Chapter 24: The Developing Mental Lexicon of Children with Specific Language Impairment

Holly L. Storkel

University of Kansas

The Handbook of Psycholinguistic & Cognitive Processes: Perspectives in Communication Disorders

Editors: Jacqueline Guendouzi, Filip Loncke, Mandy J. Williams

Publisher: Taylor & Francis

Acknowledgements: Preparation of this chapter was supported by NIH grant DC08095. S. M. Adlof, M. S. Bridges, T. P. Hogan, and J. R. Hoover provided valuable comments on an earlier version of this chapter.

Address for Correspondence: Holly L. Storkel, University of Kansas, Department of Speech-Language-Hearing: Sciences and Disorders, Dole Human Development Center, 1000 Sunnyside Ave., Room 3001, Lawrence, KS 66045-7555 USA, hstorkel@ku.edu, www.ku.edu/~wrdlrng/.

Introduction

The mental lexicon refers to "the collection of words stored in the human mind" (Trask, 1997, p. 140) with each entry "detailing the properties of a single lexical item: its pronunciation, its meaning, its word class, its subcategorization behaviour, any grammatical irregularities, and possibly other information" (Trask, 1997, p. 130). This chapter will focus on a subset of the properties of lexical items that are frequently incorporated in adult and child models of spoken language processing, namely phonological, lexical, and semantic representations (Dell, 1988; Gupta & MacWhinney, 1997; Levelt, 1989; Luce, Goldinger, Auer, & Vitevitch, 2000; Magnuson, Tanenhaus, Aslin, & Dahan, 2003; McClelland & Elman, 1986; Norris, 1994). The phonological representation includes information about individual sounds, with models varying in the specific information incorporated (e.g., phonetic features, context-specific allophones, phonemes). For simplicity of illustration, phoneme units will be used to illustrate the phonological representation in this chapter. Thus, the phonological representation of the word "cat" would consist of the individual phonemes /k/, /æ/, and /t/ (i.e., three separate units). The lexical representation includes information about the sound structure of the word as an integrated unit. Continuing the illustration, the lexical representation for "cat" would be /kæt/ (i.e., one unit). Lastly, the semantic representation consists of information about the meaning or referent of the word. Here, the semantic representation for "cat" would include, but not be limited to, information such as "four-legged furry pet that purrs."

For the developing mental lexicon, there are two processes of critical importance. The first process involves the actual creation of the mental lexicon. That is, children are not born knowing the words of their language. Instead, words must be learned through exposure to the language during every day interactions. The second process involves accessing the words in the mental lexicon for language production or comprehension. This is the process that allows children to use the words that they know to communicate. It is critical to understand the potential relationship between these two processes to differentiate different underlying causes of the same behavior. For example, one commonly used paradigm to assess the status of the mental lexicon is to have children name pictures (e.g., Brownell, 2000; Williams, 1997). If a child fails to produce a name for the target picture (i.e., no response is provided), there are at least two possible explanations. The first possible explanation is that the child may not have learned the name for the picture, either because the child has never encountered that item before (i.e., lack of exposure) or because the child has failed to create an appropriate phonological, lexical, and/or semantic representation for the word despite being exposed to the word (i.e., word learning deficit). The second potential explanation is that the child has created an appropriate phonological, lexical, and semantic representation for the word but is having difficulty accessing those representations to produce a correct response within the time constraints of the test format (i.e., retrieval deficit). It should be clear that these two potential underlying causes of the same observed behavior would lead to different diagnostic conclusions and different treatment approaches.

Models of the Lexicon

One of the difficulties in disentangling learning and access in the developing lexicon is that there are few models that incorporate both processes (but see Magnuson et al., 2003). The tendency is for models of word learning to account for patterns observed in learning new words without accounting for patterns observed in production or recognition of known words (e.g., Gupta & MacWhinney, 1997). Likewise, many models of production or recognition of known words do not account for how those words were acquired (e.g., Dell, 1988; Levelt, 1989; Luce et al., 2000; McClelland & Elman, 1986; Norris, 1994). It is not the case that researchers are disinterested in creating models of the lexicon that learn new words and access known words, but rather that the complexities of both processes make an omnibus model somewhat intractable. Although a complete model or theory does not exist, important components can be garnered from existing models of each process.

One critical component in a model that integrates lexical learning and access is to provide some mechanism to trigger learning. That is, when listening to spoken language, the child must have some way of determining whether a word is novel, and thus new lexical and semantic representations need to be created (i.e., learning), or whether a word is known, and thus existing lexical and semantic representations should be accessed so that the word can be produced or recognized. Some types of models include just such a mechanism. Specifically, adaptive resonance theory, which has been used to model a variety of cognitive processes, involves activation of existing representations whenever novel or known information is encountered (e.g., Carpenter & Grossberg, 1987). However, when the information in the environment sufficiently mismatches the representations in memory, learning is triggered. This allows for the creation of new representations in memory as well as modification to existing representations. Thus, when listening to a word, existing representations will be activated. In the case of a novel word, existing lexical and semantic representations will not sufficiently match the novel word, thereby triggering learning. In the case of a known word, an existing lexical and semantic representation will sufficiently match the known word, thereby triggering production or recognition of the word.

Assuming that word learning is triggered, how does it proceed? Here, models of word learning are useful in outlining the process (e.g., Gupta & MacWhinney, 1997). Figure 1 offers a schematic of the learning process when the novel word /goʊm/ is encountered. Phonological representations of the individual phonemes comprising the novel word will be activated and may aid in maintaining the sound sequence in working memory while a new lexical representation is created. Likewise, a new semantic representation will be created. Various forms of working memory will likely play a role in temporary storage of information while the semantic representation is being created but this will depend on the details of how the referent is presented (e.g., whether there is a visual referent or not). In addition to creating new lexical and semantic representations, a link must be created between the two new representations to support future production and recognition of the word. Finally, links must be created between the new representations and existing representations in the lexicon so that the new representations are integrated with the old. These new representations and links are accessed upon subsequent exposure to the novel word, allowing modification of the representations and links (in the case of incorrectly learned or missing information) as well as strengthening of the representations and links. Thus, word learning is a protracted process with the potential for incorrect or gradient representations prior to mastery (e.g., Capone & McGregor, 2005; Gershkoff-Stowe, 2002; Metsala & Walley, 1998).

In the case of production or recognition, multiple existing representations are activated until one representation is selected. In the case of spoken word production, activation of semantic representations will be initiated first (e.g., Dell, 1988; Levelt, 1989). In the case of spoken word recognition, activation of form based units, namely phonological and lexical representations, will be initiated first (e.g., Luce et al., 2000; McClelland & Elman, 1986; Norris, 1994). Models differ in the amount of interaction between lexical and semantic activation. Some models hypothesize that activation of one type of representation must be completed before activation of the other is initiated (e.g., Levelt, 1989), whereas others assume that activation of one type of representation influences activation of the other (e.g., Dell, 1988). This debate has not fully reached the developmental literature. Thus, the developmental literature does not necessarily favor one type of model over the other.

Normal Development

Past research documents that typically developing children rapidly acquire a lexicon. Following just a single exposure, children are able to associate a novel word form with its referent (Dickinson, 1984; Dollaghan, 1985; Heibeck & Markman, 1987). This ability has been termed fast mapping (Carey & Bartlett, 1978). It is not assumed that a child has mastered a word following a single exposure but rather has initiated the creation of an initial lexical and semantic representation, which is then refined over time and with repeated exposure to the word. This period of long term learning is often referred to as extended mapping (Carey & Bartlett, 1978). Typically developing children also are able to create initial lexical and semantic representations of words with relatively few exposures in naturalistic discourse (e.g., television programs), sometimes referred to as quick incidental learning (QUIL, Rice & Woodsmall, 1988). These abilities allow children to rapidly build a lexicon, learning as many as nine words per day by some naturalistic counts (Bloom, 1973; Clark, 1973; K. Nelson, 1973; Templin, 1957).

Additional research on typically developing children has attempted to determine what factors account for this rapid word learning. There is ample research in this area with studies focusing on phonological (Bird & Chapman, 1998; Leonard, Schwartz, Morris, & Chapman, 1981; Schwartz & Leonard, 1982; Storkel, 2001, 2003, in press; Storkel, Armbruster, & Hogan, 2006; Storkel & Rogers, 2000), prosodic (Cassidy & Kelly, 1991; Cutler & Carter, 1987; Morgan, 1986), lexical (Storkel, 2004a, in press; Storkel et al., 2006); semantic (Gershkoff-

Stowe & Smith, 2004; Grimshaw, 1981; Pinker, 1984; Samuelson & Smith, 1999; Smith, Jones, Landau, Gershkoff Stowe, & Samuelson, 2002; Storkel, in press; Storkel & Adlof, 2008b), syntactic (Gleitman, 1990; Gleitman & Gleitman, 1992; Landau & Gleitman, 1985), and pragmatic cues (Baldwin, 1993; Baldwin et al., 1996; Sabbagh & Baldwin, 2001; Tomasello, Strosberg, & Akhtar, 1996). Below, some of the research on phonological, lexical, and semantic cues relevant to word learning is highlighted.

One phonological cue that has received recent attention is phonotactic probability. Phonotactic probability is the frequency of occurrence of individual sounds or pairs of sounds such that some legal sound sequences in a language can be identified as common (e.g., /kæt/ - "cat") whereas others are classified as rare (e.g., /dɔg/ - "dog"). Phonotactic probability appears to be learned early in development with sensitivity emerging around 9-months of age (Jusczyk, Luce, & Charles-Luce, 1994). Phonotactic probability is positively correlated with a lexical cue, namely neighborhood density (Storkel, 2004c; Vitevitch, Luce, Pisoni, & Auer, 1999). Neighborhood density refers to the number of words in a language that are phonologically similar to a given word, such that some words reside in dense neighborhoods (e.g., /kæt/ - "cat") with many phonologically similar neighbors (i.e., 27 neighbors for "cat"), whereas others reside in sparse neighborhoods (e.g., /dɔg/ - "dog") with few phonologically similar neighbors (i.e., 6 neighbors for "dog"). The correlation between phonotactic probability and neighborhood density arises because words with common sound sequences tend to reside in dense neighborhoods (e.g., /kæt/ - "cat") and words with rare sound sequences tend to reside in sparse neighborhoods (e.g., /dɔg/ - "dog"). Note that this correlation is not perfect and that is it possible to identify words with common sound sequences residing in sparse neighborhoods (e.g., /dɑl/ - "doll" with 9 neighbors) and those with rare sound sequences residing in dense neighborhoods (e.g., /geɪm/ - "game" with 18 neighbors).

Word learning studies of correlated phonotactic probability and neighborhood density show that typically developing preschool children learn common/dense novel words more accurately than rare/sparse novel words, when given limited exposure to the novel words (Storkel, 2001, 2003, 2004b; Storkel & Maekawa, 2005). Recently, the individual effects of phonotactic probability and neighborhood density have been disentangled. In experimental studies of adult and child word learning, both phonotactic probability and neighborhood density appear to influence word learning with each variable affecting a different step of the word learning process (Hoover, Storkel, & Hogan, in preparation; Storkel et al., 2006). Specifically, phonotactic probability appears to play a role in triggering word learning, such that novel words with rare sound sequences are learned more accurately than novel words with common sound sequences. It was hypothesized that because rare sound sequences are more unique from other known sound sequences, they create larger mismatches, triggering creation of a new representation immediately. In contrast, common sound sequences are deceptively similar to many other known sound sequences, creating smaller mismatches. This potentially impedes the recognition of the word as novel and delays the triggering of word learning. Neighborhood density appeared to play a role in the integration of a new lexical representation with existing lexical representations. Here, novel words from dense neighborhoods were learned more accurately than novel words from sparse neighborhoods. It was hypothesized that forming links with many existing lexical representations served to strengthen the newly created lexical representation, improving retention of the new representation. Similar results were obtained in a corpus analysis of the words known by typically developing infants (Storkel, in press).

Recent work has examined a semantic variable similar to neighborhood density, namely semantic set size (Storkel & Adlof, 2008a, 2008b). Semantic set size refers to the number of words that are meaningfully related to or frequently associated with a given word, as determined by discrete association norms (D. L. Nelson, McEvoy, & Schreiber, 1998). We collected discrete association data from preschool children and adults for novel objects so that the novel objects could be classified as similar to many other known objects, namely a large semantic set size, or similar to few other known objects, namely a small semantic set size (Storkel & Adlof, 2008a). An experimental word learning study showed that preschool children learned novel words with small and large semantic set sizes equivalently. However, children retained novel words with a small semantic set size better than novel words with a large semantic set size (Storkel & Adlof, 2008b). Note that this finding is counter to the findings for neighborhood density where similarity to many known items facilitated learning. In the case of semantic set size, it was hypothesized that forming links with many existing semantic representations leads to confusion between the newly created semantic representation and existing semantic representations. This likely degraded the newly created representation, impeding retention. Further research is needed to better understand this discrepancy between the influence of lexical versus semantic similarity on word learning; however, one initial hypothesis is that lexical and semantic neighborhoods differ in neighbor diversity and this may impact how these representations influence word learning. Specifically, lexical neighbors always share the majority of phonemes with the new word (i.e., by definition, a neighbor differs by only one sound), whereas semantic neighbors could share few features with the new word and differ by many features, leading to a less focused and cohesive neighborhood.

The studies reviewed to this point have focused primarily on the early stages of learning a word when learning is triggered or when a new representation was recently created or retained over a relatively short delay. There is evidence that these newly created representations may be graded (e.g., Capone & McGregor, 2005; Gershkoff-Stowe, 2002; Metsala & Walley, 1998), such that the representation is incomplete or lacks detail. This hypothesis is supported by empirical study. For example, Storkel (2002) showed that lexical representations of known words from dense neighborhoods were phonologically detailed, whereas lexical representations of known words from sparse neighborhoods were less detailed, particularly for sounds in word final position. Likewise, McGregor and colleagues (K. McGregor, Friedman, Reilly, & Newman, 2002) showed that semantic representations of known words could be rich and complete or meager and incomplete. Thus, even when a typically developing child knows a word, the underlying lexical and semantic representation may not be as complete and detailed as in the adult lexicon. This, in turn, has consequences for production and recognition. For example, Newman & German (2005) demonstrated that the impact of neighborhood density on spoken word production diminished with development, presumably because the difference in completeness of lexical representations diminishes with development. That is, completeness of lexical representations is hypothesized to vary by neighborhood density in children. In contrast, adults arguably have complete and detailed representations of words in dense as well as sparse neighborhoods. Turning to spoken word recognition, Garlock and colleagues (Garlock, Walley, & Metsala, 2001) showed minimal developmental changes in the recognition of dense words in a gating task but greater developmental changes in the recognition of sparse words. They attribute this developmental pattern to changes in the completeness of lexical representations of words in sparse neighborhoods.

Children with SLI

Children with Specific Language Impairment (SLI) are children who show significant deficits in language acquisition in the absence of any obvious cause (Leonard, 1998). In general, language deficits in children with SLI are noted across all domains of language, although some argue that the most severe deficits occur in morphosyntax (Rice & Wexler, 1996; Rice, Wexler, & Cleave, 1995; Rice, Wexler, & Hershberger, 1998). Prevalence rates for SLI are approximately 7% for kindergarten children (Tomblin et al., 1997). There are a variety of theories about the nature of SLI, with some focusing on limitations in linguistic knowledge and others focusing on general or domain-specific processing deficits (see Leonard, 1998 for review). In terms of the lexicon, children with SLI usually score lower than their age-matched typically developing peers on standardized tests of vocabulary, although their scores may still fall within the normal range (Gray, Plante, Vance, & Henrichsen, 1999). Experimental word learning studies generally show that children with SLI learn fewer words than their same aged typically developing peers, although there is variability across studies and there is evidence of individual differences within the SLI group (specific studies reviewed below). Research by Gray (2004; Kiernan & Gray, 1998) examining individual differences in word learning indicated that approximately 30%-73% of children with SLI learned as many words as their typically developing peers. Thus, word learning by 27-70% of children with SLI fell outside the normal range. These estimates of the percentage of children with SLI who exhibit word learning difficulties should be viewed with caution because they are based on small samples of children with SLI. However, these individual differences should be kept in mind when reviewing the results of group studies (see below).

In terms of fast mapping, deficits in fast mapping have been documented in some studies (Dollaghan, 1987; Gray, 2004) but not others (Gray, 2003, February, 2004). Across studies, there is no evidence that children with SLI have difficulty associating the novel word with a novel object. When difficulties occur, they appear in later comprehending (Gray, 2004) or producing the novel word (Dollaghan, 1987). Deficits are observed more consistently during extended mapping (Gray, 2003, February, 2004; Kiernan & Gray, 1998; Oetting, Rice, & Swank, 1995; Rice, Buhr, & Nemeth, 1990), with some studies suggesting that children with SLI may need twice as many exposures to achieve the same comprehension and production accuracy as same aged typically developing children (Gray, 2003, February).

Where in the word learning process do these deficits occur in children with SLI? Triggering of word learning has received less attention in the literature on word learning by children with SLI. The results of at least some fast mapping studies would hint that triggering word learning may not be problematic for children with SLI (Gray, 2003, February, 2004). However, this conclusion can only be viewed as tentative, given the paucity of research in this area. In contrast, there is clear and consistent evidence that children with SLI have difficulty creating and retaining mental representations of novel words. Moreover, this difficulty appears to impact both lexical and semantic representations. For example, Alt and colleagues (Alt & Plante, 2006; Alt, Plante, & Creusere, 2004) exposed children to novel words paired with novel objects. After exposure, they examined lexical representations by having the children judge whether a sound sequence was the correct name of the novel object (i.e., the name paired with the object during exposure). Children with SLI recognized fewer names than their typically developing peers, suggesting deficits in the creation and/or retention of lexical representations. In addition, Alt and colleagues examined semantic representations by presenting the novel word and asking children whether its referent had certain semantic features. Children with SLI correctly identified fewer semantic features than their typically developing peers, indicating deficits in the creation and/or retention of semantic representations.

Work by Gray provides a similar conclusion, although suggests that these deficits may be true of only certain children with SLI. Gray (2004) identified children with SLI who performed significantly more poorly on the word learning task than the rest of the group. Approximately 35% of the children with SLI were classified as poor word learners. Gray then examined the word learning profiles of these children to identify potential areas of deficit. For each novel word that the child did not learn, lexical representations were viewed as the area of deficit if the child never learned to produce the novel word during training, whereas semantic representations were viewed as the area of deficit if the child drew a poor picture of referent of the novel word after training. For 79% of the unlearned words, lexical representations were implicated whereas semantic representations were implicated for the remaining 21%. Interestingly, both areas of deficit generally were observed for each child. Moreover, Gray (2005) has shown that providing phonological (e.g., initial sound, initial syllable, rhyming word) or semantic cues (e.g., superordinate category, physical characteristics, action or use) during training improves word learning by children with SLI. Presumably, provision of cues improves the child's ability to create a new lexical or new semantic representation, depending on the cue provided.

Even when children are successful in creating a new lexical or semantic representation, there is evidence that they have difficulty retaining these representations over time. Rice and colleagues (Rice, Oetting, Marquis, Bode, & Pae, 1994) examined the influence of amount of exposure on word learning by children with SLI. With 3 exposures to the novel words, the children with SLI performed more poorly than the typically developing children on an immediate post-test of comprehension. In contrast, with 10 exposures to the novel words, children with SLI performed similarly to typically developing children in an immediate post-test of comprehension. Thus, immediate learning by the children with SLI was similar to the typically developing children when greater exposure was provided. However, when the post-test was re-administered 1 to 3 days after the 10 exposures, group differences emerged with the children with SLI performing more poorly than the typically developing children, especially for verbs. This suggests that children with SLI had greater difficulty retaining new representations over time and implicates the integration of newly created representations with existing representations as a potential area of deficit in children with SLI.

These potential word learning deficits have consequences for spoken word production and recognition by children with SLI. Considering first production and semantic representations, McGregor and colleagues (K. K. McGregor, Newman, Reilly, & Capone, 2002) provide evidence that naming by children with SLI is affected by the quality of semantic representations. Children were asked to name pictures and their responses were categorized as correct, semantic error, indeterminate error (e.g., “I don’t know”), or other error. Children then were asked to draw pictures and define the same items that they had been asked to name. Analyses compared the quality of drawings and definitions for correct versus semantic errors versus indeterminate errors as a means of examining the quality of the semantic representations of the words in each response category. Results showed that children with SLI named fewer pictures correctly than their typically developing peers. For both groups of children, drawings and definitions for correctly named items were richer and more accurate than those for incorrectly named items, with no differences noted between semantic versus indeterminate errors. McGregor and colleagues also examined the pattern of responses across tasks for each word and determined that approximately one-third of erred responses were attributable to retrieval failure during naming despite adequate semantic representations (i.e., rich drawing, rich definition, and correct comprehension). Approximately another one-third of erred responses were attributable to sparse semantic representations (i.e., poor drawing, or poor definition, or incorrect comprehension). The final one-third of erred responses was attributable to missing lexical or semantic representations (i.e., poor drawing, poor definition, and incorrect comprehension). Taken together, approximately one-third of naming errors were due to retrieval failures, whereas two-thirds of naming errors were attributable to word learning deficits.

Turning to word recognition and lexical representations, Maillart and colleagues (Maillart, Schelstraete, & Hupet, 2004) provide evidence that recognition by children with SLI is affected by the quality of lexical representations. Children completed a lexical decision task where they were asked to identify auditorially presented stimuli as real words or nonwords. Children with SLI were less accurate than typically developing children in this task. Moreover, children with SLI had much greater difficulty rejecting nonwords that differed only slightly (i.e., a phoneme change rather than a syllable change) from a real word. This pattern suggests that children with SLI may have had more holistic lexical representations of real words leading to confusion between slightly modified nonwords and real words.

Finally, research suggests that the quality of lexical and semantic representations has implications for learning to read and write, placing children with SLI at risk for future academic deficits (e.g., H. Catts, Adolf, Hogan, & Weismer, 2005; H. W. Catts, Fey, Tomblin, & Zhang, 2002; Walley, Metsala, & Garlock, 2003).

Summary and Conclusions

The theoretical framework outlined at the onset of this chapter provides a means for investigating and understanding differences in the lexicons of children with SLI and their typically developing counterparts. In terms of the different types of representations in the lexicon, children with SLI exhibit deficits in both lexical and semantic representations. The status of phonological representations has received less attention. Most of the research in this area has focused on accessing phonological representations (e.g., Tallal, Stark, & Mellits, 1985), rather than examining the quality of phonological representations. Turning to the process of word learning, children with SLI appear to have deficits in creating, retaining, and/or integrating new representations in their lexicons. Additional research is needed in this area to more fully differentiate the deficits in each process (i.e., creating vs. retaining vs. integrating). Investigation of variables from studies of normal development (e.g., neighborhood density, semantic set size) may be useful in this endeavor. The process of triggering word learning has not been fully investigated, warranting future study. Considering production and recognition of known words, children with SLI show complex deficits in spoken word production and recognition. At least some of their difficulties in this area can be attributed to problems in accessing detailed representations, whereas others can be attributed to holistic or incomplete representations. This pattern highlights the interplay between word learning and production/recognition in the developing mental lexicon.

While much has been learned about the nature of the developing mental lexicon of children with SLI, clinical methods have not yet been fully informed by this knowledge. Specifically, most diagnostic tools take a global approach to assessment by examining the words that a child has already learned. The words a child has already learned, as revealed by this type of test, is a function of the child's exposure to words, the child's ability to learn words, and the child's ability to produce or recognize the words within the format and time constraints of the test. Thus, most diagnostic tools fail to differentiate environment, learning, and access in their examination of the lexicon. Consequently, if a child performs poorly on such a task, the underlying cause of that poor performance can not be immediately identified. Moreover, a deficit could be missed because strengths in one (or more) of these areas (environment, learning, access) could mask weaknesses in the other areas. Given this situation, it is important to supplement standardized test scores with clinician developed probes that are informed by theory. Probes that examine the quality of representations (lexical vs. semantic), different stages of learning (triggering learning vs. creation of new representations vs. retention/integration of new representations), and differentiate these from access to representations would be the most informative for treatment planning (see Gray, 2004; 2005 for a potentially clinically adaptable example).

References for Further Reading

1. Golinkoff, R. M., Hirsh-Pasek, K., Bloom, L., Smith, L. B., Woodward, A., Akhtar, N., et al. (2000). *Becoming a word learner: A debate on lexical acquisition*. Oxford: Oxford University Press.
2. Bloom, P. (2000). *How children learn the meanings of words*. Cambridge, MA: MIT Press.
3. Leonard, L. B. (1998). *Children with specific language impairment*. Cambridge, MA: The MIT Press.

References

Alt, M., & Plante, E. (2006). Factors that influence lexical and semantic fast mapping of young children with specific language impairment. *Journal of Speech, Language and Hearing Research, 49* (5), 941-954.

Alt, M., Plante, E., & Creusere, M. (2004). Semantic features in fast-mapping: Performance of preschoolers with specific language impairment versus preschoolers with normal language. *Journal of Speech, Language and Hearing Research, 47* (2), 407-420.

Baldwin, D. A. (1993). Infants' ability to consult the speaker for clues to word reference. *Journal of Child Language, 20*, 395-418.

Baldwin, D. A., Markman, E. M., Bill, B., Desjardins, R. N., Irwin, J. M., & Tidball, G. (1996). Infants' reliance on a social criterion for establishing word-object relations. *Child Development, 67*, 3135-3153.

Bird, E. K. R., & Chapman, R. S. (1998). Partial representations and phonological selectivity in the comprehension of 13- to 16-month-olds. *First Language, 18*, 105-127.

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

Brownell, R. (2000). *Expressive one-word picture vocabulary test - 3rd edition*. Novato, CA: Academic Therapy Publications.

Capone, N. C., & McGregor, K. K. (2005). The effect of semantic representation on toddlers' word retrieval. *Journal of Speech, Language and Hearing Research, 48* (6), 1468-1480.

Carey, S., & Bartlett, E. (1978). Acquiring a single new word. *Papers and Reports on Child Language Development, 15*, 17-29.

Carpenter, G. A., & Grossberg, S. (1987). A massively parallel architecture for a self-organizing neural pattern recognition machine. *Computer, Vision, Graphics, and Image Processing, 37*, 54-115.

Cassidy, K. W., & Kelly, M. H. (1991). Phonological information in grammatical category assignments. *Journal of Memory and Language, 30*, 348-369.

Catts, H., Adolf, S. M., Hogan, T. P., & Weismer, S. (2005). Are specific language impairment and dyslexia distinct disorders? *Journal of Speech, Language and Hearing Research, 48* (6), 1378-1396.

Catts, H. W., Fey, M. E., Tomblin, J. B., & Zhang, X. (2002). A longitudinal investigation of reading outcomes in children with language impairments. *Journal of Speech, Language, and Hearing Research, 45*, 1142-1157.

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

Cutler, A., & Carter, D. (1987). The predominance of strong initial syllables in the English vocabulary. *Computer Speech and Language, 2*, 133-142.

Dell, G. S. (1988). The retrieval of phonological forms in production: Tests of predictions from a connectionist model. *Journal of Memory and Language, 27*, 124-142.

Dickinson, D. K. (1984). First impressions: Children's knowledge of words gained from a single exposure. *Applied Psycholinguistics, 5*, 359-373.

Dollaghan, C. A. (1985). Child meets word: “Fast mapping” in preschool children. *Journal of Speech and Hearing Research, 28*, 449-454.

Dollaghan, C. A. (1987). Fast mapping in normal and language-impaired children. *Journal of Speech and Hearing Disorders, 52*, 218-222.

Garlock, V. M., Walley, A. C., & Metsala, J. L. (2001). Age-of-acquisition, word frequency, and neighborhood density effects on spoken word recognition by children and adults. *Journal of Memory and Language, 45*, 468-492.

Gershkoff-Stowe, L. (2002). Object naming, vocabulary growth, and development of word retrieval abilities. *Journal of Memory and Language, 46*, 665-687.

Gershkoff-Stowe, L., & Smith, L. B. (2004). Shape and the first hundred nouns. *Child Development, 75* (4), 1098-1114.

Gleitman, L. (1990). The structural sources of verb meanings. *Language Acquisition, 1*, 3-55.

Gleitman, L., & Gleitman, J. (1992). A picture is worth a thousand words, but that's the problem: The role of syntax in vocabulary acquisition. *Current Directions in Psychological Science, 1*, 1-5.

Gray, S. (2003, February). Word-learning by preschoolers with impairment: What Predicts Success? *Journal of Speech, Language and Hearing Research, 46* (1), 56-67.

Gray, S. (2004). Word learning by preschoolers with specific language impairment: Predictors and poor learners. *Journal of Speech, Language, and Hearing Research, 47* (5), 1117-1132.

Gray, S. (2005). Word learning by preschoolers with specific language impairment effect of phonological or semantic cues. *Journal of Speech, Language and Hearing Research, 48* (6), 1452-1467.

Gray, S., Plante, E., Vance, R., & Henrichsen, M. (1999). The diagnostic accuracy of four vocabulary tests administered to preschool-age children. *Language, Speech, and Hearing Services in Schools, 30*, 196-206.

Grimshaw, J. (1981). Form, function, and the language acquisition device. In C. Baker & J. McCarthy (Eds.), *The logical problem of language acquisition* (pp. 183-210). Cambridge, MA: MIT Press.

Gupta, P., & MacWhinney, B. (1997). Vocabulary acquisition and verbal short-term memory: Computational and neural bases. *Brain and Language, 59*, 267-333.

Heibeck, T. H., & Markman, E. M. (1987). Word learning in children: An examination of fast mapping. *Child Development, 58*, 1021-1034.

Hoover, J. R., Storkel, H. L., & Hogan, T. P. (in preparation). Differentiating neighborhood density and phonotactic probability in child word learning.

Jusczyk, P. W., Luce, P. A., & Charles-Luce, J. (1994). Infants' sensitivity to phonotactic patterns in the native language. *Journal of Memory and Language, 33*, 630-645.

Kiernan, B., & Gray, S. (1998). Word learning in a supported-learning context by preschool children with specific language impairment. *Journal of Speech, Language, and Hearing Research, 41*, 161-171.

Kroll, J. F., & Potter, M. C. (1984). Recognizing words, pictures, and concepts: A comparison of lexical, object, and reality decisions. *Journal of Verbal Learning and Verbal Behavior, 23*, 39-66.

Landau, B., & Gleitman, L. (1985). *Language and experience: Evidence from the blind child.* Cambridge, MA: Harvard University Press.

Leonard, L. B. (1998). *Children with specific language impairment*. Cambridge, MA: The MIT Press.

Leonard, L. B., Schwartz, R. G., Morris, B., & Chapman, K. L. (1981). Factors influencing early lexical acquisition: lexical orientation and phonological composition. *Child Development, 52*, 882-887.

Levelt, W. J. M. (1989). *Speaking: From intention to articulation.* Cambridge, Mass: MIT Press.

Luce, P. A., Goldinger, S. D., Auer, E. T., & Vitevitch, M. S. (2000). Phonetic priming, neighborhood activation, and PARSYN. *Perception & Psychophysics, 62*, 615-625.

Magnuson, J. S., Tanenhaus, M. K., Aslin, R. N., & Dahan, D. (2003). The time course of spoken word learning and recognition: Studies with artificial lexicons. *Journal of Experimental Psychology: General, 132* (2), 202-227.

Maillart, C., Schelstraete, M., & Hupet, M. (2004). Phonological representations in children with SLI: A study of French. *Journal of Speech, Language, and Hearing Research, 47* (1), 187-198.

McClelland, J., & Elman, J. (1986). The TRACE model of speech perception. *Cognitive Psychology, 18*, 1-86.

McGregor, K., Friedman, R., Reilly, R., & Newman, R. (2002). Semantic representaion and naming in young children. *Journal of Speech, Language and Hearing Research, 45* (2), 332-346.

McGregor, K. K., Newman, R. M., Reilly, R. M., & Capone, N. C. (2002). Semantic representaion and naming in children with specific language impairment. *Journal of Speech, Language, and Hearing Research, 45*, 998-1014.

Metsala, J. L., & Walley, A. C. (1998). Spoken vocabulary growth and the segmental restructuring of lexical representations: Precursors to phonemic awareness and early reading ability. In J. L. Metsala & L. C. Ehri (Eds.), *Word Recognition in Beginning Literacy* (pp. 89-120). Mahwah, NJ: Lawrence Erlbaum Associates, Inc., Publishers.

Morgan, J. (1986). *From simple input to complex grammar*. Cambridge, MA: MIT Press.

Nelson, D. L., McEvoy, C., & Schreiber, T. (1998). The University of South Florida word association, rhyme, and word fragment norms. Retrieved Feb 1, 2005, from http://www.usf.edu/FreeAssociation/

Nelson, K. (1973). Concept, word and sentence: Interrelations in acquisition and development. *Psychological Review, 81*, 267-295.

Newman, R. S., & German, D. J. (2005). Life span effects on lexical factors in oral naming. *Language and Speech, 48* (2), 123-156.

Norris, D. (1994). Shortlist: a connectionist model of continuous speech recognition. *Cognition, 52*, 189-234.

Oetting, J. B., Rice, M. L., & Swank, L. K. (1995). Quick incidental learning (QUIL) of words by school-age children with and without SLI. *Journal of Speech and Hearing Research, 38*, 434-445.

Pinker, S. (1984). *Language learnability and language development*. Cambridge, MA: Harvard University Press.

Rice, M. L., Buhr, J. C., & Nemeth, M. (1990). Fast mapping word-learning abilities of language-delayed preschoolers. *Journal of Speech and Hearing Disorders, 55*, 33-42.

Rice, M. L., Oetting, J. B., Marquis, J., Bode, J., & Pae, S. (1994). Frequency of input effects on word comprehension of children with specific language impairment. *Journal of Speech and Hearing Research, 37*, 106-122.

Rice, M. L., & Wexler, K. (1996). Toward tense as a clinical marker of specific language impairment in English-speaking children. *Journal of Speech and Hearing Research, 39* (6), 1239-1257.

Rice, M. L., Wexler, K., & Cleave, P. L. (1995). Specific language impairment as a period of extended optional infinitive. *Journal of Speech and Hearing Research, 38*, 850-863.

Rice, M. L., Wexler, K., & Hershberger, S. (1998). Tense over time: the longitudinal course of tense acquisition in children with specific language impairment. *Journal of Speech, Language, and Hearing Research, 41*, 1412-1431.

Rice, M. L., & Woodsmall, L. (1988). Lessons from television: Children's word learning when viewing. *Child Development, 59*, 420-429.

Sabbagh, M. A., & Baldwin, D. A. (2001). Learning words from knowlegeable versus ignorant speakers: Links between preschoolers' theory of mind and semantic development. *Child Development, 72* (4), 1054-1070.

Samuelson, L. K., & Smith, L. B. (1999). Early noun vocabularies: Do ontology, category structure and syntax correspond? *Cognition, 73*, 1-33.

Schwartz, R. G., & Leonard, L. B. (1982). Do children pick and choose? An examination of phonological selection and avoidance in early lexical acquisition. *Journal of Child Language, 9*, 319-336.

Smith, L. B., Jones, S. S., Landau, B., Gershkoff Stowe, L., & Samuelson, L. (2002). Object name learning provides on-the-job training for attention. *Psychological Science, 13* (1), 13-19.

Storkel, H. L. (2001). Learning new words: Phonotactic probability in language development. *Journal of Speech, Language, and Hearing Research, 44*, 1321-1337.

Storkel, H. L. (2002). Restructuring of similarity neighbourhoods in the developing mental lexicon. *Journal of Child Language, 29* (2), 251-274.

Storkel, H. L. (2003). Learning new words II: Phonotactic probability in verb learning. *Journal of Speech, Language and Hearing Research, 46* (6), 1312-1323.

Storkel, H. L. (2004a). Do children acquire dense neighbourhoods? An investigation of similarity neighbourhoods in lexical acquisition. *Journal of Applied Psycholinguistics, 25* (2), 201-221.

Storkel, H. L. (2004b). The emerging lexicon of children with phonological delays: Phonotactic constraints and probability in acquisition. *Journal of Speech, Language, and Hearing Research, 47* (5), 1194-1212.

Storkel, H. L. (2004c). Methods for minimizing the confounding effects of word length in the analysis of phonotactic probability and neighborhood density. *Journal of Speech, Language and Hearing Research, 47* (6), 1454-1468.

Storkel, H. L. (in press). Developmental differences in the effects of phonological, lexical, and semantic variables on word learning by infants. *Journal of Child Language*.

Storkel, H. L., & Adlof, S. M. (2008a). Adult and child semantic neighbors of the Kroll and Potter (1984) nonobjects. *Manuscript submitted for publication.*

Storkel, H. L., & Adlof, S. M. (2008b). The effect of semantic set size on word learning by preschool children. *Manuscript submitted for publication.*

Storkel, H. L., Armbruster, J., & Hogan, T. P. (2006). Differentiating phonotactic probability and neighborhood density in adult word learning. *Journal of Speech, Language, and Hearing Research, 49* (6), 1175-1192.

Storkel, H. L., & Maekawa, J. (2005). A comparison of homonym and novel word learning: The role of phonotactic probability and word frequency. *Journal of Child Language, 32*, 827-853.

Storkel, H. L., & Rogers, M. A. (2000). The effect of probabilistic phonotactics on lexical acquisition. *Clinical Linguistics & Phonetics, 14*, 407-425.

Tallal, P., Stark, R. E., & Mellits, E. D. (1985). Identification of language-impaired children on the basis of rapid perception and production skills. *Brain and Language, 25*, 314-322.

Templin, M. C. (1957). *Certain language skills in children, their development and interrelationships (Institute of Child Welfare, Monograph Series 26)*. Minneapolis, MN: University of Minnesota Press.

Tomasello, M., Strosberg, R., & Akhtar, N. (1996). Eighteen-month-old children learn words in non-ostensive contexts. *Journal of Child Language, 23*, 157-176.

Tomblin, J. B., Records, N. L., Buckwalter, P., Zhang, X., Smith, E., & O'Brien, M. (1997). Prevalence of specific language impairment in kindergarten children. *Journal of Speech, Language, and Hearing Research, 40*, 1245-1260.

Trask, R. L. (1997). *A student's dictionary of language and linguistics*. London: Arnold.

Vitevitch, M. S., Luce, P. A., Pisoni, D. B., & Auer, E. T. (1999). Phonotactics, neighborhood activation, and lexical access for spoken words. *Brain and Language, 68*, 306-311.

Walley, A. C., Metsala, J. L., & Garlock, V. M. (2003). Spoken vocabulary growth: Its role in the development of phoneme awareness and early reading ability. *Reading and Writing: An Interdisciplinary Journal, 16*, 5-20.

Williams, K. T. (1997). *Expressive vocabulary test*. Circle Pines, MN: American Guidance Services.

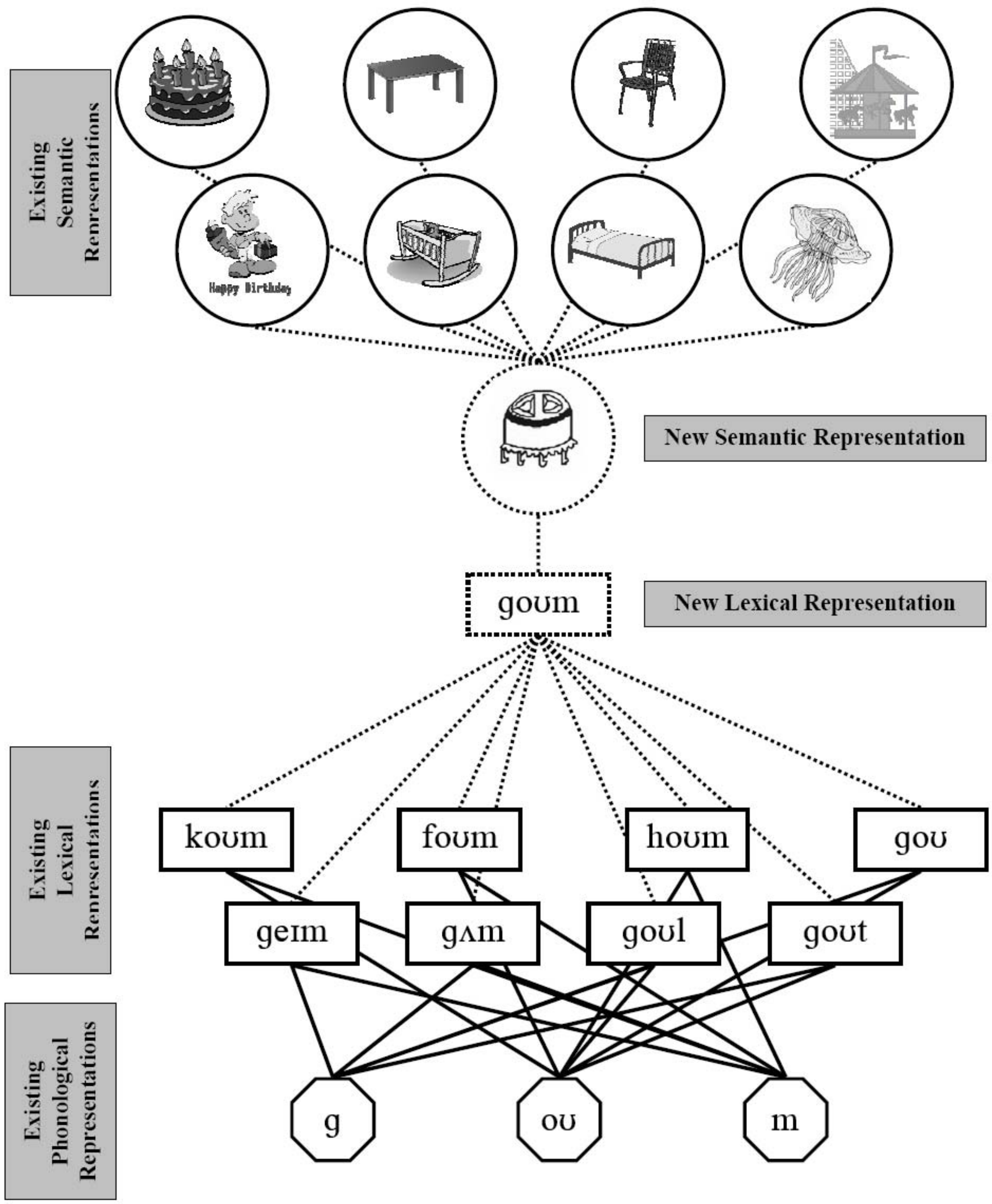
Existing Semantic Representations
Happy Birthday
New Semantic Representation
goʊm
New Lexical Representation
Existing Lexical Representations
koʊm
foʊm
hoʊm
goʊ
geɪm
gʌm
goʊl
goʊt
Existing Phonological Representations
g
oʊ
m

Figure 1: Illustration of the word learning process when the novel word /goʊm/ is encountered. Existing representations are depicted by solid lines and new representations are depicted with dashed lines. Pictures of known objects are taken from www.freeclipartnow.com (i.e., jellyfish) and www.clker.com (i.e., all pictures except jellyfish). The picture of the novel object is from Kroll and Potter (1984). Semantic neighbors of the novel object are based on the child data from Storkel and Adlof (2008a). Lexical neighbors of the novel word are based on the child calculator available at http://www.bncdnet.ku.edu/cgi-bin/DEEC/post_ccc.vi.