate changes in a knowledge domain that take place as the result of learning (Siegler, 1994). This technique allows for the inspection of the restructuring that takes place as the result of learning. Applying this kind of technique to lexical learning would help to delineate the kinds of changes that are occurring as children learn words, and help us to identify which properties of the system contribute to learning and which result from it.

Finally, the expertise literature may help integrate and refine theories of lexical learning and language learning. Currently we have different theories to account for different aspects of lexical development. However, there are few overarching theories that attempt to explain children's lexical acquisition. A global architecture on which to hang our current theories would provide the structure needed for the development of a global theory of language learning. With insight and initiative the goal of understanding children’s lexical development within the framework of expertise development is possible and likely.

The aim of the current project was to provide the evidence needed to begin the process of relating lexical learning to expertise by investigating the three main links needed to connect lexical learning with expertise. First, there are no studies that document the process of learning many new words over a short period of time. Providing a clear picture of the process of word learning itself, rather than the vocabulary measures traditionally used to investigate lexical advances, will allow for clearer vision into the mechanisms directing lexical acquisition. Thus, one goal of this study was to investigate, via microgenetic methods, the trajectory of children’s word learning for the purpose of documenting increases in learning as the result of acquiring new words. In addition, while there are numerous studies investigating variables that contribute to word learning in young children, few studies have investigated have consequences of word learning, and specifically the consequences for cognition as well as future lexical acquisition. A second goal of this study then was to investigate across time the cognitive abilities of memory, perception, attention, and abstraction, all abilities shown to contribute to children’s word learning, and all abilities that experts show increased proficiency, in order to examine whether lexical acquisition does indeed result in increasing refinement in cognition. Investigating changes in cognition that result from advances in lexical learning can help to draw alliances between the fields of expertise and word learning, allowing for the use of the sturdy, well-developed framework theories of expertise have to offer. Finally, showing that children who have learned many new words are processing new information related to those words in a way that is more efficient than children who have not engaged in the learning or new words will help to show that children are becoming proficient at dealing with novel information in a way that is similar to how experts process novel information in their domain of expertise. Satisfying these goals will provide a richer understanding of a more clearly defined progression of lexical acquisition in young children and will help to draw the analogy between word learning in young children and the development of expertise.

Summary and Hypotheses

In the past theorists have acknowledged the roles of cognitive abilities such as attention, perception, memory, and abstraction in children's acquisition of new words (Golinkoff, Mervis, & Hirsh-Pasek, 1994; Hollich et al., 2000; MacWhinney, 1998; Tomasello, 2000; Smith & Katz, 1996). For example, Gathercole and colleagues (1992, 1999) have shown that the learning of new lexical items can be explained in part by phonological memory (as well as previous vocabulary). Others, such as Bowey (1996), and Storkel and Morrisette (2002) have illustrated a relation between phonological sensitivity and lexical development such that the better one's phonological sensitivity the stronger the correlation to acquisition of past and current words learning. Further, Quinn and Eimas (1997), Reiger (2003) and others have shown that children pay attention to cues they know are important for making word-object pairings. And, finally, the ability to abstract rules is integral in the ability to categorize new lexical items (Gentner & Namy

1999) and may be mediated or modulated by short-term memory abilities (Deak, Ray and Pick, 2002).

In sum, previous literature identifies at least four cognitive abilities-- perception, memory, attention, and abstraction-- thought to aid in children's ability to learn the words of their language. Moreover, a comparison between the development of the lexicon, and expertise development suggests a similarity in terms of the processes involved in learning in any domain. Theorists interested in lexical learning suggest that these abilities that initially serve to guide word learning also change as the result of word learning such that they become fine-tuned for the language that a child has experienced (Golinkoff, Mervis, & Hirsh-Pasek, 1994; Hollich et al., 2000; MacWhinney, 1998; Tomasello, 2000; Smith & Katz, 1996), although this idea has not been experimentally examined. However, there is a wealth of evidence suggesting domain general abilities provide the basis for later language learning. The capabilities to perceive, remember, attend to, and abstract aspects of one's environment all appear to play a role in children's future capacity to learn language (Saffran, Aslin, & Newport, 1996). And, the expertise literature provides us with clues to what changes to look for in these and related skills within a period of extensive word learning by young children.

Unfortunately no investigation into how these factors may influence each other and work together to contribute to both current and future learning has been attempted, nor has any systematic investigation been performed to investigate the benefits of word learning. However, by examining how perception, memory, attention, and abstraction affect word learning, and how the result of word learning affects these abilities, one can begin to determine the nature of the underlying process of children's lexical learning. Further, possible shift in expertise can be examined with multiple variables when children's learning of an extensive new set of lexical items is tracked microgenetically.

The purpose of this study was to examine three main questions regarding lexical learning: 1) In a microgenetic study what does the course of lexical acquisition look like? 2) How do perception, memory, attention, and abstraction contribute to lexical learning across development, and related, how are they impacted by lexical learning?, 3) Does word learning appear to mimic development of expertise?

Question 1

Hypothesis 1. A first hypothesis predicted that learning rates would increase over time. In particular it was expected that the proportion of words learned would be significantly greater for each subsequently taught domain such that a greater proportion of words would be learned in the last taught domain (D3) compared to the first (D1) or second (D2) taught domains and that learning in the second domain would be significantly greater than the proportion of words learned in the first domain.

Question 2

Hypothesis 2. The second question concerned the ways specific cognitive abilities contribute to lexical acquisition across time, and how these abilities change as lexical learning proceeds. A second hypothesis predicted that levels of phonological sensitivity, working memory, attention, and abstraction would contribute to word learning initially, that these abilities would themselves improve, and that potential changes in abilities would result in different relationships between these abilities and learning across time. Because no previous studies have investigated all four cognitive variables in the same study and in relation to word-learning of a large number of words across time, it was unknown how these variables would relate to each other or to learning.

Hypothesis 3. A third hypothesis predicted that, in addition to increases in overall learning across time (as predicted in the first hypothesis) and increase in cognitive abilities (as predicted in the second hypothesis) children who were learning words would outperform a matched control group who did not engage in the word learning portion of the experiment on assessments measures measured at the second (T2) and third (T3) assessment periods.

Question 3

The final question concerned whether lexical learning across time is similar to the development of expertise. In part discussion of this question will be anchored to the results covered in the previous two questions. In addition a series of additional measurements were obtained that also bear on possible increases in expertise by the intervention children, with the expectation that children in the intervention groups would outperform children in the control group. The measurements included the Rapid Animal Naming (RAN) task, and a sorting task designed to tap into children’s developing ability to rapidly distinguish between specific exemplars from domains being learned.

In attempt to answer these questions a 12 week microgenetic study was performed, where a combination of measures were used to assess children's working memory, perception, attention, and abstraction at three points in time-- prior to word-learning (T1), midway through learning (T2), and after word learning ceased (T3). Two groups of children participated. The intervention group was taught 450 unfamiliar animal names from three animal domains over the course of 12 weeks. A matched control group engaged in the assessments but did not participate in word learning.

Chapter 2

METHODS

Participants

Participants of ages 4- to 5-years were recruited from local childcares through the use of flyers and by word of mouth. The upper and lower age limits are based on typical cooperativeness, and the typical age at which children have extensive language knowledge, but have not yet begun a systematic reading program. Children engaged in a systematic reading program may represent a population that differs from other children recruited for the study and were thus eliminated as possible participants through screening of their knowledge about letters and reading by way of the Print Awareness task from the Preschool Comprehensive Test of Phonological Processing (Lonigan, Wagner, Torgesen, & Rashotte, 2002). Studies investigating phonological memory, phonological sensitivity, attention, and abstraction (categorization) typically include children of this age. Therefore it is possible to compare results from this study to previous findings. Furthermore, research on these elements has shown that these abilities change during this age period, thus allowing for variability.

A total of 25 children participated. Of these children four did not complete testing: one parent whose child was in the learning group decided the time commitment was too cumbersome, and three children (one in the word-learning intervention group and two in the matched control group) refused to cooperate with the testing procedures. Thus a total of 21 children were included in the final analyses. Ten of these children participated in the word-learning intervention portion of the experiment, while 10 served as matched controls. In the process of finding matched controls an additional child was run on the assessments at all three time periods and is thus included analyses, resulting in a total of 11 participants in the control group. Mean age across groups was 52.86 months (*SD* = 4.11), while mean age within the intervention group and the control group was 52.10 (*SD* = 4.36) and 53.55 (*SD* = 3.96) respectively. This difference was not statistically significant. Approximately half of the children in each group were boys and half were girls (6 boys, 4 girls in the word-learning intervention and 6 boys, 5 girls in the control condition). An analysis of gender differences, age and of the different measures using the Mann-Whitney U showed that there were no significant differences between genders.

No child had ever been diagnosed as having a developmental disability. One child in the intervention group spoke Mandarin Chinese in addition to American English. Visual inspection of this child’s data suggested there was no difference in any of the assessment measures or learning curves for this child compared to the other participants. Parental reports suggested that none of the children at the outset of the study from either the intervention group or the control group had any more than everyday knowledge about the three domains that were of interest.

Children in the two groups were matched on their expressive and receptive vocabularies, their awareness of print, their initial phonological sensitivity, memory, attention, and abstraction abilities and their latency to name and sort animals from domains that were being targeted in this study as well as control domains. There were no significant differences between the two groups on any of these measures. Means and standard deviations for the print awareness task and for expressive and receptive vocabulary for each group are provided in Table 1. Initial scores for working memory, perception, the two attention measures, and abstraction are provided in Tables 2 through 6, respectively.

Table 1.

Means and standard deviations for the print awareness task and for expressive and receptive vocabulary for each group.

	Print Awareness		Expressive Vocabulary		Receptive Vocabulary	
Group	M	SD	M	SD	M	SD
Intervention	9.90	3.45	23.40	3.60	10.10	1.60
Control	8.64	3.38	24.55	1.86	9.95	0.93

Measures

Initial Cognitive Assessments

The purpose of the initial assessment battery was to determine current levels of working memory, perception, attention, abstraction abilities, general vocabulary knowledge, and awareness of print (a measure of early reading abilities) prior to the beginning of training in order to obtain baseline values.

Working memory

Memory was assessed by a composite of items from the Word Span and Nonword Repetition subtests of the Preschool Comprehensive Test of Phonological and Print

Processing or PreCTOPP (Lonigan, Wagner, Torgesen, & Rashotte, 2002), and the Digit-Span task used by Gathercole et al. (1999). These tasks are the most extensively-used measures of phonological and working memory in children, are regarded as being highly reliable measures, and demonstrate a strong relationship to retention of phonological information and vocabulary acquisition (Gathercole & Baddeley, 1989; Dollaghan, Biber, & Campbell, 1995; Gathercole et al., 1999, Gray, 2003; Lonigan, Wagner, Torgesen, & Rashotte, 2002; Wagner, Torgeson, & Rashotte, 1999). Items from all three measures were used to initially assess phonological and working memory because these measures are thought to tap into different aspects of phonological memory and can provide a more global understanding of children's proficiency in this area. The digit-span task requires a child to listen to single digit numbers presented in series of increasing lengths and repeat those numbers in the correct sequence. Research suggests that nonword repetition performance may depend not only on phonological memory ability, but also on accumulated lexical knowledge. For example, Gathercole and Baddeley (1990b) and Dollaghan, Biber, and Campbell (1995) have demonstrated that the more word-like nonwords are, the easier they are to repeat-- thus providing children with more developed lexicons an advantage in word span and nonword repetition tasks because they can utilize words stored in long-term memory to help them remember nonwords. Because normally developing children between 4 and 5 are familiar with numbers, a difference due to lexical advantages should not occur for digit span.

The phonological memory composite used consisted of a possible eight items correct on the digit-span portion of the test, seven items correct on the word-span portion of the test, and four possible items correct on the nonword repetition section of the measure, totaling a possible 19 items correct for the phonological memory portion of the assessment battery.

Perception

Phonological sensitivity is best described as a combination of skills (Hulme et al, 2002; Stanovich, Cunningham, & Cramer, 1984) that are represented by one factor (Lonigan Burgess, & Anthony, 2000; Anthony et al., 2002). Thus, to accurately assess children's sensitivity to phonological units a composite measure needs to be employed. The phonological sensitivity measure used in this study was adapted from the PreCTOPP, a commonly used measure designed to assess blending, elision, and initial sound matching phonological abilities. In all, seven items from the blending subtest, five from the elision subtest, and four items from the initial sound matching subtests of the PreCTOPP were used, resulting in a phonological sensitivity composite consisting of 16 items. Correct answers received a score of 1, and incorrect answers a score of 0, for a maximum total correct of 16 points.

Attention

Related to but separate from both working memory and perception is attention. In the context of this study attention is defined as both vigilance and in terms of children's identification of relevant (and inhibition of irrelevant) parameters of a word. Rapid Object Naming (RON) tasks allow for the investigation of a number of abilities- including attention. Fluid access to familiar verbal names and related efficiency in activating names from memory, sustained attention to the task, and children's processing speed are all important components of rapid naming (Wagner, Torgesen, & Rashotte, 1999). Working memory constraints are minimal in these tasks because recall of stimulus names from a set in working memory is not required- pictures of the to-be-named elements are available throughout the task. In addition, once elements have been retrieved from long-term memory in this task that constantly uses these elements they should be heavily primed and re-retrieved rapidly as needed or just maintained in working memory. What is left to be successful, and what is most likely measured in this task, is children's sustained attention during the task. Children must not only name the elements as quickly as possible, but also continue to do so over a period of time. Thus, latency to name the items on the rapid naming subtest of the PreCTOPP was used as one measure of attention.

The ability to allocate resources to word-relevant parameters may rely on the inhibition of irrelevant parameters of the stimulus as well as allocation of attention. Thus, attention is comprised of both perseverance, measured by the rapid-naming task, and ignoring of characteristics contained within a task that are not directly relevant to the success of that task (Luria, 1973). To assess children's ability to ignore interesting, but irrelevant characteristics in a word-learning task children were presented with a modified version of the dimensional change card sort (DCCS)- a measure that is typically used to measure executive function, but can also be used to assess the ability to attend to changing dimensions. In this task children are presented with two target pictures that differ on two dimensions (color, and shape) and must sort a series of test cards according to one of the dimensions, and then the other. Children between 4 and 5 vary on their ability to successfully sort the cards (Zelazo, Mueller, Frye, & Marcovitch, 2003), with some children perseverating on the first sorting dimension. Children engaged in five pretrial sorts, and five sorting trials for each dimension, for a total of 15 trials. The total number correct (out of 15 items) was used as the second part of the assessment for attention.

Abstraction

Abstraction was tested using the word-extension task outlined in Gentner and Namy (1999) and Namy and Gentner (2002). In this task, children were presented with a familiar object labeled with a nonword (for example, flitwick for an apple). They chose between two possible matches for that object-- one that was perceptually similar (a balloon) but not from the same basic category and one that was from the same basic category as the target but was perceptually different (a banana). Children were asked to choose which item was also another “X” (in this case a flitwick). Ten items of this kind were presented. In a second part of this task children were shown multiple target exemplars and asked to select the category match. Gentner and Namy suggest providing multiple exemplars of the target item allows for comparison processes to occur, aiding in children’s ability to categorize items based on conceptual dimensions (i.e. kind). This section also contained a total of 10 items. Because the focus of the study concerned abstraction skills as a whole, all items were combined, resulting in an overall measure consisting of 20 items, and a possible total correct of 20 items. Correct was defined as the choice of a conceptual match.

Print awareness

The print awareness measure used in this study was adapted from the PreCTOPP. It was shortened for the purposes of this study. In this task children were asked to identify which of a series of stimuli were letters, what the letters were, and/or what sound they make. A total of 14 items correct were possible on this task.

Vocabulary

Both expressive vocabulary and receptive vocabulary were measured using shortened versions of the Expressive and Receptive Vocabulary subtests from the Preschool Comprehensive Test of Phonological Processing (PreCTOPP). In the expressive vocabulary test children were shown a picture and were asked to label the item presented in the picture. This measure contained a total of 28 items of increasing difficulty, resulting in a possible total score of 28. In the receptive vocabulary test children were shown 12 pages consisting of four pictures. Children were provided with a label for one of those four pictures and were asked to point to the picture that represented that label. A total of 12 items correct was possible.

Mid and Final Cognitive Assessments

With the exception of the vocabulary and print awareness measures, modified versions of the initial assessments were given. Modifications included different specific items from the original tasks. These items were taken from the unmodified PreCTOPP. Because split-half reliability is good for all of the subtests (Torgesen & Wagner, 1998), and for all of the phonological memory measures a change of the specific items did not pose a problem to the validity of the study.

Expertise Assessments

Children engaged in three additional tasks at each assessment period that were designed to examine possible development of expertise. The first was the Rapid Animal Naming (RAN) task. In this task children were asked to name a list of three common, repeated animals (a robin, a poodle, and a mustang) as quickly as possible. The procedure for this test was identical to the Rapid Naming Object task with the exception of the different specific items. Pilot work suggested these domain exemplars are all familiar to children of this age and easily identifiable. In addition, these specific animals were not taught in the learning section of the experiment. Latency to name the animals was used as the outcome variable. As children develop expertise about a domain they should show increasing ability to rapidly identify and label exemplars from domains for which they are gaining expertise, allowing for quicker naming of these exemplars. In contrast to the Rapid Object Naming task, we would expect that for children learning an extensive number of words, children in the intervention group, there would be a decrease in naming latency of a larger magnitude for RAN items compared to RON items. Furthermore, there should be a difference in RAN performance for children learning items from these domains compared to children who are not. Thus, we would expect that for both the RAN and the RON performance across time would be relatively stable for matched control children, but would increase for children engaged in the learning condition.

An additional measure was used to gauge children's ability to sort similar domain exemplars from domains where children were learning words compared to control domains. Developing expertise is thought to include the ability to rapidly identify differences between domain items for the purposes of quick identification. In this task children were asked to sort five tokens of three different domain exemplars (for a total of 15 items to sort) for each kind of animal being learned and for a set of control animals. In all children sorted six sets of cards—three sets of experimental animals (one dog set, one horse set, and one bird set), and three sets of control animals at the first domain and three sets of experimental and two sets of control animals in the second and third domains. For the experimental sets none of the specific items were being taught to the children in the intervention portion of the experiment. Furthermore, the specific items for each group differed for each assessment period, such that while at each assessment children needed to sort a group of horses, a group of dogs, and a group of birds, and control animals, they never sorted the same specific set of items twice. Which set was sorted first was randomly determined. Control animals were mice, monkeys, frogs, beetles, butterflies, cats, and penguins. For all animal sets a group of eight adults rated items within domains (sets) as being highly similar, and rated all of the sets to be of similar difficulty. Average latency to sort experimental items and average latency to sort the control items were as used as the dependent variables.

A final task, called the daily matching task was performed in order to examine possible changes in children's conceptual understanding of the domains being taught. In this task, called the daily matching task, children were presented with three animals from a domain: a target animal, an animal that was perceptually similar (the perceptual match) to the target but did not belong to the same subdomain (e.g. working dogs), and an animal that did belong to the same class but did not look similar to the target (the conceptual match). All animals were labeled and the children told the subdomain prior to each matching trial. For example “This is a hound dog (target animal). This is a hound dogs (conceptual match). This is a toy dog (perceptual match). Who would this one (the target animal) rather play with?” Regardless of the child’s choice, the investigator always followed the response by saying. “O.K. Why do they want to play together?” This procedure was repeated five times with five different target animals from the same subdomain. Target animals always corresponded to the subdomain that the child was to learn that day. This procedure provided two kinds of data. First, total number of conceptual versus perceptual preferences was obtained. Second, justifications for those choices were collected, including the number of perceptually-based justifications, conceptually-based justifications, and justification that could be classified as neither, called nonsense justifications, were calculated. Because there were five trials per day the maximum score for each day for each score was five. Justifications were coded by two trained coders. Cohen’s kappa revealed agreement of 93% between these two coders. In cases were disagreement occurred the two coders discussed the disagreement until a consensus was reached.

Procedure

All children in the intervention group were tested at the Language Pathways Laboratory at The Pennsylvania State University. Children in the control condition were either tested at the above location or in a quiet room at their childcare center. Care was taken to ensure that the surroundings were equated so that any difference in the location was minimized.

Cognitive Assessments

For both the word-learning intervention group and control group the procedure for the initial, mid, and final assessments were the same, with the exception of the print awareness and vocabulary measures, which were only administered at the initial assessment. All children were introduced to the investigator and the testing room, and testing and/or training occurred when the child was visibly comfortable with the testing situation. The initial assessment measures were collected on the first visit. The second assessment period occurred at the halfway point of intervention, between learning of the third and fourth category of the second domain, and the third assessment period occurred at the end of Domain 3 learning. For children in the control group each child was matched with the child in the intervention group whose initial scores most closely approximated her own scores. In addition, the number of days between assessments was equated for those two children so that for the number of days between assessments was same for children in the same pair. There were two exceptions where the assessment (once for second assessment and once for the third assessment) fell on a day the child could not participate. In one case the control child was run one day earlier than her match and in the other the child was run two days later. The mean number of days between the first and second assessments was 40.30 days (*SD* = 2.69) for the intervention children and 40.20 (SD = 2.56) days for children in the control group. Mean number of days between the second assessment and the final assessment was 40.80 (2.48) and 41.00 (SD = 2.65) days for the intervention and the control children respectively. The number of learning sessions between testing was the same for all of the children in the intervention group.

Children were always taught the entire first domain and half of the second domain prior to the second assessment, and the rest of the second domain and the entire third domain prior to the final assessment.

The order of testing was the same for each child. In all cases receptive vocabulary was assessed first, followed by expressive vocabulary. This order was followed because prior research investigating receptive and expressive tests have been standardized using this order and because this order allows children who are temperamentally shy extra time to become acclimated before having to produce spoken speech. The vocabulary measures were followed by the print-awareness measure, the phonological sensitivity composite, the phonological memory composite, the DCCS, the RON, and the match-to-target abstraction task. The expertise assessments (the RAN and the sorting task) were administered last. This order was specifically chosen because in pilot testing some children found some measures to be more difficult than others and some tasks to be more enjoyable than others. Thus measures that were found to be especially tedious for children were interspersed with the easier or more enjoyable measures in order to keep children from becoming discouraged due to continual difficult assessments. Testing lasted approximately one hour for the initial assessment and 45 minutes for the interim and final assessments.

Learning Sessions

Children in the intervention group participated two to three days a week for approximately 10 weeks. Each session lasted roughly 45 minutes. Over the period of learning children were taught 450 new lexical items- 150 types of dogs, horses, and birds, with approximately 50 new words being taught each week (16, 16, and 17 words per day). In some cases fewer animals or more animals were taught in a session. This occurred when only a few remaining items were left to be learned in a category, or when the number of animals left to learn in a category was less than 16.

All children learned the same animals from the same domains: dogs, birds, and horses. These domains were selected because there are at least 150 kinds of animal within each domain and the animals in each domain can be classified into at least seven subdomains. Furthermore, when asked during pilot work, children stated they would be most interested in learning about animals in these domains. Because children in the experiment all showed interest in these domains, but which domain was considered most interesting varied by child, presentation of the domains was standardized such that four children were presented with dogs first, then birds, then horses, three children learned birds first, then horses then dogs, and three children learned about horses, first, dogs second, and birds last. Which domain the children started with was randomly determined.

Approximately four weeks were allocated to learning of each domain. Because change in children’s ability to learn words within a domain was of interest, all words from a domain were presented to children prior to the learning of the next domain. During piloting, when presented with a small learning set from each of these domains, children did not vary in their ability to learn words in any particular set. Thus it was unlikely that order effects were incurred by learning any particular domain before the others.

While the domain order was prespecified, the words each child learned each day were randomly determined by the investigator teaching the words. New lexical items were presented during child-directed play. Play included any number of activities, such as games, story-book reading, and free play. Games include a memory game, in which the child turned over cards in an attempt to find a matching animal, and a game played on a game board, where the child would spin a spinner to move a game piece to a square that displayed a new animal. Story-book reading included looking through a book with pictures of domain animals engaging in some activity, and discussions between the child and the investigator that arose as stories were being read or books were being looked at. Both games and stories were designed by the investigator to promote interest and engagement with target animals. Free play included activities such as drawing or coloring domain animal pictures, pretend play with stuffed animals of the targets and miscellaneous activities. It is important to note that what activity was engaged in and for how long was determined by the child. In this way the investigators could maintain the child's engagement throughout the session and could incorporate recasts and expansions of utterances concerning the animal names. Previous work by Nelson and colleagues (Camarata, Nelson, & Camarata, 1994; Nelson, 2001; Nelson, et al., 1996; Nelson, Welsh, Camarata, Tjus, & Heimann, 2001) demonstrates that when children are presented with language input by way of recasting, children with syntactic difficulties show increases in their syntactic competence at a rate greater than that which would be expected otherwise. Furthermore, unpublished research from our laboratory suggests that during syntactic intervention sessions that employed recasting, children with syntax delays learned new vocabulary items as well as showing gains in syntactic competence over the term of their treatment, even though the purpose of the intervention was not focused on children learning new words. This suggests that the use of recasts during training of new vocabulary items is one powerful method for exposing children to new words. Moreover, prior research indicates for recasting, story reading, and other activities with children that more rapid learning occurs when challenges are combined in short episodes that dynamically bring together also favorable social and emotional and attentional conditions. A strong theoretical rationale for the importance of such challenge, plus other-conditions and episodes also has been provided in writing on dynamic systems theory (e.g. Camarata, Nelson, & Camarata, 1994; Nelson, 2001; Nelson, et al., 1996; Nelson, Welsh, Camarata, Tjus, & Heimann, 2001) and on the variant labeled Dynamic Tricky Mix theory (Nelson, Craven, Xuan, & Arkenberg, 2003; Nelson, Welsh, Camarata, Tjus, & Heimann, 2001). Accordingly all the varied ways of presenting lexical items in this study were designed and monitored to try to insure high levels of dynamic convergence of multiple learning conditions, with the expectation that this would support high lexical learning rates by the 4-year-old participants.

Teaching of the animal names consisted of the investigator producing the name of each target animal at least eight times, the child producing the animal name at least once, and the subcategory (e.g. working dog) of the animals being learned produced at least once. To illustrate, when a child found a match in the memory game, the investigator would say “Hey, nice job! You found another ‘kuvasz’. This dog is called a ‘kuvasz’. Yep, a ‘kuvasz’. Can you say ‘kuvasz’? That’s right a ‘kuvasz’. Let’s look at the ‘kuvasz’. Did you know a ‘kuvasz’ is a kind of sporting dog? The ‘kuvasz’ likes to swim.” These teaching methods were similar to those used by Johnson and Mervis (1994) during the teaching of shore bird names.

Assessment of Learning

The visit after each learning session began with an assessment of what the child had learned the day before. This visit took place from one to seven days after initial learning had occurred, with the average interval being 2.76 days (*SD* = 1.50) days. Color pictures on cardstock measuring 4 x 4 inches square that corresponded to the animals the child had learned on the previous visit were placed before the child and the child was asked to label each of the animals. Instances of recall were scored as a 1. Children were then given a test of recognition with the remaining animals. For this portion four of the remaining animals would be randomly grouped together and the child was required to point to the animal whose name was produced by the investigator. The child was required to correctly point out the animal two out of three times in order to be considered correct. Correct recognition was scored as a 1. Learning, then, was defined as the number of animals recalled plus the number of animals recognized over the total number of animals taught that session, resulting in the proportion of animals learned.

Analyses

All analyses were performed using SPSS version 9.0. In studies with few participants the variables being measured rarely approximate the normal curve, violating one of the major assumptions of parametric testing. Furthermore, inspection of the assessment measures at the different points in time and across the two groups showed that the assumption of homogeneity of variance was untenable in this experiment. In many cases there was either an increase or a decrease in the variability associated with the intervention group relative to the control group. Lastly, for almost all assessment measures at least some violation of skewness or kurtosis was present. For these reasons, it was felt that the use of nonparametric statistics to investigate predictions would be most appropriate. Nonparametric statistics do not require assumptions that the underlying distributions are normal, are less resistant to effects of outliers, and are generally more appropriate for testing small samples sizes than are parametric statistics. It should be noted however, that while nonparametric approaches were employed, parametric statistics were also run. Comparisons of results from these different statistical procedures revealed very few instances where results were discrepant and none where they were divergent. For only one instance parametric statistics employed without the nonparametric equivalent performed as well—learning data were revealed to be normally distributed and relatively homogeneous across time. For this information the use of parametric statistics was appropriate.

Chapter 3

RESULTS

The purpose of this study was to examine three main questions regarding lexical learning: 1) In a microgenetic study what does the course of lexical acquisition look like? 2) How do perception, memory, attention, and abstraction contribute to lexical learning across development, and related, how are they impacted by lexical learning?, 3) Does word learning appear to mimic the development of expertise?

Question 1: In a microgenetic study what does the course of lexical acquisition look like?

Hypothesis 1

In this study, children's learning was assessed microgenetically, that is, the proportion of words learned was obtained for each of the seven categories of animals within the three domains. Results of learning across the seven categories for Domains 1, 2, and 3 are plotted in Figure 2.

Several trends are immediately apparent when examining these plots. First, for each domain there appears to be a period of decreased learning, a regression period, in the middle of domain learning. In Domain 1, Domain 2, and Domain 3, children were better able to remember animals from the first and last taught categories than they were animals in Categories 2 through 6. For Domain 1 the proportion of animals remembered from the Category 1 was .59 (SD = .18), while the proportion of animals remembered from Category 7 was .69 (SD = .13). For Domain 2 the proportion of animals remembered from the Category 1 was .60 (SD = .21), while the proportion of animals remembered from Category 7 was .75 (*SD* = .20). Finally, for Domain 3 the proportion of animals remembered from the Category 1 was .65 (*SD* = .20), while the proportion of animals remembered from Category 7 was .76 (*SD* = .18). The low point of learning occurred at Category 5 for the first Domain, where mean proportion of words remembered was .43 (*SD* = .18), and Category 3 for both Domain 2 and Domain 3, where mean proportion remembered was .44 (*SD* = .22) and .51 (*SD* = .24) respectively. Results from the Wilcoxon Signed Ranks tests revealed a significant difference between the first category within the Domain 1 and category in which the lowest proportion of words was remembered for Domain 1 (category 5), where $z = -1.89$ ($p < .03$). In addition, the comparison between the last category in Domain 1 and the category in which the lowest proportion words was remembered for each of the three domains was significant, where $z = -2.67$, $p < .004$. For Domain 2 only the difference between the last category and the category in which the lowest proportion of words was learned (Category 3) was significant ($z = -2.56$, $p = .005$). Comparisons within Domain 3 revealed a significant difference between Category 1 and category in which the lowest proportion of words was learned (Category 3), where $z = -1.68$, $p < .05$, and Category 7 and Category 3, where $z = -2.67$, $p < .004$. Thus, the pattern of learning was remarkably similar for each of the domains that were learned, with the only difference in terms of the regression period being the tendency for children to show a decrease in the proportion of words learned sooner for the first domain than the other two.

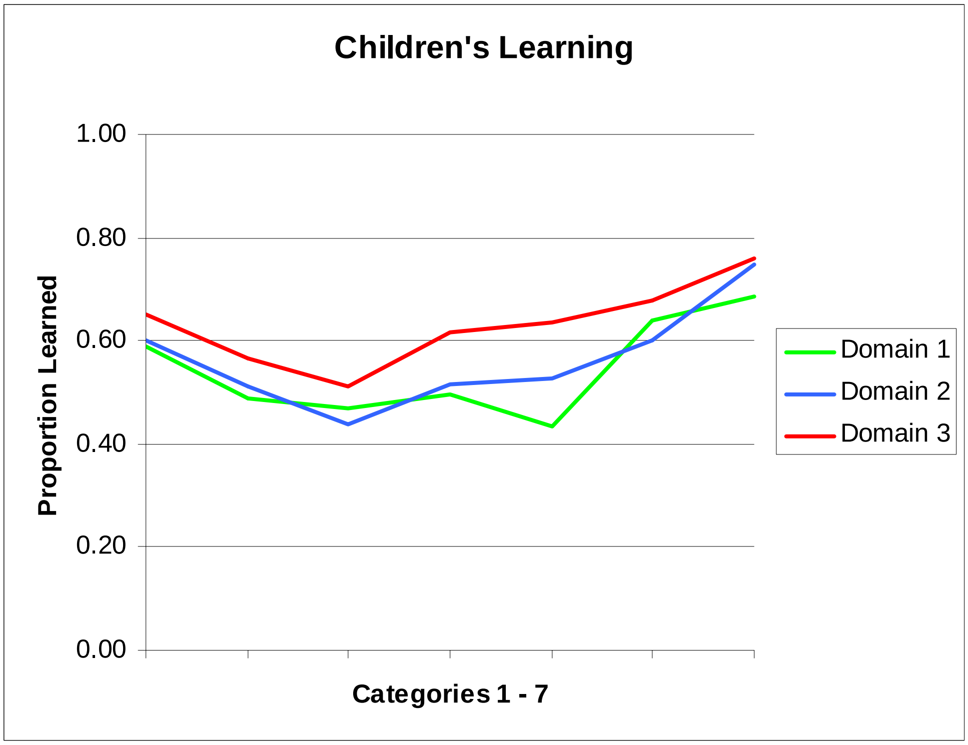


Figure 2. Mean proportion learned for each animal category across the three taught domains.

An additional trend concerned the proportion of words learned at the beginning of each domain compared to the end of each domain, that is, the difference between learning for Category 1 and learning for Category 7. To determine whether these differences were stable, three Wilcoxon Signed Ranks tests were computed. In the Wilcoxon Signed Ranks test the median rank across the two groups of scores is obtained, and then each score is assigned a positive or a negative rank, depending on whether that score falls above the median or below it. The number of positive ranks and negative ranks for each group of scores is calculated and then compared. A significant difference occurs if there are more positive ranks associated with one group of scores than with another.

For each domain the difference between learning at the beginning of the domain and learning at the end of the domain was statistically significant; the proportion of words learned at the end of the domain was always greater (there were more positive ranks) than the proportion learned at the beginning of that same domain. Thus, for the first domain the proportion of animals learned in the last category (Category 7) was significantly greater than the proportion of animals in the first category ($z = -1.68$, $p < .05$). Similarly, learning of animals in Category 7 was significantly greater than learning of animals in Category 1 in the second domain ($z = -1.68$, $p < .05$), and learning of the last taught category in the third domain was significantly greater than was learning of animals in the first category of that same domain ($z = -1.78$, $p < .04$).

In sum, the picture of word learning within domains is one that is marked by two consistent features. Learning increases over time such that learning for animals at the end of a domain is always greater than learning of animals of the beginning of that domain, and learning within a domain consistently shows a period of decreased learning in the middle of learning of that domain. Thus, in general it appears that learning increases over time, but it that within periods of learning many highly related items these 4-year-olds show a decrease in performance in the middle of their domain learning.

In addition to within-domain learning, learning between the three animal domains was examined. Following from the first hypothesis it was predicted that learning would increase over time. In particular it was expected that the proportion of words remembered would be significantly greater for each subsequently taught domain such that a greater proportion of words would be remembered in the last taught domain (D3) compared to the first (D1) or second (D2) taught domains and that learning (i.e. the proportion of words remembered) in the second domain would be significantly greater than the proportion of words remembered in the first domain. As predicted a significant increase in learning, as measured by the proportion of words remembered, was seen over time. Children remembered an average of 54% (*SD* = .17) of the words taught to them in Domain 1, compared to 56% (*SD* = .18) remembered in Domain 2, and 63% (*SD* = .18) remembered for the third domain. While the difference in learning was not significant for the first compared to the second domain, or the second to the third domain, there was a significant increase in the proportion of words remembered from the first to the last taught domain [$t(9) = -2.06$, $p < .05$]. This increase in learning is graphically presented in Figure 3. Recall that above it was shown that the last category in each domain was learned the fastest, and close inspection of Fig. 2 indicates that this accelerated learning for Domains 1 and 2 for the last category nearly matches the learning rate for Domain 3 at the last category (the proportion of words remembered was.69, .75, and .76 for Category 7 for Domain 1, Domain 2, and Domain 3 respectively).

In sum, across learning of the three animals domains children showed a significant increase in the proportion of words remembered from the first to the last domain.

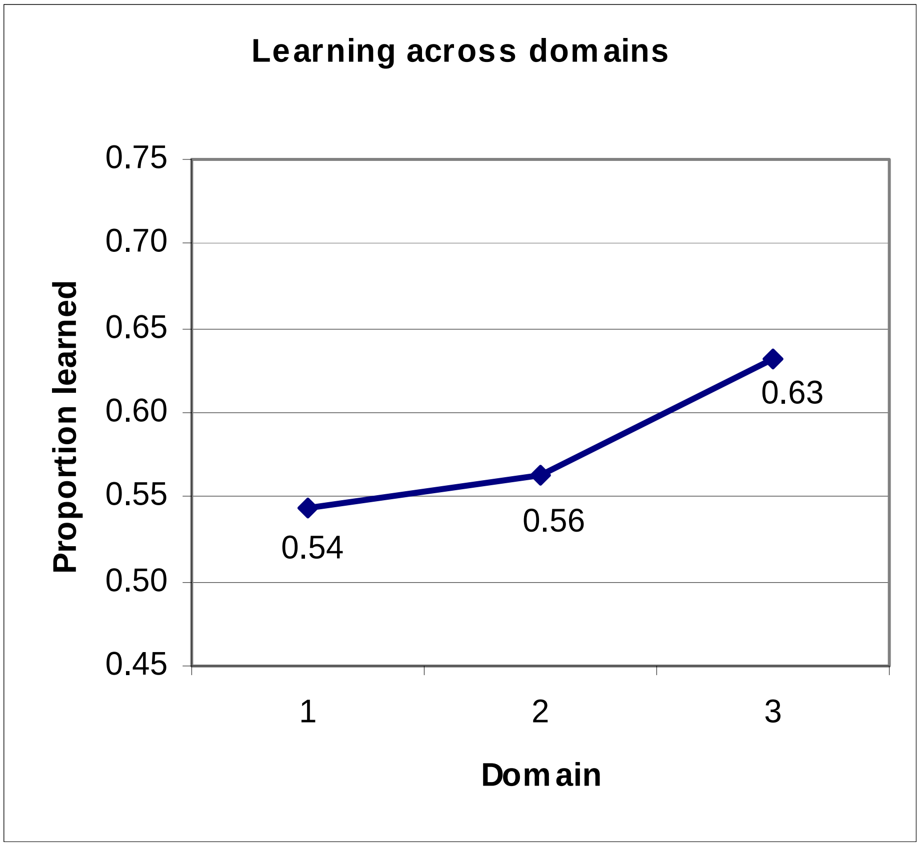


Figure 3. Mean proportion learned as a function of domain.

It is important to note that learning was incredibly fast even for children who remembered the fewest words. The portion of words remembered across any one domain ranged from 25% to 94%. At the low end that means children were learning at a rate of close to eight words an hour. On the high end that means children were closer to learning 20 words per hour. Bloom (2000) has estimated that preschool children can learn up to 20 words a day. Results from the current study suggest that even this number drastically underestimates children's true learning capabilities—here children learned about 15 new words for every *hour* of interaction they spent in the intervention. Children, it appears, have the ability to learn many, many words very quickly. Moreover, the rate of learning accelerates as learning continues, allowing for increasingly powerful learning to take place over the course of continued exposure.

Further analyses show that learning itself significantly predicted future learning. A hierarchical regression analysis was conducted with the proportion of words remembered in the last domain serving as the criterion and with the proportion of words remembered in Domain 1, and proportion of words remembered in Domain 2, as the predictors. The resulting overall regression model was significant, where $y = .0003 + .55X_1 + .58X_2$, $F(2,7) = 13.41$, $p <.01$. The amount of variance in Domain 3 learning explained by these two predictors was 79%. To determine whether learning in Domain 1 or Domain 2 was a better predictor of Domain 3 learning we examined the standardized beta weights as well as the change in *F* as the result of the addition of Domain 2 learning. While learning in Domain 1 plus the variance shared with Domain 2 learning was a significant predictor alone ($\beta = .53$, $t = 2.93$, $p =.02$) and explained a significant 48% of the variance in learning in the last taught domain [$F(1,8) = 7.63$, $p = .025$] , it was revealed that learning in the second domain was explained 31% additional unique variance in learning of the last taught domain, $F\Delta(1,7) = .10.30$, $p = .015$, where $\beta = .58$, $t = 3.21$, $p = .015$. That the standardized beta weight was larger for Domain 2 learning compared to Domain 1 learning suggests that learning in the second domain made a greater contribution to the overall explanation of learning in the last taught domain compared to the first domain. In general then, it appears that learning that occurs closer in time to final learning contributes significantly more to the explanation of change in learning in that last domain compared to learning that occurred earlier.

In summary, the results from Question 1 suggest a number of noteworthy findings. First, learning within domains shows characteristic dips in the center of word learning as well as characteristic increases in learning after that dip so that learning is highest (despite the risk of high interference from previously learned items) for the last group of animal names learned in the domains of dogs, horses, and birds. In addition, children's propensity to learn increases over time and that increase is predictive of even further learning. In essence, these results suggest that learning begets learning. Adaptive improvements are taking place as learning proceeds. While learning then appears to predict future learning, our understanding of the processes involved might be improved by examining the question of what may be changing as the result of learning. To answer this question an investigation of the cognitive variables previously indicated as contributors to word learning was conducted.

Question 2: How do perception, memory, attention, and abstraction contribute to lexical learning across development, and how are they impacted by lexical learning?

Hypothesis 2

The second hypothesis concerned the contribution of specific cognitive abilities to lexical acquisition across time, and how these abilities change as lexical learning proceeds. In particular it was predicted that levels of phonological sensitivity, phonological memory, attention, and abstraction would contribute to word learning initially, and that potential changes in these abilities would result in different relationships between these abilities and learning across time such that Time 2 assessments would be more strongly related to word learning in the second and third domains compared to the first. In addition, the third hypothesis predicted that, in addition to increases in overall learning across time and an increase in cognitive abilities, children who were learning words would outperform a matched control group who did not engage in the word learning portion of the experiment, as indicated by assessment measures employed during the second and third assessment periods.

To determine if a relation existed between learning across the first domain and any of the cognitive variables of interest, several Spearman Rho rank-order correlation coefficients were obtained. The Spearman is a commonly used nonparametric technique that is used to compute the Pearson r correlation coefficient on the rank ordering of participants on the variables of interest. To test the initial portion of Question 2, that is that phonological sensitivity, memory, attention, and abstraction contribute to initial word learning, the proportion of words learned across Domain 1, and the initial composite scores for phonological sensitivity, phonological memory, abstraction, and attention were correlated with one another. Two interesting results were found. First, a nearly significant negative relation was observed for learning between children's initial phonological sensitivity scores and learning in the initial domain (r = -.62, p = .05); *low* initial scores on the phonological sensitivity composite were related to increases in learning. A similar trend was seen for the relationship between phonological memory and learning in the initial domain, where r = -.73, p <.02, suggesting that increases in learning are related to *poorer* performance on the phonological memory measures. While direction of the relationship between cognition and learning was not specifically predicted, it was expected based on previous research that any significant relationship would be a positive one. Thus, an attempt was made to explain the counterintuitive findings. Investigations into what specific skills might be driving these relations revealed a significant relation only between elision and proportion learned across Domain 1 (r = -.61, p = .03). It appears then that for phonological sensitivity the ability to remove parts of words may actually inhibit learning, at least initially. In terms of phonological memory, two subscores were responsible for the negative correlation between initial learning and phonological memory assessed at Time 1. While digit-span was not significantly related to initial learning in terms of the proportion of words learned, both the word span subscore and the nonword repetition subscore were significantly negatively related to the proportion of words recognized in the first domain (r = -.58, p =.04, and r = -.60, p = .03 for word span and nonword repetition respectively). Both attention and abstraction were unrelated to learning in the initial domain. In general then it appears that initially the learning of a challenging number of new animal names may be influenced by both phonological sensitivity and phonological memory. However, these relationships are somewhat contrary to what one might expect. In fact higher skills for some aspects of these abilities may actually serve to disadvantage some children in terms of learning, at least at the onset of acquisition of words in an unfamiliar domain. These results will be discussed in relation to expertise and the particular demands of the present study in the conclusions.

The initial assessment composites were minimally related to learning in the second and third domains, suggesting that initial scores are only somewhat predictive of later learning. The negative relationship between initial nonword repetition and learning held over time, where $r = -.60$, $p = .04$ for learning in the second domain and $r = -.81$, $p < .01$ for learning in Domain 3. Interestingly then, while it appears that initial scores are somewhat related to learning over time, at what point children are in their learning of new words appears to matter. Certainly this has implications for cross-sectional and longitudinal studies that do not control for the amount of lexical acquisition when investigating the contributions of cognition on word learning.

To determine if assessments performed closer in time were better potential predictors than those farther out, the relations between assessments performed at Time 2 and learning for Domains 2 and 3 were examined. While neither memory nor perception was significantly related to learning across Domain 2 or Domain 3, learning in the second domain was significantly and positively related to children's abstraction abilities when measured at the second assessment period ($r = .59$, $p < .04$) as was learning in the third domain ($r = .58$, $p <. 04$) .That is, increasing abilities to match conceptually related items together was associated with greater learning in both the second and third domains. No other cognitive abilities measured at Time 2 appeared to be related to learning in Domains 2 or 3.

In summary only some of the predictions from the second hypothesis regarding the influence of cognition on word-learning were supported. While some abilities were predictive of initial learning (phonological sensitivity and phonological memory), not all of them were. Attention and abstraction were unrelated to initial learning. Importantly, the influence of these skills changes as the time period (and lexical experience) increases. Using initial assessment scores to predict later learning (learning across Domains 2 and 3) reveals a different picture. In fact phonological sensitivity measured initially is not predictive of later learning.

When looking at abilities that have been measured after Domain 1 learning has occurred and thus presumably have been altered as the result of extensive lexical acquisition, an altogether different picture emerges concerning the relation between cognition and learning. When cognition is assessed at Time 2, that is halfway through the word-learning intervention, it appears that phonological sensitivity and phonological memory no longer play a significant role in the prediction of learning. Rather, the ability of children to recognize that conceptually-based items go together is the only ability that is related to learning in either the second domain or the last taught domain. Attention, it appears, does not play a role in children's learning at any point in time, at least, not as measured in this study. Results from Hypothesis 2 suggest that two cognitive abilities, memory and perception, are associated negatively with initial word learning rates. The impact of phonological memory appears to persist across learning while the impact of phonological diminishes. It also appears that abstraction abilities play a role in later word learning and that they may be initialized by previous learning. In general then, there is some support that at least memory and perception are influencing initial word-learning, lending additional support to the idea that general cognitive abilities may influence the initial stages of word learning. An additional piece of evidence is needed however, to determine if children are showing changes in cognition as the result of learning new lexical items. Evidence of this type would further support the claims of two-process models of lexical learning and the help to solidify the link between word learning and expertise. These claims were examined in Hypothesis 3.

Hypothesis 3

In Hypothesis 3 it was predicted that children who were learning words would surpass children in the control condition on cognitive measures assessed at both Time 2 and Time 3. To examine this question it was important not only to document changes in abilities over time, but also to show that these changes were due to learning words, rather than time (i.e. maturity) itself. Thus phonological sensitivity, phonological memory, attention, and abstraction were measured prior to, in the middle of, and after the word learning intervention, and at identical time periods for a matched group of children who did not engage in word learning. If increases in cognition across time were seen for children who experienced lexical gains as the result of the intervention compared to children who did not learn the words then it is reasonable to conclude that in fact increases were related to learning, rather than to time alone.

To test this claim a series of nonparametric tests were employed. There is no non-parametric equivalent to the parametric repeated measures design that would be appropriate here. However, by using both the Mann-Whitney-Wilcoxon tests to examine effects between group and the Friedman test to examine effects across time, we can approximate the parametric repeated measures procedure. The Mann-Whitney-Wilcoxon Test tests for differences in the sum of ranks assigned to participant scores. Ranks are assigned to every score regardless of group and are then added together within group. If there are was no difference between groups than the summed ranks should be relatively equal. The ranks are then summed and averaged for each repeated measure. It should be noted that the power-efficiency of this test ranges from 95% to 100% and is thus an excellent nonparametric alternative to the t-test. The Friedman test allows for the test of repeated measures. Each participant's score is assigned a rank order and mean ranks for each time period are compared. Power efficiency for this test approaches that for parametric tests when $N > 20$. Results from these analyses for phonological sensitivity, phonological memory, abstraction, and attention are discussed, in turn, below.

Working Memory

Based on the Mann-Whitney-Wilcoxon there was a significant difference in ranks between the control and intervention children for the last assessment period only ($W = 97.00$, $z = -1.73$, $p = .05$), where children in the intervention group scored significantly higher than did children in the control group. The Friedman revealed a significant increase in rank for the number of items correct for the intervention children ($\chi 2 = 6.24$, $p = .04$) from Time1 to Time 3 ($d = 1.00$, $p < .025$). However, there were no significant differences across time found for the children in the control condition. Mean phonological memory for the children in the intervention group was 8.80 ($SD = 1.99$) 9.80 (SD = 1.81), and 10.40 ($SD = 1.71$) for Time 1, Time 2, and Time 3 respectively, while mean phonological memory for children in the control condition was 8.91 ($SD = 1.92$), 8.45 ($SD = 2.62$), and 8.64 ($SD = 1.96$) for the same time periods. This interaction can be seen in Figure 4. Means and standard deviations for phonological memory scores can be seen in Table 2.

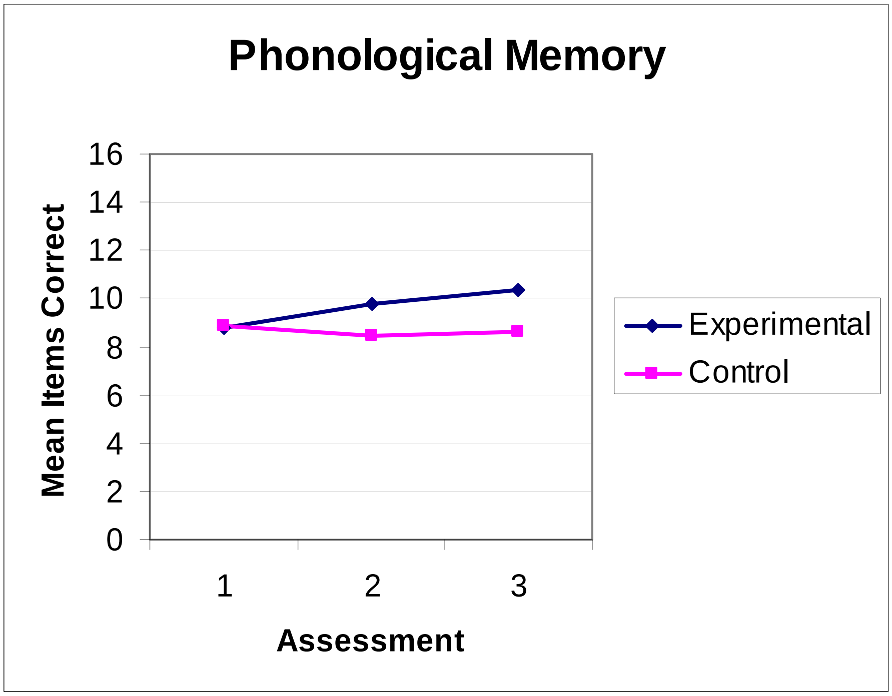


Figure 4. Mean items correct on the phonological memory composite as a function of assessment period.

Table 2.

Means and standard deviations for the phonological memory composite for each assessment period for the intervention and control groups.

	1		2		3	
Group	M	SD	M	SD	M	SD
Intervention	8.80	1.99	9.80	1.81	10.40	1.71
Control	8.91	1.92	8.45	2.62	8.64	1.96

In general an increase in performance was seen across assessment periods for the intervention children but not the control children for phonological memory, supporting the hypothesis that phonological memory improves with lexical acquisition.

Perception

Group comparisons revealed a significant overall difference between performance on the phonological sensitivity composite for the children who engaged in learning and those who did not, at two of the three time periods. While there was no difference in performance at the initial assessment period, a group difference was seen at both the second and third assessments, where $W = 97.50$, $z = -1.67$, $p < .05$ *and* W = 80.00, $z = -2.92$, $p < .002$ respectively. At both times performance on the phonological sensitivity composite was better for the children who were in the word-learning intervention compared to children who served as matched controls. In other words while mean phonological sensitivity between groups was not different at Time 1, in line with expectations, at both Times 2 and Time 3 mean scores were significantly greater for the children in the intervention group. Mean phonological sensitivity at Time 2 was 11.60 (SD = 2.32) for the intervention group and 9.18 (SD = 3.09) for the control group, and mean phonological sensitivity at Time 3 was 12.90 (SD = 1.73) and 9.27 (SD = 2.76) for the intervention group and the control group respectively.

The Friedman test of repeated measures confirmed the above analyses as well—a significant overall difference was found for children in the intervention group ($\chi 2$ = 16.05, p < .000) but not for the control group. For children in the intervention group the increase the number of items correct from Time 1 to Time 2 was marginally significant

(d = .65, p < .06) and there was a significant increase in scores from Time 2 to Time 3 (d = 1.10, p < .025). Dissimilar results were seen for the control group; at no time was there a significant improvement in rankings for the number of items correct on the phonological sensitivity measure. This interaction is represented graphically in Figure 5. Means and standard deviations for phonological sensitivity across time are presented in Table 3.

In sum, while children in the intervention group showed significant increases in their phonological sensitivity across time, children in the control condition did not, supporting the prediction that learning itself contributes to overall increases in children's ability to perceive and manipulate the speech of the language being learned.

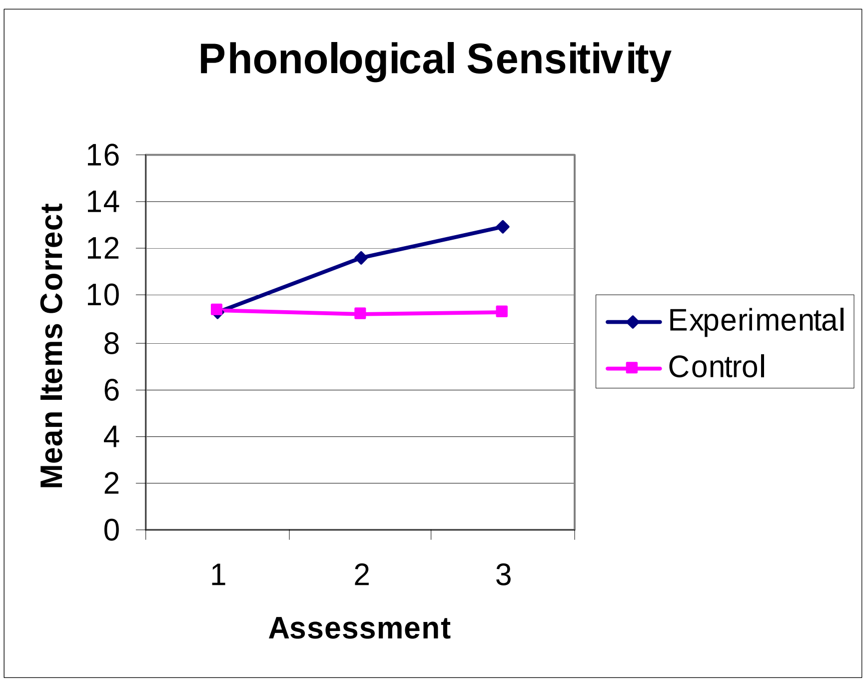


Figure 5. Mean items correct on the phonological sensitivity composite as a function of assessment period.

Table 3.

Means and standard deviations for the phonological sensitivity composite for each assessment period for the intervention and control groups.

	1		2		3	
Group	M	SD	M	SD	M	SD
Intervention	9.30	2.26	11.60	2.32	12.90	1.73
Control	9.36	1.50	9.18	3.09	9.27	2.76

Attention

Two measures of attention were used to gauge children's abilities, the Dimension Change Card Sort task (DCCS) and the Rapid Object Naming task (RON). The Mann-Whitney-Wilcoxon examining differences between the two groups showed no significant difference between groups emerged for the DCCS at any point in time. Furthermore, no significant effect of repeated measures for either the intervention group or the control groups was found. It appears that the skills that underlie performance on this measure are not subject to the effects of continued lexical advancement. It is important to remark here that results for both groups were near ceiling. Out of a possible 15 items correct children in the intervention condition succeeded on 13.90 trials (*SD* = 1.10) at Time 1, 13.30 trials (*SD* = 2.06) at Time 2, and 14.80 trials (*SD* = .63) at Time 3, while children in the control condition succeeded on 14.36 trials (*SD* = .67) at Time 1, 13.82 trials (*SD* = 1.54) at Time 2, and 14.55 trials at Time 3 (*SD* = .93). Thus, while it is possible that attention as a component of executive functioning does play a role in learning words, the lack of variability in scores may have masked any potential effect. DCCS mean scores, and standard deviations across assessment period and within group are presented in Table 4 and are represented graphically in Figure 6.

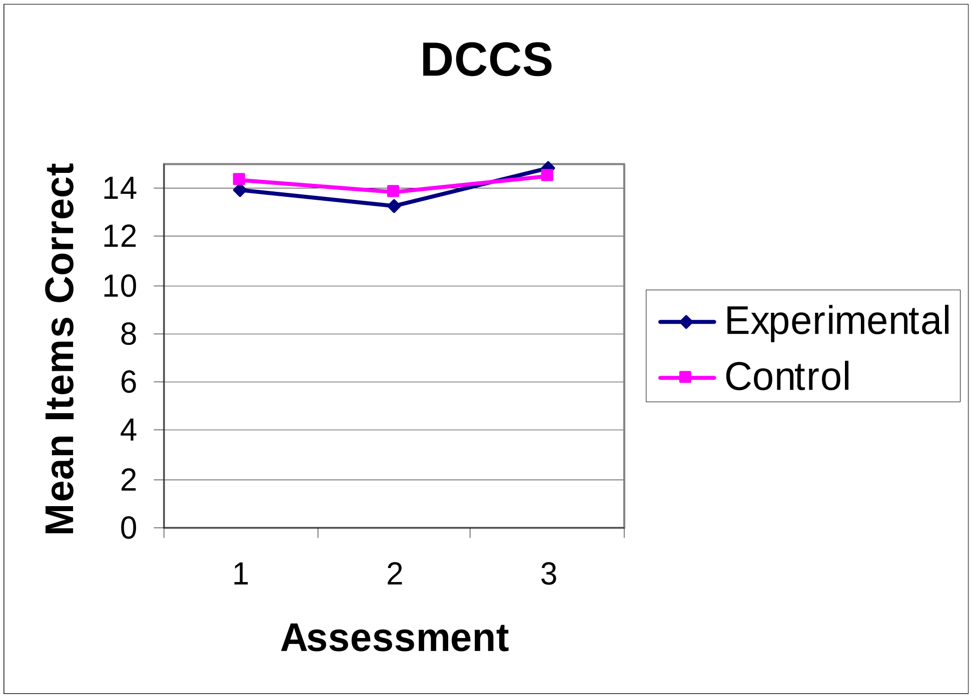


Figure 6. Mean items correct on the DCCS as a function of assessment period.

Table 4.

Means and standard deviations for the DCCS for each assessment period for the intervention and control groups.

	1		2		3	
Group	M	SD	M	SD	M	SD
Intervention	13.90	1.10	13.30	2.06	14.80	0.63
Control	14.36	0.67	13.82	1.54	14.55	0.93

Results for the Rapid Object Naming task were somewhat different. First, data for one case in the matched control group were excluded from analyses because the child persisted in saying “And this is a X.” prior to the labeling of each object. This difference in procedure for that one child added a significant source of error and thus it was felt group differences would be more accurately reflected without that case. Thus for the following results N for each group is 10.

The Mann-Whitney-Wilcoxon revealed no overall group differences in naming latency at Time 1, Time 2, or Time 3, suggesting there were no differences at any point in time in the time it took to name the objects on the RON. However, the Friedman Test of repeated measures within groups showed a different pattern of responding for children in the intervention group compared to children in the control condition. For children in the intervention group there was a significant decrease in latency across time ($\chi 2 = 7.00$, $p = .03$) with both a significant decrease from Time 1 to Time 3 ($d = 1.10$, $p < .025$) and Time 2 to Time 3 ($d = .65$, $p < .05$), where mean naming latency decreased from 49.58 seconds at Time 1 (*SD* = 13.08 seconds), to 42.50 seconds at Time 2 (*SD* = 13.48 seconds) and 37.14 seconds at Time 3 (*SD* = 8.91). In contrast, a flat pattern emerged for children in the control condition. No difference in naming latency across time was seen for children in the control condition, where means for Time 1, Time 2 and Time 3 were 46.94 seconds, 48.12 seconds, and 45.49 seconds (*SD*s are 23.05, 21.38, and 21.49 for Time 1, Time 2, and Time 3 respectively). Based on these results it appears that lexical acquisition may impact children’s ability to attend to parameters needed to quickly name familiar items. Means and standard deviations are presented in Table 5. The different patterns can be viewed in Figure 7.

Table 5.

Means and standard deviations for the latency to name in the Rapid Object Naming task for each assessment period for the intervention and control groups.

	1		2		3	
Group	M	SD	M	SD	M	SD
Intervention	49.58	13.08	42.50	13.48	37.14	8.91
Control	46.94	23.05	48.12	21.38	45.49	21.49

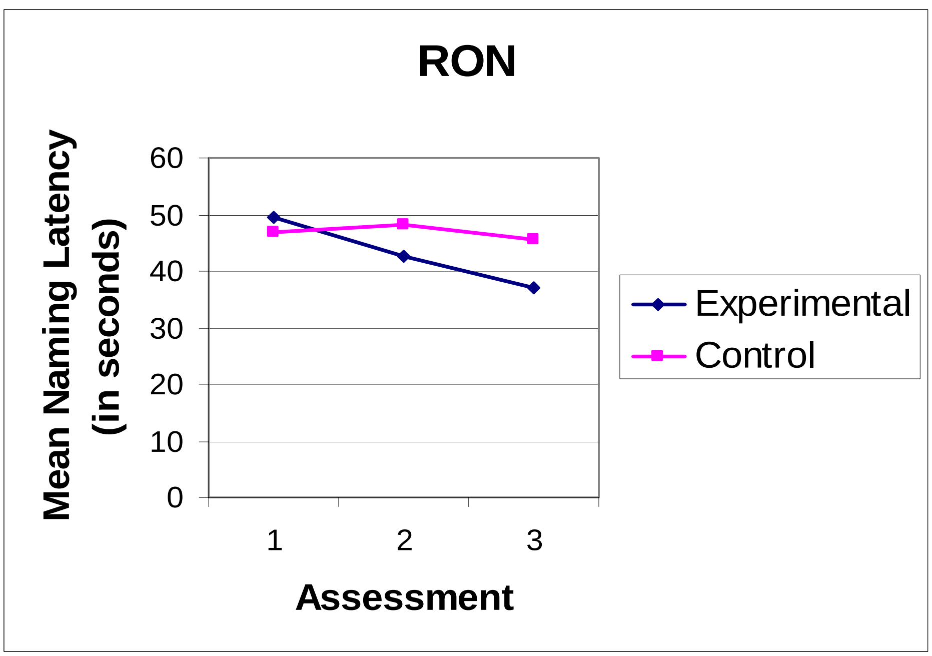


Figure 7. Mean naming latency on the Rapid Object Naming task as a function of assessment period.

Abstraction

Results from the Mann-Whitney-Wilcoxon test of group differences showed a significant difference between groups at third assessment period (*W* = 88, *z* = -2.339, *p* < .01), but not for the first assessment period or the second assessment period, with children in the intervention group scoring significantly higher at Time 1 than children in the control group. The Friedman test of repeated measures revealed a significant increase in abstraction scores for the intervention children from Time 2 to Time 3 (*d* = .85, *p* < .025). This difference was not seen for children in the control condition, indicating that while scores were improving for those children who had engaged in the word-learning. The mean number of conceptual matches in the abstraction task at the first, second, and third assessment periods was 6.65 (*SD* = 3.35), 7.00 (*SD* = 4.24) and 11.20 (*SD* = 5.90) for the intervention group, while the mean number of conceptual matches for the control children at each point in time was 6.36 (*SD* = 2.66), 6.36 (*SD* = 3.41), and 5.73 (*SD* = 2.94). Means and standard deviations are presented in Table 6.

Table 6.

Means and standard deviations for the abstraction task for each assessment period for the intervention and control groups.

	1		2		3	
Group	M	SD	M	SD	M	SD
Intervention	6.65	3.35	7.00	4.24	11.20	5.90
Control	6.36	2.66	6.36	3.41	5.73	2.94

The interaction is presented graphically in Figure 8.

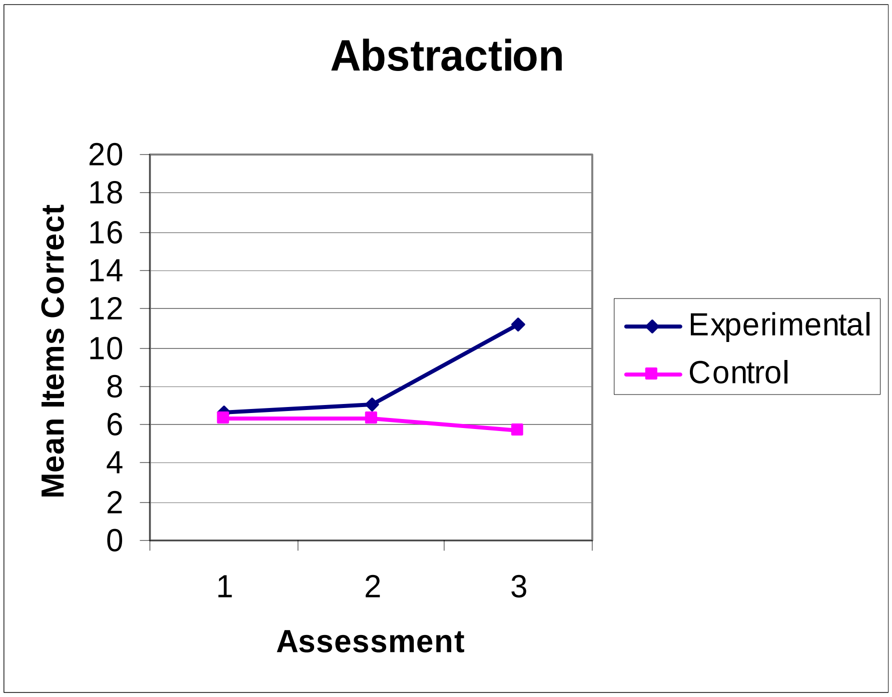


Figure 8. Mean items correct on the abstraction task as a function of assessment period.

In summary, for all of the cognitive measures except the DCCS we saw an increase in ability as a function of assessment period. However, this was seen only for children who were in the intervention. Children who did not participate in the intervention showed no benefit in cognition across the three months of the study. It is reasonable to conclude then that lexical acquisition does have an impact on basic cognitive abilities as evidenced by an increase in ability across the assessment periods for intervention children but not for controls.

Taken together the results of Question 2 show that, similar to previous research, different cognitive abilities may be influencing word learning at different points in time and that that influence may change as lexical learning proceeds. Furthermore the same abilities that are important for initial word learning also change as a result lexical acquisition, lending support to both components of two-process models, as well as to the claim that the results of lexical learning are similar acquired expertise. An important question that remains, however, is do these results reflect burgeoning expertise in children's ability to learn words?

Question 3: Does the process of learning words mimic development of expertise?

This final question concerned whether lexical learning across time results in the kinds of processing advantages espoused by experts in their domain of expertise. This is a theoretical question reflecting whether lexical acquisition might be best thought of as developing expertise in word learning, and whether in the context of this study, clues generally associated with acquiring expertise in any domain are present and can be used as evidence for the claim of developing lexical expertise. The first such clue comes from the results above for the first hypothesis- the ability to learn improved from Domain 1 to 2 to 3. Furthermore, expertise theory predicts that changes in basic cognitive abilities result from gaining knowledge about one's domain of expertise, resulting in processing advantages for information related to that domain. This prediction was also supported, as discussed under the second and third hypotheses. Other abilities not directly tested by the previous analyses will also help to determine if children were becoming word learning experts.

First, experts show a change in their categorization strategies over time. In particular as children gain knowledge about a domain they show changes in the way they pair together exemplars of that domain. There is a shift from an emphasis only relying on perceptual information to relying on information based on functional/conceptual properties of the domain, rather than on superficial properties as novices do. To determine if children in this experiment were showing a similar trend in the way they categorized exemplars from acquired domains after just three months of intense exposure to those domains, the number of perceptual matches and conceptual matches from the daily sorting task were examined.

Table 7 shows the mean number of perceptual and conceptual choices for each domain. In general there was a decreasing propensity to match animals based on perception and an increasing trend to match animals conceptually, based on kind. Mean perceptual choices for Times 1, 2 and 3 were 10.30 (SD = 7.63), 6.10 (SD = 5.78), and 5.40 (SD = 6.82), while mean conceptual choices were 24.80 (SD = 7.66), 28.00 (SD = 6.73), and 29.40 (SD = 6.67) for these same time periods. Friedman simple effects tests revealed the decreases in perceptual matches from both Domain 1 to Domain 2 and Domain 1 to Domain 3 were significant (d = .70, $p < .05$ and d = .65, $p < .05$ respectively). The change in the number of perceptual choices from Domain 2 to Domain 3 was not significant. For conceptual matches none of the increases were significant at the .05 level. In general then, children showed a clear-cut decreasing tendency to match animals on the basis of appearance, and a moderate increasing trend to match animals on the basis of conceptual information, that is category names.

Table 7.

Means number of perceptual matches and conceptual matches and standard deviations on the daily matching task across domains.

	1		2		3	
Match	M	SD	M	SD	M	SD
Perceptual	10.30	7.63	6.10	5.78	5.40	6.82
Conceptual	24.80	7.66	28.00	6.73	29.40	6.67

It should be noted that children were far and away more likely to match animals based on naming for all of the domains than they were on the basis of perceptual characteristics. Wilcoxon Signed Ranks tests looking at the difference between the number of perceptual choices versus conceptual choices for Domain 1, Domain 2, and Domain 3, showed that these differences were all statistically significant, where, for Domain 1 z equaled -2.15 (p = 0.02), for Domain 2 z equaled -2.81 (p =.003), and for Domain 3 z was equal to -2.71 (p = .02). At every point in time there was a preference to match animals based on the category names rather than on perceptual similarities.

In prior literature children's justifications for why they chose a perceptual over a conceptual match or vice versa have also demonstrated children's changing strategy use. Mean number of justification types across domains, including whether that justification was perceptually based ("Because they look alike"), conceptually based ("Because they're both sporting dogs"), or nonsensical ("Because they like to dance and sing") are presented in Table 8. As with the matching results, there was a decrease in perceptual justifications over time, where the means for Times 1, 2 and 3 were 4.70 (*SD* = 7.50), 2.80 (*SD* = 2.53) and 2.00 (*SD* = 2.67) respectively, and a small increase in conceptual justification over time where the for means for Times 1, 2 and 3 were 21.30 (*SD* = 13.30), 21.70 (*SD* = 13.37) and 22.50 (*SD* = 14.35) respectively. Nonsense justifications also increased slightly over time. The mean and standard deviations at each time period were 9.00 (*SD* = 13.02) at Time 1, 9.60 (*SD* = 13.14) at Time 2 and 10.30 (*SD* = 13.82) at Time 3.

Table 8.

Mean number of perceptual justifications, conceptual justifications, and nonsense justifications and standard deviations for the daily matching task across domains.

	1		2		3	
Justification Type	M	SD	M	SD	M	SD
Perceptual	4.70	7.50	2.80	2.53	2.00	2.67
Conceptual	21.30	13.30	21.70	13.37	22.50	14.35
Nonsense	9.00	13.02	9.60	13.14	10.30	13.82

Friedman tests for repeated measures for the number of perceptual justifications, conceptual justifications, and nonsense justifications within domain were performed in order to look at trends in reasoning within domains, and to compare these trends across domains. While there were no significant differences found for the number of different justification types across the first domain, analyses for Domain 2 revealed a different story. Results showed that there was a significant overall difference in the number of the three different kinds of justifications provided ($\chi^2 = 6.32$, $p = .04$). For Domain 2 children provided significantly more conceptual justifications than perceptual justifications (d = 1.05, $p < .03$) or nonsense justifications (d = .75 $p < .05$). The number of perceptual versus nonsense justifications was not significant. For Domain 3 a marginally significant difference was found among the three different justification types (χ^2 = 4.92, p = .085), with a significantly greater number of conceptual justifications than perceptual justifications (d = .95, $p < .03$). Neither the difference between perceptual justifications and nonsense justifications, nor the number of conceptual justifications versus nonsense justifications was significant.

Taken together this series of results suggests a change in the way children are thinking about how different domain items can be grouped together. Initially there is a greater likelihood that children will both choose a perceptual match and provide either a perceptually-based reason or a nonsensical reason for that choice. However, with increasing knowledge about the way in which different kinds of animals can be best structured, that is knowledge that there are different kinds of, for example, dogs, and that these dogs can be grouped together based on the predictive dimension of a name like "working", children show an increasing tendency to use this information to match animals and justify those matches. These results are directly in line with predictions from expertise theory. In particular, it is expected that as children gain knowledge about animal domains, their matching behavior will be revised in such a way that the number of target-conceptual match pairings will increase relative to target-perceptual matches, as will the number of conceptually based reasons. Note that which animal domain was learned first, second, and third by each child varied randomly**.** So the apparent "carryover" effect to Domains 2 and 3, with relatively fewer perceptual matches and justifications and more conceptual matches and justifications, from learning from 48 to 141 animal names (varied range across children) in the first domain was sometimes from birds to the other domains, sometimes from dogs to the other domains, and sometimes from horses to the other domains. It is not the learning of the particular animals that matters, then, but rather the learning itself that appears important for changes in categorization strategies.

An additional change that would reflect children's burgeoning lexical expertise is their changing ability to rapidly name animals from the domains they are learning. In particular a decrease in intervention children's Rapid Animal Naming latency across time and as well as a more rapid decline in naming relative to the change in latency for the Rapid Object Naming task would be expected. In addition, we would expect that the difference between naming latency in the RON compared to the RAN would be smaller for children in the control condition compared to children who were learning words. Thus a difference in magnitude of change for children in the intervention relative to the children in the control condition would suggest that intervention children were not only showing a decrease in naming latency over time, but that this decrease was systematically larger for children who were engaged in extensive lexical exposure.

Overall there was a significant difference in naming latency between the RON and the RAN, where naming latency was greater for the RAN than the RON. This overall difference was anticipated based on the design of the RAN. In that test animal names are all two-syllable words rather than the one-syllable object names used in the

RON. This does not pose a problem for the purposes of this study which is simply to compare changes in the magnitude of the differences between the tests rather than testing differences between latencies between the two tests. In particular it was expected that for children who were not in the intervention there would be little or no difference in naming latency for both tests across the assessment periods, while for intervention children a decrease in naming latency for RAN was expected.

To test this assumption the difference between naming latency between the RAN and the RON at each point in time was calculated for children in both groups. The Mann-Whitney-Wilcoxon test of group differences showed that while there was no significant difference between the groups in naming latency between the RAN and RON at the first assessment period, there was a significant difference at both Time 2 ($W = 80.00$, $z = -1.89$, $p = .033$) and Time 3 ($W = 79.00$, $z = -1.97$, $p = .025$), where children in the intervention group showed a smaller mean difference in their naming of animals versus objects compared to children in the control group. Children in the control group showed a mean difference in naming latency between the RAN (longer latency) and the RON of 14.66 seconds ($SD = 12.54$ seconds) at Time 2 and 12.30 seconds at Time 3 ($SD = 10.41$ seconds), thus showing very little change over time. In contrast, intervention children, children who were learning animal names, showed a decrease in their naming difference of animals and objects, where the mean difference at Time 2 was 3.70 seconds ($SD = 13.02$ seconds) and the mean difference at Time 3 was 1.36 ($SD = 10.39$). In fact the Friedman test revealed that naming latency for these intervention children for the RAN significantly decreased ($\chi 2 = 15.74$, $p < .00$) over time, specifically from Time 1 to Time

2 ($d = .95$, $p < .025$) and from Time 2 to Time 3 ($d = .80$, $p = .025$). This suggests that children who are gaining expertise about the domains being taught are showing a significant decrease in the time it takes them to label those animals, despite not being taught those particular items, and suggesting that unlike children who did not engage in the intervention portion of the experiment, children who did learn dogs, horse, and birds are showing an increasing tendency to name animals from those domains as if they were the common objects found on the rapid object naming task. That children who were learning showed a decrease in naming latency over time for the Rapid Animal Naming task, but control children did not, suggests that children are gaining increasing in their proficiency to identify and use domain information to quickly name words from domains they are learning about. Furthermore, the finding that the difference between the Rapid Object Naming Task and the Rapid Animal Naming task declined over increasing time and increasing extent of learning suggests that children in the intervention groups are not just showing an advantage in terms of their attention to word-relevant properties, but that this advantage is specific to what is being learned.

Means and standard deviations for the RAN are presented in Table 9. The difference in naming latency between the RAN and the RON for each group across time is presented in Table 10. This relationship is graphically presented in Figures 9 and 10.

Table 9. *Means and standard deviations for the RAN for children in the intervention group and children in the control group for the three assessment periods.*

	1		2		3	
Group	M	SD	M	SD	M	SD
Intervention	63.90	22.55	46.20	12.80	38.50	8.58
Control	62.93	18.01	62.78	25.28	57.79	22.71

Table 10. *Means and standard deviations for the difference in naming latency between the RAN and RON for children in the intervention group and children in the control group for the three assessment periods.*

	1		2		3	
Group	M	SD	M	SD	M	SD
Intervention	14.32	27.53	3.70	13.02	1.36	10.39
Control	15.99	14.39	14.66	12.54	12.30	10.41

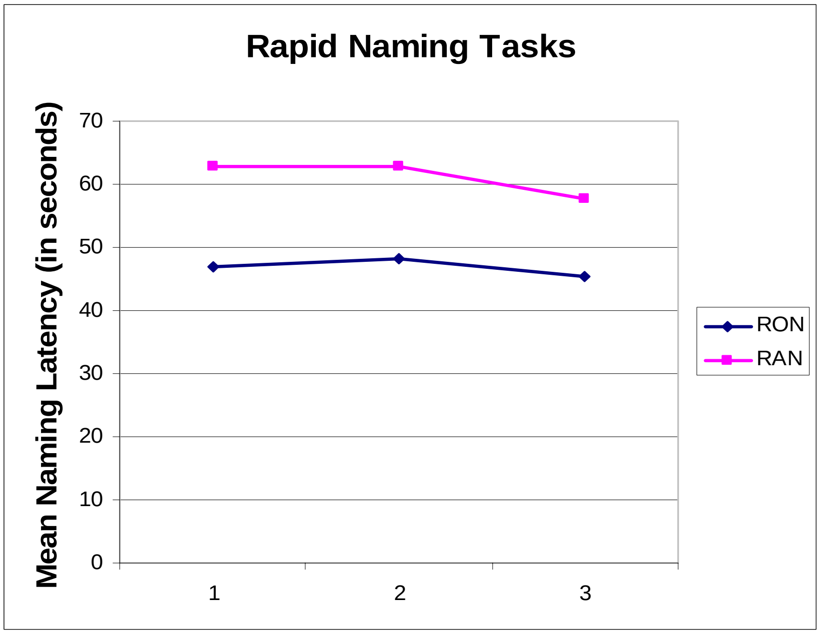


Figure 9. Mean naming latency in seconds for the RON and the RAN for children in the control group as a function of assessment period.

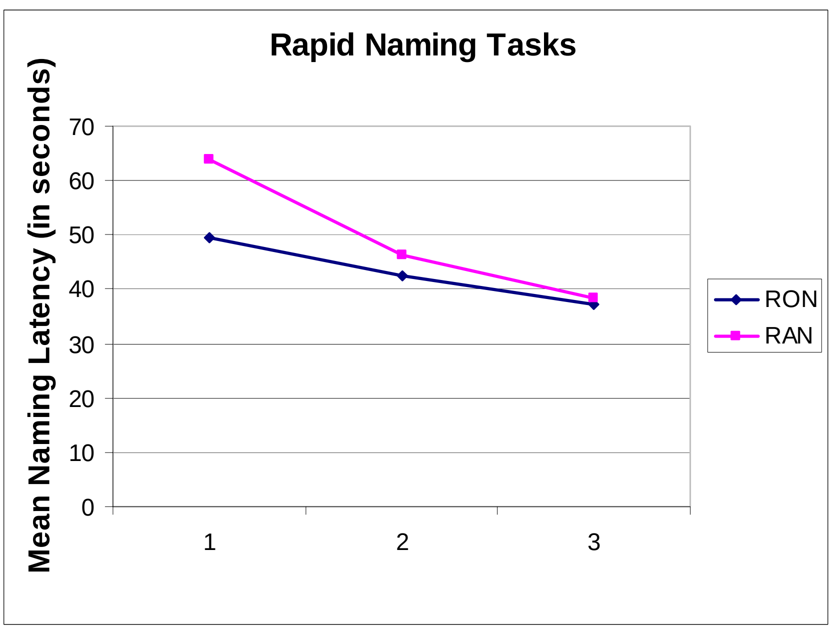


Figure 10. Mean naming latency in seconds for the RON and the RAN for children in the intervention group as a function of assessment period.

A final task examining children's lexical expertise was designed to tap into children's ability to quickly recognize and use subtle differences in domain exemplars. It was hypothesized that children in the intervention group would sort exemplars from domains they were learning more quickly than items from domains they were not learning, and more quickly than children in the control condition. This hypothesis was not supported. The Mann-Whitney-Wilcoxon tests of group differences revealed that no difference existed between the groups for any time period for either the control items or the items from the learning domains; children in both groups performed similarly. In addition, the Wilcoxon Signed Ranks test was performed to examine whether there were any differences in sorting latency between the control items and the learned items for both the intervention and control groups at the three different assessment periods. Again no significant differences were found, suggesting the performance was similar for domain items as well as items outside the target domains for both groups of children. Mean latency and standard deviations to sort the experimental animals children in the intervention group and matched controls at each of the three points in time are provided in Table 11. Mean latency and standard deviations to sort the control animals children in the intervention group and matched controls at each of the three points in time are provided in Table 12.

The Friedman test of repeated measures showed that there was no significant effect of repeated measures for the control stimuli. An overall effect of repeated measures was found for the experimental stimuli however ($\chi 2$ = 12.90, p =.002). This effect was prominent for both children in the intervention group ($\chi 2$ = 6.82, p =.03) and the control group ($\chi 2$ = 6.12, $p < .05$). Children in the intervention group showed a significant decrease in sorting latency from Time 1 to 2 (d = .65, p .05) and from Time 1 to 3 (d = 1.15, $p < .025$). Within the control group children showed a significant overall decrease in time to sort from Time 1 to 3 (d = 1.05, $p < .025$).

Table 11.

Mean sorting latency and standard deviations for intervention domains for intervention children and matched controls.

	Intervention Domains					
	Time 1		Time 2		Time 3	
Group	M	SD	M	SD	M	SD
Intervention	74.30	12.66	63.53	12.12	59.42	19.71
Control	68.00	14.46	64.73	26.19	55.30	19.03

Table 12.

Mean sorting latency and standard deviations for control domains for intervention children and matched controls.

	Control Domains					
	Time 1		Time 2		Time 3	
Group	M	SD	M	SD	M	SD
Intervention	72.50	14.80	61.10	20.37	63.48	19.84
Control	68.09	17.57	64.50	19.45	57.64	18.85

In general children who were engaged in lexical learning and children who were not did not differ in their sorting behavior for either the domain items that children in the experimental condition were learning or for domain exemplars from domains in which children had only ancillary exposure. While there was no difference for items for which no domain experience had been provided, there was a significant decrease in sorting latency across time for children in both groups for the animal exemplars from domains that the intervention group, but not the control group, had been exposed to. The null results for this sorting data stand in contrast to the consistent indications from all other measures that shifts toward increasing knowledge and skills are clear-cut in the intervention children across the three months of the study but are absent in the matched control children.

Results from Question 3 suggest that children are showing some evidence of developing expertise as the result of lexical learning. Children showed an overall change in their matching strategies and justifications as well as a change in the way they perceived and rapidly recalled items related to the domain being learned. Further, children showed rapid learning in all three animal domains that was highest for the last category of names learned within a domain and they also increased their overall rate of learning when they reached the last domain—results that indicate a “learning to learn” effect. Finally, the impact of these 4-year-olds’ extensive and rapid learning of animal names on multiple cognitive skills when measured at Time 2 (halfway through the intervention) and Time 3 (after the intervention) provides a further clue that expertise was developing.

Chapter 4

DISCUSSION

Many different theories of children's lexical acquisition exist (e.g. Hollich et al., 2000; Hulstijn, 2002; MacWhinney, 1998; Nelson, 2001; Smith and Samuelson, 1998; Tomasello, 2000). Across theories of lexical acquisition we see a trend towards recognition of the idea of a two-process model of word-learning that is suggestive of two processes responsible for word learning: elementary cognitive abilities that serve to direct input processing, and higher-level abilities that reflect refinements that emerge as the result of experience. In the past theorists have acknowledged the role of cognitive abilities such as, memory, perception, attention and abstraction in children's acquisition of new words (Golinkoff, Mervis, & Hirsh-Pasek, 1994; Hollich et al., 2000; MacWhinney, 1998; Tomasello, 2000; Smith & Katz, 1996). For example, Gathercole and colleagues (1992, 1999) have shown that the learning of new lexical items can be explained in part by phonological memory. Others, such as Bowey (1996), and Storkel and Morrisette (2002) have illustrated a relation between phonological sensitivity and lexical development such that the better one's phonological sensitivity the stronger the correlation to acquisition of past and current word learning. Further, Quinn and Eimas (1997), Reiger (2003) and others have shown that children pay attention to cues important for making word-object pairings. And, finally, the ability to abstract rules is integral in the ability to categorize new lexical items (Gentner & Namy 1999) and may be important for children's ability to acquire new lexical items.

Other fields adhere to two-process models as well. Of particular relevance is literature on expertise. Previous research on children's language learning has identified at least four cognitive abilities-- memory, perception, attention, and abstraction-- thought to aid in children's ability to learn the words of their language. Similarly, these abilities have also been implicated as relevant to expertise. Moreover, a comparison between the development of the lexicon and expertise suggests similarity in terms of the processes involved in the acquisition of domain knowledge and result of that acquisition of knowledge. Theorists interested in lexical learning have previously suggested that the cognitive abilities that serve to guide initial word learning also change as the result of word learning such that they become fine-tuned for the language that a child has experienced (Golinkoff, Mervis, & Hirsh-Pasek, 1994; Hollich et al., 2000; MacWhinney, 1998; Tomasello, 2000; Smith & Katz, 1996). Prior to this study this idea had not been experimentally examined. However, there is a wealth of evidence suggesting domain general abilities provide an important basis for later language learning. The capabilities to perceive, remember, attend to, and abstract aspects of one's environment all appear to play a role in children's lexical learning. Furthermore, the expertise literature provides us with clues as to what changes to look for in these and related skills within a period of extensive word learning by young children. However, while theories highlight common properties and processes involved in word learning, no direct tests have been performed to examine whether these ideas hold with respect to actual lexical acquisition across time. To date no prior studies have attempted to actually document children's word learning across time in order to examine the effects of these cognitive variables on lexical acquisition or the effect of lexical learning on cognition.

Researchers in the area of children's lexical acquisition sometimes characterize children as "expert word learners". While this label is generally used in a figurative sense, it is possible that there may be more truth in this label than has been previously supposed. Using the analogy of children as budding lexical experts would provide a number of benefits to the field of word learning, including the adoption of a similar theoretical framework, the investigation of specific abilities known to impact and result from expertise, and the application of a global architecture to our currently piecemeal theories of children's word learning.

Thus, the aim of this study was three-fold: 1) to provide a picture of children's lexical acquisition as it was occurring via a microgenetic approach across three months time; 2) to document the cognitive abilities of working memory, perception, attention, and abstraction as related to word learning during an initial period of intensive lexical acquisition, and throughout that acquisition in order to document possible cognitive changes as the result of that learning; and 3) to more thoroughly examine the hypothesis that word learning in children may be thought of as the development of a domain of expertise.

Question 1: In a microgenetic study what does the course of lexical acquisition look like?

Hypothesis 1

While many theories of lexical learning exist, there have been few studies on the acquisition of words in preschool children. Furthermore, what has been conducted has been limited in terms of the overall number of words taught and the number of learning sessions included. The first goal of this study was to rectify this situation by provide data on the course of word learning in preschool children as they attempted to learn 450 unfamiliar lexical items. Consequently, the aim of Question 1 in of this study was to simply provide a picture of word learning across time in order to begin to fill this hole in the literature on word-learning and to document changes in the ability to learn words over time in an attempt to draw the analogy between lexical acquisition and expertise.

Ten children were taught 450 unfamiliar animals names from three different domains: 150 each of dogs, birds, and horses. Each of these domains could be divided into seven different types. For example, dogs can be classified into seven different kinds: working dogs, sporting dogs, hound dogs, etc. One at a time, children were taught the animals from each of the seven categories of the three animal domains. Over twenty-seven 45 minute, highly engaging, child-based intervention sessions between the child and the experimenter, children were presented with multiple tokens of and corresponding labels for each of the new animals.

Learning Within Domains

For each of the taught domains children showed two general trends. First, regardless of the kind of animal being learned, children showed a period of inefficient learning in the middle of their learning about that domain. For each domain taught children evidenced a u-shaped function. Regression periods such as these are not uncommon in microgenetic research (e.g. Lewis, 2002; van Geert, 2002) and have been documented in investigations of children’s motor development (Thelen & Corbetta, 2002), attentional control (Ruff & Rothbart, 1996), grammatical development (Marcus et al., 1992) and others (see Heimann, 2003). Granott (1992) suggests that three types of processes are at work in children's development: backward transitions, reiterations, and ordered fluctuations. Specific to this discussion are reiterations, the continued use of an ineffective strategy, and backward transitions, i.e., temporary regressions followed by heightened ability. At any point in time children are able to make use of numerous cognitive strategies for dealing with new information (Siegler, 2002). When newly presented information is provided, the most cognitively efficient strategy for problems similar in type is used. This is the strategy in which problem outcome and processing load are equalized (Chen & Siegler, 2000). However, because this strategy is based on prior rather than current knowledge, it may result in only moderate success. The impetus for change may be the introduction of information that conflicts with or is counterintuitive to what is already known (Gelman, Romo, & Francis, 2002), or information that results in the placement of very high processing restrictions (Case, 1992). Reiterations and backward transitions are the result of adaptation to those problematic circumstances (Granott, 2002). Both require fewer cognitive resources for awhile, but at the cost of declining performance. The benefit of using these less cognitively cumbersome strategies, however, is the freeing up of additional processing resources. These additional resources can then be applied to the process of comparative analyses between similar knowledge domains as well as the reanalysis of the properties implicitly provided in the data that are most predictive for developing new lexical categories.

Regression periods are the result of these reiterations and backward transitions that allow for easier comparison of old and new information, and reconciliation of that information. These transitions serve to create analogies between new and old domains (Granott, 1992, 1993), facilitate the discovery process, test the validity of old information, prepare for subsequent bursts of learning**,** and enable qualitative shifts in development (Granott, Fischer, & Parziale, 2002). A process such as this appears to be taking place for children in the intervention group in this study. These children did not have extensive knowledge about any animal domain, suggesting the structure of their network about the kinds of animals they were learning was relatively simplistic in terms the connectedness of its overall structure. The result of initial exposure to a few instances of a type of animal may have been to simply create initial categories of dogs based on superficial information (e.g. shape), the kind of strategy most commonly used by novice learners (Chi & Koeske, 1982; Landau, Smith & Jones, 1988). However, superficial perceptual information is only somewhat useful in distinguishing between different domain exemplars and reliance on this information can quickly result in the development of cumbersome lexical entries that would burden recollection of new information. Continued use of this kind of strategy or a more general strategy such as assimilating many new instances under the overarching label of "dog" would have resulted in decreased learning for a period as children were increasingly unable to make the distinctions necessary to accurately remember name-exemplar mappings. While children in this study knew of only a few kinds of dogs, children did have knowledge about how different domain exemplars can be divided into subordinate distinctions based on perceptual properties and conceptual information. For example, every child in the study could name multiple colors, and varying shades within these colors. Drawing the analogy between how colors can be best arranged, and how dogs, for example, can be best arranged, would have resulted in a strategy that stressed differences between subordinate items. That kind of strategy could have supported the increase in learning that was seen here after the low point in learning and continuing through the last category of the first domain. Furthermore, drawing the analogy between domains such as color and animal type may have taken longer than the analogy between, say, dogs and horses, as these both fall under the same general rubric of "animal" and are thus closer in terms of conceptual space. Again this matches what was seen—increased learning rates in the second and third animal domain as compared to the first.

In addition to the general u-shaped trend, the increase in the proportion of domain items learned at the end of the domain was greater than for learning at the beginning of the domain. This was seen for each of the intervention domains; in every case the proportion of words learned for the last category taught was greater than the proportion of animals learned from the category that was first taught to children. These findings reflect an overall change in learning ability across domains and are the result of the reorganization of knowledge that result from the acquisition of new information (Chi, Glaser, & Feltovitch, 1992; Granott, 2002). Part of this reorganization process may have served to reduce levels of interference between animal names that may have contributed to the dip in learning rates part way through each domain.

In sum, two findings of the investigation of children's within-domain learning suggest developing expertise. Both the regression periods and the periods of increased learning after these periods with a peak learning rate at the end of each domain are indicative of children's reorganization processes and strategy shifts and fit well with development of expertise in word learning.

Learning Between Domains

Learning across domains was also telling of children's developing lexical knowledge and their developing lexical expertise. In general the results from questioning children about the animals they remembered showed that children learned, on average, 58% of these words, approximately 260 of them, with overall learning ranging from 25 to 94 percent across children. Learning was not stagnant over time—across the three animal domains children showed an increase in the proportion of animals remembered from that domain, where the average proportion remembered for animals in the first domain was 54%, average proportion remembered for animals from the second domain was 56%, and the proportion of words remembered in the last domain was 63%.

It was not simply that learning increased across domains, however, but that this learning was predictive of further learning. Learning across Domain 1 and Domain 2 significantly predicted 79% of the variance accounted for in the proportion of words learned in the last domain. In addition, it was particularly telling that learning in the second domain was an excellent predictor-- 31% of the variance accounted for in that last domain was uniquely contributed by learning across the second domain.

That children's learning rates can increase almost 10% after they have been exposed to just 300 new words in two domains and have learned an average of 63% of these words, suggests that children have powerful abilities to take in new lexical information over a short period of time, an ability that has thus far been underestimated. This can be seen when learning rates are examined in prior literature. Multiple estimates suggest preschoolers may be learning an average of 20 new words per day (see Bloom, 2000). Results from this study suggest this drastically underestimates children's potential for new word learning—children here learned up to 20 new words *per hour* of interaction! Even children who learned the fewest number of words showed rates of acquisition that far and away surpass even the highest estimates of new word learning across this time period, including those seen in studies of fast-mapping. Moreover, the finding that learning begets learning, that is, the more learning that occurs the more efficient learning becomes, is highly indicative of children's increasing ability to learn words as they gain lexical experience. It appears that children are showing the same kinds of benefits from lexical learning that experts show regarding their learning of information related to their area of expertise.

These results on children's acquisition of new lexical items over time provide the first piece of tangible evidence in the literature that directly and experimentally demonstrates the process of extensive lexical learning and that learning of many new lexical items has consequences for future acquisition. Inherent in the two-process model of lexical acquisition that emerges from current theories of lexical learning is the idea that as children are learning their language they progressively are becoming more highly equipped to deal with that language. This process appears to emulate the process of developing expertise in any domain. Children who know more about their domain of expertise learn related information more quickly than do novices, that is, children without the same degree of topic sophistication and network complexity (Chi & Koeske, 1983, Johnson & Mervis, 1994). Recall that the more robust one's knowledge base about a domain, the easier it is to recall new information about that domain, even years later (Gobbo & Chi, 1986). There are indications that the lexicon is a structure that adheres to these same principles. For example, younger children have fewer similarity neighbors than do older children, and the presence of neighbors increases as children gain new lexical items (Charles-Luce & Luce, 1990). Furthermore, when there appear to be no systematic gaps in one's lexicon, such as there would be for children with specific-language-impairment, the learning of new lexical items by language-typical children requires fewer presentations of object-word pairings (Rice et al., 1990).

Bedard and Chi (1992) suggest experts in any field are characterized by a number of traits. Experts know more about a domain, their domain knowledge is better structured, they show quicker learning of domain-related material, they show clear memory advantages for information in their domain of expertise, they show clear attentional and perceptual advantages for material related to their expertise, and they use different strategies for obtaining information about their domain of expertise than do novices. In terms of the similarity between word-learning and the development of expertise at least one thing now seems clear from the present 3-month microgenetic study: the learning of extensive animal domain information (lexical items) is undisputedly similar in many respects to acquisition of expertise as studied previously in both children and adults**.** However, it remains to be discussed whether children who are learning words are showing the cognitive advantages that characterize experts. The aim of Question 2 was to examine the role of the four cognitive abilities that are routinely put forth as providing evidence of expertise- memory, perception, attention, and abstraction- and that have been previously linked to vocabulary in preschoolers. If a strong tie between lexical acquisition and expertise is to be secured then documentation that these abilities change as the result of gaining experience with word-learning is imperative. Children learning words should show the same increasing proficiencies seen in experts from any field.

Question 2: How do memory, perception, attention, and abstraction contribute to lexical learning across development, and how are they impacted by lexical learning?

Previously researchers have suggested that memory, perception, attention, and abstraction contribute to lexical learning (e.g. Adams & Gathercole, 1995; Bowey, 1996, 2002; Deak, Ray, & Pick, 2002; Gathercole et al., 1992, 1999; Gentner & Namy, 1999, Storkel & Morrisette, 2002; Quinn & Eimas, 1997, Reiger, 2003). However, the learning of a large number of new words has rarely served as the criterion for lexical acquisition. In addition, these cognitive abilities are also the same abilities in which experts show advantages relative to novices (e.g. Chi & Koeske, 1986; Chase & Simon, 1973; Chastrette, 2003; Newell & Simon, 1972; Reingold et al, 2001; Weber & Brewer, 2003). If children are becoming experts at word learning then they should show increases in their memory, perception, attention, and abstraction abilities after they learn new lexical items and compared with children who are considered lexical “novices”, that is, children are not part of the word-learning intervention. Thus two specific hypotheses were proposed relating to Question 2. First, it was predicted that memory, perception, attention, and abstraction would contribute to initial learning and later learning, although the timing of the influence of these relations might differ for the abilities. Next, it was predicted that learning new words would have a positive influence on children's cognition as evidenced by increases in these abilities over time and in relation to children who were also being assessed but were not participating in the word-learning intervention portion of the study.

Hypothesis 2

In an attempt the uncover the relations between children's word-learning and these cognitive skills we investigated both the role of these abilities on initial and later word learning and the results of that word learning on children's cognition. A total of 21 children were assessed at three different points in time on their abilities to manipulate part of words (i.e. their perception or phonological sensitivity), remember real and made up words (their phonological memory), their attention in two separate tasks, and detect and use information about words and their referent objects that could form the basis for creating rules for categorizing new words (their abstraction). Ten of these children were taught the 450 lexical items. The other 11 served as matched controls. The abilities of children in the intervention group were assessed prior to the onset of the word learning intervention, after learning of Domain 1and half of Domain 2 had taken place, and after the rest of Domain 2 and all of Domain 3 had been learned. Although children in the matched control group did not learn the words, the timing between each of the assessments was the same as for children in the intervention group. Discussion of the results, for memory, perception, attention, and abstraction follow.

Previous studies have documented the relationship between children's phonological memory and their vocabulary (e.g. Adams & Gathercole, 1995; Baddeley, Gathercole, & Papagno, 1998). A relationship between these two variables was uncovered in this study as well. When the number of items correct on the expressive vocabulary measure plus number of items correct on the receptive vocabulary measure divided by the total possible number of correct items was used as the dependent measure, the pattern of results seen in other studies was found. Bowey (1996, 2002), Adams and Gathercole (1995), Gathercole et al. (1997) and others have repeatedly shown that there exists a significant relationship between phonological sensitivity and phonological memory. This study was no exception. The correlation between phonological sensitivity and phonological memory when both measured at Time 1 was .48 ($p = .08$). Although technically this relationship was not significant, the correlation was of a magnitude similar to what has been reported previously (see Arkenberg and Ryalls, submitted). Furthermore, these abilities were related to children's vocabulary scores; the correlation between phonological sensitivity and vocabulary .72 ($p < .01$) and the correlation between phonological memory and vocabulary was .40 ($p = .12$). That the relationship between phonological memory and vocabulary was not significant is not concerning—the findings in the literature are mixed regarding whether this relationship holds for all tests and for all ages (Baddeley, 2004). In fact when expressive vocabulary and the nonword repetition subtest scores were correlated the result was a significant positive relationship of .47 (*p* = .02), a finding that mirrors previously reported findings using these two measures (e.g. Adams and Gathercole, 1995). Similarly both measures of attention were related to overall vocabulary as well. The dimension change card sort task and vocabulary was .39, (p = .04), where fewer errors on the DCCS was related to higher overall vocabulary. In addition the relationship between rapid object naming and vocabulary was -.30 (p <.10), where a decrease in latency to name objects was associated with an increase in vocabulary. Again this supports previous literature that suggests a relationship exits between attentional skills and vocabulary.

However, unlike previous studies where most often current vocabulary rather than lexical learning has been the dependent measure, a negative relationship was observed. Learning in the initial domain and phonological memory were negatively related to each other, where the number of items correct on the composite phonological memory measure consisting of digit-span, word-span, and nonword repetition items, was associated with a fewer animals being learned from Domain 1. In particular, two of the three types of items were responsible for the negative correlation, items pertaining to word span and to nonword repetition. Of particular relevance is the notion that these skills are thought to be more advanced than simple digit-span in that they both require not only phonological memory itself, but also on an accumulated lexical knowledge base (Dollaghan, Biber, and Campbell, 1995; Gathercole and Baddeley, 1990b).

Children with more developed lexicons that contain knowledge and awareness about the phonological systems of a language show an advantage in word span and nonword repetition tasks because they can utilize phonological information, including words, stored in long-term memory (Gathercole et al., 1992). In the learning of many new words, however, this existing knowledge may serve as an initial detriment to the processing and learning of needed new structures. Recall that Ericsson and Kintsch (1995) have suggested that strategic retrieval structures, structures that contain both cues used for retrieval as well as the to-be-retrieved item, are stored as separate entries in the lexicon, which allows for information to be recalled rapidly during instances where constraints on processing are present. As lexical learning proceeds, less frequently recalled terms may be routinized into retrieval structures allowing individuals the benefits of being fast and accurate. Retrieval structures may represent a type of forward-working strategy that emerges only with extensive experience. Thus, for children gaining lexical experience it might be expected that initially, but not later in learning, children with high phonological memory might misapply existing long term knowledge and show a relatively low rate of new lexical learning for an extensive set of relatively complex subordinate animal names.

In summary, like studies prior to this one a relationship between phonological memory and word learning was detected. However, unlike previous studies that have used different dependent measures to approximate learning, a negative, rather than positive initial relation was found. Previous studies have looked at the relationship between vocabulary (as assessed by standardized measures or rate of learning, defined as the number of repetitions needed to learn a word) and phonological memory. In general these studies have evidenced an increase in vocabulary with increasing phonological memory. However, examination of the relationship between lexical learning *per se*, that is the actual proportion of words children remembered across a number of taught items, and phonological memory has revealed the opposite pattern- that some memory skills are related to a decrement in initial learning. The finding of a negative relationship between initial learning and initial scores on the phonological sensitivity measure seems, at first glance, counterintuitive. When viewed through the lens of expertise, however, this finding, as well as the u-shaped learning curves covered previously, are not contrary—detriments for a limited period of time in learning and performance because prior strategies fit poorly and also as the result of advancing knowledge in a domain are commonplace in situations where domain knowledge is initially tenuous and where accumulation of extensive knowledge and the resulting changes in strategy use are occurring (Siegler, 1996). These effects are specifically related to one's domain of expertise (Omodei, McLennon, Elliot, Wearing, & Clancy, 2005; Rassmussen, 1985; Rehder & Burnett, 2005).

The finding that initial phonological memory and word learning are related held across time. Both learning in Domain 2 and learning in Domain 3 were related to children's initial phonological memory skills. However, only the negative relationship between nonword-repetition and learning was sustained. It appears that as learning continues the relationship between the remembering of familiar words and low learning diminishes over time. Thus, as children are gaining lexical experience the array of skills that comprise phonological memory may shift in weight. That is, skills associated with a detriment in learning may become less influential over time, as children either become better able to handle additional complexities of word learning or begin to use strategies associated with word-learning that are based on their increasing lexicon rather than on their phonological memory skills alone (Baddeley, Gathercole, & Papagno, 1997).

Bowey, (1996, 2002) has shown that the ability to detect and manipulate sounds in a language, or phonological sensitivity, is associated with children's vocabulary knowledge. Furthermore Metsala (1999) and Werker et al. (2002) have suggested that phonological sensitivity is associated with children's ability to learn words. Similar to findings on the relation between initial learning and initial scores on the phonological memory composite we found that, contrary to expectations, a negative relation appears to exist between initial word learning and phonological sensitivity. Results showed that higher scores on the composite phonological sensitivity measure used in this study were related to decreases in word learning. Of the three phonological sensitivity skills tested, only one of these skills appeared to be driving this relationship—elision. Success on tests of elision requires children to be able to correctly recognize that words are made up of different parts and that, when these parts are taken away, the initial word becomes another one. For example if one takes the "tooth" away from "toothbrush" the remaining word is "brush". For 4-year-olds performance on this task is related to their previous vocabulary in prior literature (Lonigan et al., 2002) and in this study at Time 1. If, however, children use previous vocabulary as a basis for their guesses about names of animals that are not well-known they will likely guess incorrectly. Charles-Luce & Luce (1990) suggest phonological errors, errors like those reflected in some naming errors in this study, are the result of a children's premature commitment to guesses about heard words. That is, speculation about what a word is may be based only on partial phonetic information. Without the lexical background necessary for correct deductions, this tendency can lead to errors and thus interfere with word learning. For example, use of forward-working strategies when recalling the name of a Pomeranian might result in producing the word “pom-pom”. Similarly for a Spinone a produced word might be “spaghetti”. Thus, forward-working strategies based on partial knowledge in this case would fail, resulting in a decrease in the number of words learned for that domain. As children gain expertise however, that is as their database of words within a domain increases, the negative effects of such strategy use may decline. In fact, when initial phonological sensitivity scores and learning in the second and third domains were examined, the relationship between phonological sensitivity and learning disappeared.

Hypothesis 2 concerned the ways specific cognitive abilities contribute to lexical acquisition initially and across time, and how these abilities change as lexical learning proceeds. In addition to contributions by working memory and phonological sensitivity (i.e. perception), it was also hypothesized that attention and abstraction skills would be important in children’s initial lexical acquisition.

Unlike previous studies no relation was found between children’s attention, as measured by the Rapid Object Naming task, and children’s learning in the first domain. The fluid naming required for successful performance on the RON is thought to require both the ability to accurately activate names from memory as well as the ability to maintain attentional focus and inhibit previously activated names (Wagner, Torgeson, & Rashotte, 1999) and thus is used as a general attentional measure in the Preschool Comprehensive Test of Phonological Processing. In addition, the executive functioning required to attend to one dimension while inhibiting other interesting but irrelevant characteristics of a stimulus may be important for the allocation of attention to dimensions required for naming objects. The Dimension Change Card Sort test was used as a measure of this ability. For both of these measures there was no relation to initial word learning. Thus, at least during the initial period of lexical acquisition, abilities that comprise attention seem to be of little importance.

Abstraction is the ability to identify and use information from previously presented information, generalized to form a rule that best predicts how future information should be structured. In terms of word-learning and for the purposes of this study abstraction was the change in categorization strategies regarding new words (Gentner & Holyoak, 1997; Markman & Gentner, 2001; Waxman & Namy, 2001; Quinn & Eimas, 1997) The animals taught in this study could be grouped together in at least two ways: by how they looked, or by kind. Categorization of words by kind was the more predictive strategy for determining how novel instances (animals) could be grouped. Based on previous research implicating abstraction as important for word learning it was predicted that the increasing abilities to match familiar objects together based on names and category**,** rather than on shape, would be positively correlated with a greater proportion of words learned in the first domain. This prediction was not supported. There was no significant relationship between children's learning of the first domain and their tendency to choose conceptual, rather than perceptual, matches.

In summary it appears that two abilities play a role in children's initial word learning, while two do not. Working memory and phonological sensitivity may actually serve to disadvantage some children, while attention and categorical rule abstraction appear unrelated to initial learning. However, researchers have suggested that the influence of these different cognitive abilities may be exerted at different points in lexical advancement. For example, Arkenberg and Ryalls (submitted) have shown that phonological memory may be an important contributor to vocabulary acquisition across the preschool period, while phonological sensitivity may be important only in early preschool. In addition, Reiger (2003) and Keil (1998) suggest abilities such as attention and generalization of categorization strategies (abstraction) may result from continued word learning, and thus may contribute to later, rather than earlier lexical learning. The examination of the relationships between the different cognitive abilities measured initially and later learning, that is learning in the second domain and learning in the third domain showed that initial assessments of phonological memory and phonological sensitivity were minimally related to later learning. In fact only the negative relationship between initial nonword repetition and learning held over time. Interestingly then, while it appears that initial cognitive scores are sometimes related to lexical learning, the point children are in their learning of new words appears to matter. Certainly this has implications for cross-sectional and longitudinal studies that do not control for the amount of lexical acquisition when investigating the contributions of cognition to word learning.

Hypothesis 2 also predicted that potential changes in these abilities would result in different relationships between them and learning across time such that Time 2 assessments would be more strongly related to word learning in the second and third domains compared to the first. Only part of this hypothesis was supported as well. No evidence of a stronger relationship between Time 2 assessments and learning for the second or the third domain was found. Only the measure of abstraction at Time 2 was significantly related to later learning, where increasing abilities to match conceptually related items together was associated with greater learning in both the second and third domains. It is important to note that similar to Keil's claims (1992, 1994) abstraction appeared to be significantly related to learning in animal domains only after considerable learning had occurred. That is, it is not only possible, but likely that initial domain learning influenced gains in abstraction ability, which in turn influenced learning in Domains 2 and 3.

In sum, for the first part of Hypothesis 2, when cognition is assessed at Time 2, that is halfway through the intervention, it appears that phonological sensitivity and phonological memory no longer play a significant role in the prediction of learning. Rather, the ability of children to recognize that conceptually-based items go together is the only ability that is related to learning in either the second domain or the last taught domain. Attention, it appears, does not play a role in children's learning at any point in time, at least not as measured in this study.

Finally, for Hypothesis 2, it was expected that the intervention children would show increased scores on the cognitive ability measures as lexical learning proceeded and the cognitive measures were readministered at the halfway point of the word learning sessions (T2) and at the end of all learning sessions (T3). This held true for the most part and will be discussed along with the control/intervention comparisons covered under Hypothesis 3.

Hypothesis 3

A third hypothesis predicted that, in addition to increases in overall learning across time (as predicted in the first hypothesis) and increase over time in cognitive abilities (as predicted in the second hypothesis) children who were learning words would outperform a matched control group who did not engage in the word learning portion of the experiment, as gauged by assessment measures given at the second and third assessment periods.

Hypothesis 3 predicted that children in the intervention group would surpass children in the control group on cognitive measures assessed at both Time 2 and Time 3. To examine this question it was important not only to document changes in abilities over time, but also to show that these changes were due to learning words, rather than time itself. Comparisons between children in the learning intervention and their matched controls across time allowed for the investigation of whether learning was having an effect on cognition. Overall, it appeared it was. For phonological memory children in the intervention group showed an average increase of one and a half items, from 8.80 to 10.40 items correct (of 19 possible correct), from the initial to the final assessment periods. Matched controls showed no such increase over the same period of time. In terms of phonological sensitivity, average number correct increased from 9.30 items at Time 1 to 11.60 at time 2 to 12.90 at Time 2, a total of three and one-half items out of a possible 16. Matched controls showed no such increase. For intervention children latency to name objects on the Rapid Object Naming task, a measure of children's attention, improved (decreased) significantly across the three assessment periods. For children who were learning words as part of the intervention Time 1 latency to name the objects was approximately 49 seconds, Time 2 latency was approximately 43, and latency at Time 3 was approximately 37 seconds. Thus children showed a significant decrease of 12 seconds. In contrast, children in the matched control group showed no significant decrease in their latency to name the objects across the assessment periods. Finally, children whose lexical acquisition was being experimentally manipulated showed a change in their capacity for conceptually-based naming, as the basis for their paring of familiar items. That is, these children showed an increasing tendency to use conceptual rather than perceptual abstractions on the match-to-target task. While at Time 1 and Time 2 children were only matching approximately 7 items based on naming, that is conceptually, at Time 3 they had increased that number to an average of 11.20— over 4 additional items. Again, children in the control group did not show a difference across the assessment periods. Only on the DCCS did children in both groups perform similarly, and near ceiling. Thus, results for all of the cognitive measures except the DCCS suggest that, compared to matched controls, children who were learning a great many animal names were evidencing positive changes in cognition associated with that learning. Learning words positively impacted children's future cognitive abilities and in turn appeared to result in their increase in the proportion of words learned over time.

Most theories of children's language learning, including word learning, suggest some elementary processes help to guide the process of acquiring language, and that these same processes may become refined as the result of language acquisition-- that is they posit a two-process model of development. In the past theorists have acknowledged the roles of cognitive abilities such as attention, perceptual sensitivity, memory, and abstraction in children's acquisition of new words (Golinkoff, Mervis, & Hirsh-Pasek, 1994; Hollich et al., 2000; MacWhinney, 1998; Tomasello, 2000; Smith & Katz, 1996). For example, Gathercole and colleagues (1992, 1999) have shown that the learning of a small number of new lexical items can be explained in part by phonological memory (as well as previous vocabulary). The more items a child can store in phonological memory and the more words she knows, then the more words she can acquire. Others, such as Bowey (1996), and Storkel and Morrisette (2002) have illustrated a relation between phonological sensitivity and lexical development such that the better one's phonological sensitivity the stronger the correlation to acquisition of past and current word learning. Further, Tomasello, Baldwin, and others have shown that children pay attention to cues they know are important for making word-object pairings, including eye-gaze, body posture, voice-direction, hand position, and emotional expression (Akhtar & Tomasello, 1996; Baldwin, 1993a,1993b; Baldwin & Moses, 1996; Tomasello & Barton, 1994; Tomasello, Strosberg, & Akhtar, 1996). The ability to pay attention to relevant properties of the word-learning situation, including the properties of the word itself, may help to decrease other, extraneous information presented in word-learning situations that does not appear to play an important role in learning in the current situation. Children who do not use these cues learn words at a slower pace, and have fewer words in their lexicon than do children who do pay attention to word reference cues. Finally, the ability to extract information about words from verbal context and environmental contexts appears to contribute to children's novel-word learning such that children who abstract more information about context learn words more quickly (Childers & Tomasello, 2003; Markson & Bloom, 1997). Attention would require children to identify this information, while abstraction processes insure that information gained is used to support further learning and organization within a domain.

The result that children who are learning words are showing steadily increasing advances in cognition provides support for two-process models of lexical acquisition, with cognition influencing language and language influencing learning. The clear cut gains for the intervention children in terms of cognitive skills also suggests, as elaborated below, that learning words is similar to the development of expertise in a broad range of skill domains.

Question 3: Does word learning appear to mimic development of expertise?

The final question in this project concerned whether lexical learning across time is similar to the development of expertise. Clues suggesting that the answer here is ”yes” come from support of the first hypothesis- that the ability to learn improved from Domain 1 to 2 to 3, and the second and third hypotheses- that changes in cognition were the result of increased lexical acquisition. Learning was found to systematically increase both within and across domains, suggesting children are "learning to learn". Furthermore for every cognitive ability tested, phonological sensitivity, phonological memory, attention, and abstraction, we saw a systematic increase in performance across the three month period in association with the learning of new lexical items. From what is currently known about expert performance, children in this study who were learning animals names were showing the same benefits that are consistently found in experts—they were showing increases in their learning of domain-related information, increases in their perception of domain information, increases in their memory of domain information, increased attention to domain related properties, and increases in their ability to abstract rules about domain objects.

In addition, it was found that children in this experiment showed changes in their understanding of nonintuitive functional properties of the domain that could be used to group category items together. This was evidenced by children's matching choices and justifications in the daily matching task. Over time children showed a decreasing preference for pairing target animals with animals that were similar in appearance, and an increasing preference for pairing target animals and animals that belonged to the same subordinate category, that is, that shared the same name.

The decrease in the tendency to match animals together based on perceptual characteristics was large and significant, dropping by half from the first to the last domain. However, while children showed a decreasing tendency to pair animals together on the basis of what those animals looked like, they were still much more likely to pair items together based on the use of category names. Moreover, children were more likely to provide a conceptually-based reason for their choice as learning of words proceeded.

Numerous researchers have demonstrated gains in conceptual understanding with the acquisition of knowledge about that domain (Bedard & Chi, 1992; Chi & Keoske, 1983; Johnson & Mervis, 1994, 1998). Individuals who know more about a domain are able to generate more links between domain items, are able to recall domain information more quickly, and are more apt to identify unobservable functional characteristic as their reason for grouping similar domain items together. That children showed a restructuring of their understanding of the different animal domains over time, suggests that children in this study were showing the same types of changes that experts display. However, by 4 years of age children already have a relatively well-established representation of different kinds of animals and the way those animals can be grouped together (Deak, Ray, & Pick, 2002). Thus it is not surprising that children showed an overwhelming tendency to group animals together based on names. Furthermore children as young as 20-months of age have been shown to use naming for the purpose of classifying items together (Nazzi & Gopnik, 2001), suggesting the comparison of items with like names may initiate abstraction of how particular items can be most usefully grouped together (Gentner & Holyoak, 1997) and that names themselves may direct attention to those object properties, even nonobservable ones, that can be used as predictors for how to assimilate new lexical items upon future encounters (Smith, 1995; Smith & Heise, 1992, Yoshida & Smith, 2003). Learning not only the names of animals but also the names of the categories that are commonly used to distinguish between animals of different abilities, may provide children the core knowledge needed to categorize animals in the way that is most helpful and predictive for learning future domain items (Waxman & Booth, 2003; Waxman & Markman, 1995; Waxman & Namy, 1997).

The reasoning behind why children chose to pair animals together based on perception or based on conception echoed their matching choices. Again there was a decreasing tendency to focus on perception as the reason for pairing items together, and an increase (albeit very small) in children's tendency to provide reasons based on function.

Rassmussen (1985) has suggested that the development of expertise in any domain results in several layers of understanding and discovery, or abstraction, of the rules that apply to that hierarchy. First, individuals must recognize that a domain can be divided hierarchically, and that while different levels of the domain may exist, one can draw similarities across those levels. Each level deals with the very same system; the only difference is that different level provides different descriptions, or different models, for observing the system. Different levels of the hierarchy consist of their own unique set of terms, concepts, and principles, and vary in how they are described and measured. By moving up the hierarchy, one obtains a deeper understanding of significance with regard to the goals that are to be achieved, whereas in moving down the hierarchy, one obtains a more detailed explanation of functioning in terms of how those goals can be carried out. For example, learning about dinosaurs allows individuals to recognize that different types of dinosaurs exist, thus recognizing the need for classification, and that dinosaurs can be classified according to nonperceptually-based characteristics, like function, for the most accurate distinctions. The development of these different level of understanding has three benefits: it allows for problem-solving within a domain by allowing individuals to structure information; it allows them to start their problem-solving activities at a higher hierarchical level to simplify the problem; and it allows for focusing on different levels to selectively attend to only those parts of the domain that are relevant to the current context and interest (Vicente & Wang, 1998). Furthermore, children who evidenced cognitive change and who are unsure about the reasoning behind answers are frequently inconsistent in their justification for why they answered the way they did (Golden-Meadow & Alibali, 2002; Parziale, 2002; Siegler, 2002). This inconsistency, and corresponding decrease in performance, is hypothesized to result from competition between emerging computational strategies (Siegler, 1996) and is particularly apparent in both microgenetic work and work concerning dynamic systems theories (Thelen & Corbetta, 2002).

In general trends from the daily matching task where children were asked to match a target animal to one that was similar in kind or in appearance, and then to provide justifications for those matches suggest that children are indeed gaining expertise about that domain. These expertise gains appear to have resulted from the extensive learning of the words from those domains. Again, it appears that children are becoming experts at determining the features useful for the assimilation of new lexical items that arises from acquiring names of domain exemplars.

An additional change that would reflect children's burgeoning lexical expertise is their changing ability to rapidly name animals from the domains they are learning. The present results support conclusions of increased expertise by children with increasing lexical experience. In particular, a decrease in children's Rapid Animal Naming (RAN) latency across time and a change in the difference between the RAN latency and Rapid Object Naming (RON) latency were found. The same trend was absent in data from children in the control group. Only for children who were learning animal names did we see a decrease over time in RAN latency.

In essence this suggests that children who were learning about the same animal domains shifted their treatment of untaught animals on the RAN from items of unfamiliarity to items of commonality. Children showed an increasing propensity to treat the animals as if they were common, every day items (such as those found on the Rapid Object Naming Task), despite the fact that they were purposely not taught those individual exemplars. We did not teach children about poodles, mustangs, or robins- the specific items on the RAN-, nor were these animals referred to in any portion of the experiment other than testing on the RAN. Rather, taught to children were simply the names of other animals from those same domains. By the end of the learning of all three animal domains, horses and birds and dogs, latency for the intervention children on the RAN now resembled that for the RON.

Prior to this study, no experiments have looked at the culminating effects of lexical acquisition. However, there are some clues to changes in processing as the result of increasing knowledge. Recall that Chi and Koeske (1982) found that recall of associated concepts and elements was faster for well-known dinosaurs than for dinosaurs that were less well-known. In addition in studies of medical expertise, variables such as case typicality have been shown to impact speed of diagnosis (Custers, Boshuizen & Schmidt, 1996). Furthermore, Vogt and Magnussen (2005) have shown that recognition memory for both figurative and abstract photographs is significantly faster in artists (painters) than in individuals lacking the same kind of expert visual knowledge. Taken together and coupled with the extensive literature on lexical-priming effects these findings suggest that the more often information about a domain is accessed the quicker information related to that domain is recalled.

A final task designed to examine children's lexical expertise was designed to tap into children's ability to quickly recognize and use subtle differences in exemplars of similar but different domain items. It was hypothesized that children who were learning words would sort exemplars from the domains they were learning more quickly than items from domains they were not learning and more quickly than children in the control condition. In general children who were engaged in lexical learning and children who were not did not differ in their sorting behavior. No significant differences between the two groups of children were found at any point in time or for either the experimental or the control stimuli. Furthermore, within groups children showed the same overall pattern of behavior for animals from domains that were being learned by children in the intervention groups and animal domains that these children were not being explicitly taught. For both children in the intervention group and matched controls there was no significant difference in terms of children's latency to sort the items from the control domains. There was, however, a significant difference in sorting time for items from the domains targeted in the intervention. Both groups of children showed a decrease in their latency to sort animals from these domains from the first to the last assessment period. In general it appears that while children seem to be showing developing expertise in some regards, the effects of lexical learning do not appear to have impacted children's ability to differentiate among increasingly familiar domain items. It is unclear why children in both groups failed to show a decrease in their time to sort domain items from the control stimuli, yet improved in their ability to sort domain items. One possibility is that the domains of dogs, horses, and birds may already be more familiar to children than the domains from the control stimuli- bugs, frogs, etc. - thus giving all children an advantage in their latency to differentiate the animals. Another possibility is that while there were five separate control domains, there were only the three experimental domains. Although the specific stimulus items within each of the experimental domains were different at each assessment period, it is possible that the increased exposure to those domains in general resulted in a decrease in latency across time. Because all children sorted all of the domains, all children would then be expected to show a decrease in their latency to sort the stimuli from those domains. Moreover it is possible that the ability to rapidly distinguish between domain items is an ability that does not require labels to have been put to specific stimuli- that visual exposure to the domain is enough. Attention to object properties and resulting ability to quickly make within-category distinctions appears to be an ability that develops early in life and that requires little previous exposure to be employed. Thus the ability to differentiate between domain animals may be one of the initial elements of developing expertise in young children.

In summary, it appears that children who participated in the intervention potion of the experiment where they were being taught numerous new lexical items from three animal domains, showed evidence of developing expertise in multiple ways. In most, but not all, tasks designed to assess the skills resulting from children’s developing domain knowledge children learning words showed an increase in abilities that are generally associated with knowing a lot about a domain. While developing expertise was clearly evidenced in the distinction between performance on the Rapid Object Naming task and the Rapid Animal Naming task and in the distinction between children in the two groups, there was less evidence seen in tests of children's ability to differentiate domain items. In the sorting task all children showed a benefit from repeated exposure to animals from the experimental domains. It appears that children were showing signs of the developing expertise. This expertise is arising as the result of learning the names of domain items, as well as being exposed to object properties.

The combination of results from this study suggest that children who are learning new lexical items from specific domains are demonstrating behavior that is extremely similar to the behavior exhibited by experts. The intervention children in this study not only demonstrated positive and beneficial changes in their pattern of learning both within and across domains, they also showed significant increases in the cognitive abilities that have been previously hypothesized to aid in future word learning. Furthermore these children showed increases in their understanding of domain related information- that is how domain items can best be grouped together in a way that maximizes cognitive efficiency for that domain. This was apparent in their increased ability to quickly name domain items that have not been specifically taught to them. These results taken as a whole undeniably suggest that children are showing signs of expertise.

Children here were not only learning the names of the individual animals, but also the category to which that animal belonged. The use of multiple labels for the different dogs, horses, and birds, differs from previous research where different objects are labeled with one name, rather than many. Providing multiple names in this study- for example, “dog”, “working dog”, “kuvasz”- may have allowed children to develop a system of categorization that made use of this information in way that helped children to both group together and distinguish between different exemplars.

Rasmussen (1985) has suggested that developing expertise results in structural changes within a domain hierarchy. Both research on attention and abstraction suggest that this information may be obtained from the learning of individual domain items, and the resulting abilities to attend to different perceptual parameters, functional parameters, and corresponding names, and abstraction of common elements for the purpose of reorganizing the knowledge base. Gentner and Markman (1997) and Gentner and Holyoak (1997) have suggested that comparison between exemplars is the mechanism for abstraction and that this comparison highlights both commonalties between and differences among categories and category items. Comparison changes knowledge by inviting inferences that can be used to more efficiently assimilate new information. Common labels may allow children to notice more abstract similarities between objects and the comparison between these similar items allows for matching of semantically similar representations both within and between categories (Markman & Gentner, 2001). That is, it allows for structural alignment.

New lexical items themselves, then, may be inviting children to discover categories (Waxman & Markow, 1995) by applying what they know about words for the purpose of assimilating information. To illustrate, recall that Waxman and Booth (2001) showed that even very young children can use word type, such as nouns and adjectives, determine whether to classify objects at the basic or superordinate level. They argue that word types allow children to direct their attention to the property that they know best describes either as basic or superordinate match. Furthermore Waxman and Booth (2003) suggest that children appear to learn this as they gain linguistic experience. Additionally Johnson and Mervis (1994) have shown that acquiring knowledge about a domain does in fact result in reorganization of one's conceptual hierarchy and that this reorganization results in abstracting rule-based information that can be applied to new category exemplars. The more knowledge a child gains about a domain, the more their lexicon becomes interconnected and the better able they are to make the structural alignments needed to infer new rules for assimilating or accommodating information into their lexicon. Repeated exposures to relative information increasingly connects the lexicon, allowing for increasingly efficient abstraction processes to occur.

This evidence coupled with the findings from this study suggest that children are provided with an advantage of learning multiple domain items with overlapping names. The complexity of the words taught in this study appears to have facilitated children lexical acquisition by initiating the processes that result from gaining related information. This point should not be taken lightly. That children benefit from complex relations between lexical items is counterintuitive to educational practices today. Rather than providing simplified versions of information to children, these results indicate that perhaps more is better. Allowing children the opportunity to construct their own knowledge bases from complex interwoven material can provide multiple opportunities that simpler information cannot provide.

Chapter 5

CONCLUSION

There are gaps in the literature concerning children's lexical acquisition. Prior to this study there was no accurate picture of what children's lexical learning looked like when a very large set of new lexical items were acquired. Furthermore, it was unclear how cognitive variables such as memory, perception, attention, and abstraction contributed to extensive new word learning. Moreover, while theories of lexical acquisition had implied that consequences of learning words were probable in terms of these cognitive abilities, no experimental investigations of this claim had been performed. The purpose of this study was to provide sound experimental evidence concerning these issues with the aim of bridging some of the gaps that were apparent in the literature on children's word learning and in an effort to draw the analogy between lexical acquisition and expertise.

Using a microgenetic design it was found that the learning of words is an adapting and adaptive process- children show evidence of changing strategies across time that result in an overall increase in their propensity to learn words. Initial word-learning may be based on previously used strategies for acquiring new words. At the point at which those strategies become inefficient and learning rates decline temporarily there may be analysis and reanalysis of information for the development of new strategies. The resulting new strategies are more adaptive for word-learning and result in increasing proficiency in children's ability to learn new words. The levels of proficiency shown by the children in this study were in all likelihood dependent upon the theory-driven teaching procedures, all of which served to scaffold children's learning of new lexical items. These 4-year-olds given these conditions of learning showed rates of learning on average that far exceed the rates estimated from prior naturalistic or experimental studies. In this study the rates of learning were close to 20 words per hour compared with estimates of 20 words per day.

Strong, but somewhat surprising evidence was found to support the idea that cognition plays a role in the initial learning of words. Both memory and perception appear to influence initial word learning. However, because children in this study were not naïve to word learning and because they were learning many more words than most prior learning studies have examined, their phonological sensitivity and phonological memory skills may have led to too much use of prior knowledge of word structures in general and too little processing of the complex names and examples and therefore to a decrement in initial performance in learning animal names. Attention, it seems, does not contribute to the onset of children's word learning while abstraction appears to contribute to children's later word learning and may be initialized by previous lexical acquisition of many names in Domain 1.

The consequence of learning words is the refinement of cognitive abilities. Children's ability to perceive, remember, attend to, and abstract all improved over time. Because children in the matched control group did not show these same benefits over time, it can be concluded that these increases in ability are results of learning many new words. Recall that the number of animal names learned across the 10 intervention children ranged from 144 to 369 and averaged 261. Word learning of this extent allows for the fine-tuning of children's cognitive abilities- revisions that allow, along with the shifts in strategies and organization attributed to the children, for even greater learning to take place. These cognitive abilities and the corresponding changes associated with them after word learning has occurred are the same as those seen in literature on experts. Experts show the same performance advantages in their perception, memory, attention, abstraction and learning that were seen here.

This set of results is important in many regards. First they give validity to the two-process models that were previously tentatively supported by direct empirical evidence. Second, it encourages more systematic application of models of expertise to children's lexical acquisition. This support, coupled with results suggesting children who are learning words are showing evidence of developing expertise suggests an excellent fit between these two previously separate areas of study. It appears children who are learning words show the same benefits and detriments as documented experts. Thus, word learning is developing "lexpertise".

These findings have definitive implications for the ways in which parents and educators interact with children. In terms of the learning of words, helping children to develop a rich knowledge base of associations may be extremely beneficial. Thus, the simple strategy of explaining that there are, for example, many kinds of trucks- pickup trucks, dump trucks, Mac trucks, and others, may aid in children's development of a more sophisticated domain and thus to a greater ability to pay attention to, remember, perceive, and abstract rules about other kinds of trucks as well as other domains that can be structured in a similar way. These increasing abilities will help children to learn words faster and in turn to become better able to communicate with others and in the world around them.

The results of this study however, should not be viewed as all-encompassing or complete; there is still much work to do. The results of this study are based on a relatively small number of children. Thus, there is need for replication to determine if these same results hold for larger samples of children. Furthermore it appears that there may be a difference in using word-learning versus vocabulary as the dependent measure in studied of children lexical acquisition. Less disturbing is the fact that similar to previously reported results, separate measures of different cognitive abilities here were correlated to a varying degree with each other, and with children's total vocabulary scores. Based on results from this study it is likely that learning of words rather than static vocabulary may be the impetus for cognitive change and that developmental changes in learning words may result from the awareness that different explanations may be used for the determination of category membership—a lesson that comes from exposure to words that provide information that would allow for this insight (Keil, 1992; 1994).

Finally, it should be noted that while lexical learning may look like developing expertise, only very initial tests of this claim were performed in this study. It is estimated that it takes 10 years or more to become an expert (Diamond & Carey, 1986). It is unlikely that the teaching of 450 new animal names resulted in expertise as defined by the current literature. However, it is entirely likely that the changes seen in children who participated in the intervention portion of the study showed the initiation of processes involved in the development of expertise, and that these same processes needed to become an expert also underlie increasing proficiency in lexical acquisition.

Despite these caveats the results from this work are promising for taking the steps needed to draw the analogy between children's lexical learning and the development of expertise. Children do show the benefits associated with increasing lexical knowledge in terms of both their cognition and their learning. Continued investigation into the similarities and differences between child word learners and experts can only move forward the fields of word learning and of expertise.

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