Compare and contrast between egypt and china

Countries

ABSTRACT: The purpose of this paper is to underscore the importance of the link between lexical and phonological acquisition by considering learning by children beyond the 50-word stage and by applying cognitive models of spoken word processing to development. Lexical and phonological variables that have been shown o influence perception and production across the lifep are considered relative to their potential role in learning by preschool children. The effect of these lexical and phonological variables on perception, production, and learning are discussed in the context of a two-representation connectionist model of spoken word processing. The model appears to offer insights into the complex interaction between the lexicon and phonology and may be useful for clinical diagnosis and treatment of children with language delays. KEY WORDS: language development, lexicon, phonology, neighborhood density, phonotactic probability

LSHSS To acquire the native language, a child must do two things: Learn the words of the language and extract the relevant phonological characteristics of those words. For the most part, the acquisition of words and sounds has been investigated independently. That is, some lines of investigation concentrate exclusively on how the words of the language are acquired (e. g. , Carey & Bartlett, 1978; Dollaghan, 1985; Heibeck & Markman, 1987; Jusczyk & Aslin, 1995; Rice & Woodsmall, 1988), whereas other lines of

research examine how the sounds of the language emerge (e. g. , Dinnsen, Chin, Elbert, &

Powell, 1990; Dyson, 1988; Smit, Hand, Freilinger, Bernthal, & Bird, 1990; Stoel-Gammon, 1985). The mutual influence of lexical and phonological development is an area that has received only limited attention. The few descriptive and experimental studies that have addressed this issue, however, provide preliminary evidence for an interaction between lexical and phonological development. Descriptive studies primarily have examined the relationship between the phonological characteristics of babble and first words. Studies of typically developing children have shown that first words are phonologically similar to babble (e. . , Oller, Wieman, Doyle, & Ross, 1976; Stoel-Gammon & Cooper, 1984; Vihman, Ferguson, & Elbert, 1986; Vihman, Macken, Miller, Simmons, & Miller, 1985). For example, the distribution of consonants and the syllable structure of first words are identical to that of babble (Vihman et al. , 1985). This association between lexical and phonological development is observed in children with precocious language development as well as in children with delayed language development (Paul & Jennings, 1992; Stoel-Gammon & Dale, 1988; Thal, Oroz, & McCaw, 1995; Whitehurst, Smith, Fischel, Arnold, & Lonigan, 991). In particular, children who know many words tend to produce a greater variety of sounds and sound combinations, whereas children who know few words tend to produce a limited variety of sounds and sound combinations. There appears to be a potentially robust relationship between the phonological characteristics of first words and babble. This is suggestive of an intimate connection between word learning and productive phonology. In addition to

descriptive evidence, experimental studies provide further support for the hypothesis that lexical and phonological development influence one another. For xample, one study of young children with expressive language delay demonstrated that treatment focused on 1 Currently affiliated with the University of Kansas. Storkel • Morrisette: The Lexicon and Phonology 25 increasing a child's expressive vocabulary led to subsequent improvements in phonological diversity (Girolametto, Pearce, & Weitzman, 1997; but see Whitehurst, Fischel et al. , 1991). This finding suggests that the breadth of a child's lexical knowledge may influence phonological acquisition. An expansion of vocabulary in this case went hand in hand with an expansion of the sound system.

In complement, there is experimental evidence that phonological characteristics may influence lexical acquisition. In particular, infants have been shown to produce novel words composed of sounds that are in their phonetic inventory more frequently than other novel words composed of sounds that are out of their phonetic inventory (Leonard, Schwartz, Morris, & Chapman, 1981; Schwartz & Leonard, 1982). Here, the child's phonetic inventory influenced the acquisition of new words. Taken together, descriptive and experimental evidence suggests that phonological development and word learning utually influence one another, but one limitation of this work is its emphasis on infants who produce fewer than 50 words (but see Shillcock & Westermann, 1998; Stoel- Gammon, 1998). This is relevant because a rapid increase in rate of word learning has been noted as children cross the 50-word threshold, leading some researchers to posit a fundamental change in the word learning process (Behrend, 1990; Bloom,

1973; Dore, 1978; Gopnik & Meltzoff, 1986; Mervis & Bertrand, 1994). Also at this point, it is hypothesized that children transition from a holistic to an analytic phonological system, which may demarcate a fundamental hange in phonological learning (Ferguson & Farwell, 1975; Vihman, Velleman, & McCune, 1994). The purpose of this paper is to examine this link between lexical and phonological development by considering the acquisition process beyond the 50-word stage and by applying a cognitive model of spoken word perception and production to this issue. In particular, lexical and phonological variables that have been shown to influence perception and production across the lifep will be considered relative to their potential influence on learning by preschool children. Furthermore, a model that has been sed to explain spoken word processing in the fully developed system of adults is used to provide a framework for understanding the interaction between the lexicon and phonology in development. The term spoken word processing refers collectively to the act of perceiving and producing words in spoken language. The paper is organized to first provide background to the lexical variables of word frequency and neighborhood density and the phonological variable of phonotactic probability. A two-representation model of spoken word processing is introduced. This model depicts two types of mental representations, words versus sounds, providing a eans of understanding the interaction between these two different representations. The model is then applied to spoken word processing in the developing system of children and to lexical and phonological learning. Finally, the interaction between the lexicon and phonology will be reconsidered by examining the role of lexical variables in sound learning and phonological variables in word learning by preschool children who have surpassed the 50-

word stage. A discussion of the implications of these lexical and phonological variables for clinical diagnosis and treatment will conclude the article. BACKGROUND TO LEXICAL AND

PHONOLOGICAL VARIABLES Two lexical characteristics that have emerged as relevant predictors of spoken word processing are word frequency and neighborhood density. Word frequency is the number of times a word occurs in the language. For example, sit is an infrequent word occurring only 67 times in a written sample of 1 million words. In contrast, these is a frequent word occurring 1, 573 times in a written sample of 1 million words (KucUera & Francis, 1967). 2 Turning to neighborhood density, words presumably are organized into similarity neighborhoods in the mental lexicon based on phonological similarity.

In particular, it is assumed that a similarity neighborhood includes all of the words differing from a given word by a one phoneme substitution, deletion, or addition (Luce & Pisoni, 1998). For example, neighbors of sit include words such as sip, sat, hit, it, and spit and neighbors of these include words such as those, tease, and ease. The number of neighbors defined in this way is the word's neighborhood density. In total, sit has 36 neighbors and these has 9 neighbors (Nusbaum, Pisoni, & Davis, 1984). Thus, sit is said to reside in a dense neighborhood because it has many neighbors, whereas these is said to eside in a sparse neighborhood because it has relatively few neighbors. A phonological characteristic that appears influential in spoken word processing is phonotactic probability. Oneobservationthat has emerged from studies of language structure is that certain sound patterns are more likely to occur than others. This likelihood of sound occurrence is termed

phonotactic probability. Phonotactic probability generally is determined by counting the words in the language that contain a particular sound or sound pattern as well as the number of times those words occur (see Jusczyk, Luce, & Charles-Luce, 1994; Luce, Goldinger,

Auer, & Vitevitch, 2000; Storkel, 2001; Storkel & Rogers, 2000; Vitevitch & Luce, 1998, 1999). To illustrate, the sound pattern of sit is a common sound sequence in English. The individual sounds (/s/, /I/, /t/) frequently occur in their given word positions in many frequent words of the language. For example, word-initial /s/ occurs in the words seat, safe, said, sat, sun, surge, soon, soot, soap, song, sock, south, soil, and size, as well as in many other words of the language. In addition, the adjacent sounds in sit (/sI/, /It/) frequently occur together in many frequent lexical items.

The sound combination /sI/ is found in the words sing, sip, sick, sin, and sill, as well as in other English words. In contrast, the sound pattern of these is a rare sound sequence, having individual sounds (/D/, /i/, /z/) 2Word frequency counts are available from a variety of sources including adult written (e. g. , KucUera & Francis, 1967), adult spoken (e. g. , Brown, 1984), child written (e. g. , Rinsland, 1945), and child spoken (e. g. , Kolson, 1960) databases. 26 LANGUAGE, SPEECH, AND HEARING SERVICES IN SCHOOLS • Vol. 33 • 24–37 • January 2002 and sound combinations (/Di/, /iz/) that occur in relatively few words of the language.

In fact, word initial /D/ is found only in the words this, them, then, thus, their, those, that, and their, and the sound combination /Di/ is not contained in any other words of the language. MODEL OF WORD PROCESSING The lexical variables of word frequency and neighborhood density and the phonological

variable of phonotactic probability reportedly influence adults' perception and production. This influence may be accounted for by a tworepresentation model of word processing (e. g. , Gupta & MacWhinney, 1997; Luce et al. , 2000). 3 This model may potentially provide insights into the complex interaction etween the lexicon and phonology in development, but the characteristics of the model and its success in capturing spoken word processing by adults will first be considered. An illustration of this model is given in Figure 1 for the word sit and in Figure 2 for the word these. The two types of representations in the model are lexical and phonological. The lexical representation corresponds to a word as a whole unit. In Figures 1 and 2, the lexical representation for the word sit, /sIt/, and these, /Diz/, is denoted by rectangles. In contrast, the phonological representation corresponds to the individual sounds or sound sequences.

In Figures 1 and 2, the phonological representations for the words sit, /s/, /I/, and /t/, and these, /D/, /i/, and /z/, are illustrated by the open circles. The structure of the lexical representation may influence perception and production by adults. Likewise, the characteristics of the phonological representation may play a role in adult spoken word processing. Interactions between lexical and phonological representations may also occur in adult word recognition and production. Each of these issues will be considered in turn. Lexical Representations This two-representation model is a connectionist model.

One feature of a connectionist model is that representations can be activated. That is, hearing or thinking about a word provides external activation to a lexical representation. For a word to be recognized or

produced, the activation of its representation must reach a set activation threshold. An activation threshold refers to the amount of activation that must accumulate in order for the representation to become available to consciousness. It is at this point that the listener recognizes the word or that the speaker selects the word to be produced. Representations can differ from one another in their resting threshold. The resting threshold efers to the initial level of activation of a representation before further external activation is accrued either by hearing the word or by thinking of the word. Past experience with the language has been proposed to alter the resting threshold of lexical representations. Specifically, when a lexical representation is frequently activated for recognition or production, the resting threshold supposedly increases. This provides a mechanism for learning the characteristics of the language, namely word frequency. Thus, words that are frequently recognized or produced presumably will have a higher resting threshold than words hat are infrequently recognized or produced. In Figures 1 and 2, resting threshold is depicted by the thickness of the rectangles. Heavier rectangles represent higher resting thresholds; lighter rectangles represent lower resting thresholds. The lexical representation of the frequent word /Diz/ in Figure 2 has a darker rectangle indicating a higher resting threshold than the lexical representation of the infrequent word /sIt/ in Figure 1. The implication of this difference in resting threshold for perception or production 3Note that the two-representation model we describe is a simplified and generic version of those described by Luce et al. 2000 and Gupta & MacWhinney, 1997. The interested reader is referred to the original manuscripts for complete details of the full models. Also, we consider the ability of this model to account for both perception and

production, although the original models focus primarily on one aspect of spoken word processing. Figure 1. Illustration of a two-representation connectionist model of word processing for the word sit. Lexical representations are illustrated with rectangles. The thickness of the rectangle indicates the resting threshold as determined by word frequency (e. g. , sit is infrequent).

Inhibitory connections between words are indicated by lines terminating in circles. The number of connections between words illustrates neighborhood density (e. g. , the neighborhood of sit is dense). Phonological representations are illustrated with circles. The thickness of the circle indicates the resting threshold based on phonotactic probability (e. g. , /s/, /I/, and /t/ are common). Facilitory connections between sounds are indicated by lines terminating in arrows. The thickness of the connecting line indicates the strength of the relationship based on phonotactic probability (e. g. /sI/ and /It/ are common). Storkel • Morrisette: The Lexicon and Phonology 27 is that words with higher resting thresholds (i. e. , frequent words) are already more activated at rest than are words with lower resting thresholds (i. e. , infrequent words). As a result, these frequent words should require less external activation than infrequent words to reach the activation threshold for recognition or production and, thus, recognition or production should be facilitated. In fact, studies of spoken word recognition and production with adults support this claim. Adults recognize frequent words more rapidly nd more accurately than infrequent words (Landauer & Streeter, 1973; Luce & Pisoni, 1998) and produce frequent words faster and more accurately than infrequent words (Dell, 1990; Dell & Reich, 1981; Huttenlocher & Kubicek,

1983; Oldfield & Wingfield, 1965; Stemberger & MacWhinney, 1986; Vitevitch, 1997). This influence of experience on resting thresholds also allows for the possibility of individual differences across speakers because the exact resting threshold of a given word may vary from speaker to speaker based on a particular speaker's unique language experience.

Another feature of this two-representation connectionist model is that relationships among words are represented by connections. Connections between words are illustrated by lines in Figures 1 and 2. These connections are important because they allow activation to spread between related words, damping or amplifying the related lexical representation's activation. In this way, related lexical representations can influence the activation of the target lexical representation. The presence of two antagonistic processes, damping versus amplifying, are important in capturing decrements in performance and improvements in erformance, respectively. Damping activation is depicted in the model by inhibitory connections; amplifying activation is depicted by facilitory connections. An inhibitory connection damps the activation of the connected representation, thereby impeding that representation from reaching the activation threshold for recognition or production. In this case, recognition or production of the word would be slower or less accurate. In contrast, a facilitory connection amplifies the activation of the connected representation, thereby helping that representation reach the activation threshold for recognition or production.

In this case, recognition or production of the word would be faster or more accurate. In Figures 1 and 2, inhibitory connections are depicted by lines terminating in filled circles and facilitory connections are depicted by lines

terminating in arrows. Neighborhood membership is depicted by inhibitory connections between related lexical representations. For example, the lexical representation /sIt/ in Figure 1 has inhibitory connections to the lexical representations of all of its neighbors, such as /sut/, /pIt/, and /nIt/. Likewise, the lexical representation /Diz/ in Figure 2 has inhibitory onnections to its neighbors, such as /DoUz/, and /tiz/. Note that not all of the neighbors of sit and these are displayed in Figures 1 and 2 due to space limitations. For example, spit is omitted as a neighbor of sit. The strength of these connections are also based on the degree of association between words. Thus, words that are more similar to one another will spread more activation between each other. In Figures 1 and 2, the strength of a connection is depicted by the thickness of the line. Heavier lines indicate stronger associations than lighter lines. Note that connections between lexical representations are all imilar in strength, as indicated by the uniform thickness of the lines. In Figure 1, the lexical representation /sIt/ has equally strong connections to /sut/, /pIt/, and /nIt/, as well as to all of its other neighbors. Similarly, in Figure 2, the lexical representation /Diz/ has equally strong connections to /DoUz/, /tiz/, and all of its neighbors. Thus, all neighbors of a word are considered equally related to the word. The importance of this architecture for perception and production is that the number of neighbors determines the degree of activation damping for the target word. A word like sit, which resides in a dense neighborhood, will eceive inhibition from many more words than a word like these, which resides in a sparse neighborhood. This leads to greater damping of activation for sit relative to these. As a result, a word from a dense neighborhood will be impeded in reaching the activation threshold for recognition or

production. This claim is once again supported by data Figure 2. Illustration of a two-representation connectionist model of word processing for the word these. Lexical representations are illustrated with rectangles. The thickness of the rectangle indicates the resting threshold as determined by word frequency (e. g. these is frequent). Inhibitory connections between words are indicated by lines terminating in circles. The number of connections between words illustrates neighborhood density (e. g. , the neighborhood of these is sparse). Phonological representations are illustrated with circles. The thickness of the circle indicates the resting threshold based on phonotactic probability (e. g. , /D/, /i/, and /z/ are rare). Facilitory connections between sounds are indicated by lines terminating in arrows. The thickness of the connecting line indicates the strength of the relationship based on phonotactic probability (e. . , /Di/ and /iz/ are rare). 28 LANGUAGE, SPEECH, AND HEARING SERVICES IN SCHOOLS • Vol. 33 • 24–37 • January 2002 from studies of word processing in adults. Adults recognize words from dense neighborhoods more slowly and less accurately than they do words from sparse neighborhoods (Luce & Pisoni, 1998; Luce, Pisoni, & Goldinger, 1990). Likewise, word pairs from dense neighborhoods are produced more slowly than are word pairs from sparse neighborhoods (Goldinger & Summers, 1989, but see Vitevitch, 2001a). 4 Phonological Representations The second type of representation in the model is the honological representation. It has been proposed that two aspects of the phonological representation are affected by phonotactic probability—resting threshold and connection strength. Considering resting threshold, recall that language experience alters resting threshold. As a result, sounds that are commonly encountered in recognition or production will likely have higher resting thresholds than

those that are encountered rarely. In Figure 1, the phonological representation /s/, /I/, and /t/, has dark circles, indicating a higher resting threshold because these sounds commonly occur in the language.

In contrast, in Figure 2, the phonological representation /D/, /i/, and /z/, 5 has light circles, indicating a lower resting threshold because these sounds rarely occur. This difference in resting threshold indicates that common sounds are more activated at rest than are rare sounds. Consequently, common sounds should reach the activation threshold for recognition or production more rapidly than should rare sounds. Turning to connection strength, each sound has a facilitory connection to sounds that it may co-occur with, and the strength of these connections may be altered by language experience. When sounds are commonly encountered ogether in word processing, it is thought that the connection between the two sounds is strengthened. In this way, the model captures how an adult or child would learn the phonotactic probability of the language through experience. In Figure 1, the phonological representation /s/ has a strong facilitory connection to that of /I/ because these sounds commonly occur together in words of the language. In contrast, in Figure 2, the phonological representation of /I/ has a weak facilitory connection to that of /i/, because these rarely occur together. Because the strength of the facilitory connection determines how much ctivation will spread to the related sound, sound sequences with strong facilitory connections, namely common sound sequences, should reach the activation threshold for recognition or production more rapidly than should sound sequences with weak facilitory connections, namely, rare sound sequences. The influence of phonotactic probability on resting threshold and

connection strength leads to the prediction that common sound sequences should be recognized or produced more rapidly than rare sound sequences. Support for this hypothesis is found in studies of spoken word processing by adults. In fact, adults recognize common ound sequences more rapidly than they do rare sound sequences (Vitevitch & Luce, 1998, 1999; Vitevitch, Luce, Charles-Luce, & Kemmerer, 1997). A similar pattern is observed in speech production, where adults are faster to name a word if it is composed of a common sound sequence rather than a rare sound sequence (Levelt & Wheeldon, 1994). Interactions Between Lexical and Phonological Representations Turning to the interaction between lexical and phonological representations, it is important to note that there are facilitory connections between lexical and phonological representations.

That is, /slt/ has facilitory connections to /s/, /l/, and /t/, whereas /Diz/ is connected to /D/, /i/, and /z/. The lexical representations of the neighbors of /slt/ and /Diz/ also have connections to phonological representations, but not all of these connections are shown in Figures 1 and 2 because it becomes difficult to follow the connections when all are presented together. For example, /sut/ should have facilitory connections to /s/ and /t/, but these are not displayed in Figure 1. The implication of these lexicalphonological connections is that once a lexical representation is activated, it will also activate its corresponding honological representation. Activation can also occur in the opposite direction, with a phonological representation activating corresponding lexical representations. These connections between lexical and phonological representations allow for interactions between lexical and phonological processing. One way that the interaction between lexical and

phonological representations has been investigated in the fully developed system of adults is by considering the unique relationship between neighborhood density, a lexical variable, and phonotactic probability, a phonological variable. Namely, words from dense neighborhoods tend to e composed of common sound sequences, and words from sparse neighborhoods tend to be composed of rare sound sequences (Vitevitch, Luce, Pisoni, & Auer, 1999). The evidence detailed in the previous sections indicated that dense neighborhoods slow spoken word processing, whereas common sound sequences speed word processing. Given the association between neighborhood density and phonotactic probability, the inhibitory effect of neighborhood density and the facilitory effect of phonotactic probability would seem incompatible. If the two factors are associated, how is it that one aids word recognition and production but the ther interferes with it? If one appeals to the variable of neighborhood density, one would predict that processing of a word from a dense neighborhood, such as sit, would be 4In some cases, asymmetries have been noted in the effect of neighborhood density across perception and production. In fact, some models predict that dense neighborhoods should facilitate production (see MacKay, 1987; Vitevitch, 2001a). 5Note that computations of phonotactic probability are based on a 20, 000- word dictionary generally consisting of uninflected word forms (see also Jusczyk et al. , 1994; Luce et al. 2000; Storkel, 2001; Storkel & Rogers, 2000; Vitevitch & Luce, 1998, 1999). Therefore, /z/ is considered to occur infrequently in uninflected word forms, although it may occur often as a plural morpheme. The status of lexical representations of inflected words is an open question. Storkel • Morrisette: The Lexicon and Phonology 29 inhibited relative to a word from a sparse

neighborhood, such as these. In contrast, if one appeals to the variable of phonotactic probability, one would predict that processing of a word having a common sound sequence, such as sit, would be facilitated relative to a word having a rare sound equence, such as these. How can processing of sit be both inhibited and facilitated? This paradox may be resolved by appealing to the tworepresentation model. If one type of representation is able to dominate word processing in a given context, this will dictate whether an inhibitory or facilitory effect is observed. The lexical status of the stimulus is predicted to influence the effect of neighborhood density and phonotactic probability on processing. In particular, lexical processing is predicted to dominate language tasks involving real words because real words have a lexical representation.

In contrast, phonological processing is predicted to dominate language tasks involving nonwords because nonwords have no lexical representation. This prediction is borne out by evidence from studies of spoken word processing by adults. In fact, recognition of real words from dense neighborhoods is inhibited relative to real words from sparse neighborhoods, supporting the dominance of lexical processing (Vitevitch & Luce, 1998, 1999). In complement, recognition of nonwords composed of common sound sequences is facilitated relative to nonwords composed of rare sound sequences, supporting the dominance f phonological processing (Vitevitch & Luce, 1998, 1999). Because spoken word processing typically involves real words, lexical processing generally should dominate recognition and production (but see Vitevitch, 2001b). APPLICATION TO DEVELOPMENT The two-representation model seems to capture lexical and phonological

influences on perception and production successfully in the fully developed system of adults. Can this model be applied to perception and production in the developing system of infants and children? To address this question, evidence of how the lexicon influences spoken word processing in infants and children is reviewed and ompared to the findings from adults. If the findings from the developing system parallel those from the fully developed system, then the two-representation model may easily be extended to the developing system. In contrast, if word processing in the developing system differs from word processing in the fully developed system, then the tworepresentation model may require modification before application to the developing system. This question is important because it bears on the issue of whether the tworepresentation model may offer insights into learning and clinical practice. Studies of the developing language system provide urther insight into the role of word frequency and neighborhood density in spoken word processing. Perception studies with infants have investigated aspects of the spoken input that infants attend to while building the mental lexicon (see Jusczyk, 1997 for review). In one representative study of word frequency, infants were exposed to sets of words that were frequently repeated in stories versus other sets of words that were infrequently repeated (Hohne, Jusczyk, & Rendanz, 1994; Jusczyk & Aslin, 1995). Results indicated that infants preferred listening to the frequently occurring words in the story. This finding suggests that nfants have the ability to attend to specific words in the input. Moreover, the infants in the study were able to differentiate words based on their frequency of occurrence. Word frequency has also been shown to influence young children's production accuracy of target sounds. Leonard and Ritterman (1971) found that 7-year-old children

had better production accuracy of target /s/ sounds in frequent versus infrequent words in the language (but see Moore, Burke, & Adams, 1976). Computational studies of young children have further explored the structure of words in the early lexicon relative to neighborhood density.

These studies used receptive and expressive estimates of young children's lexicons. One important finding was that young children have relatively sparse neighborhoods in comparison to older children and adults (Charles-Luce & Luce, 1990, 1995; Logan, 1992). That is, a word in a young child's lexicon would have fewer neighbors than that same word in an older child's or an adult's lexicon. Neighborhood density may increase across the lifep as more phonetically similar words are added to the lexicon (Logan, 1992). This finding led to the hypothesis that young children se global recognition strategies to identify words (Charles- Luce & Luce, 1990, 1995). Because neighborhoods are so sparse, all of the fine-grained phonetic contrasts of language may not be necessary to uniquely disambiguate one word from another. Alternatively, it has been argued that children do rely on fine-grained recognition strategies (Dollaghan, 1994). The basis for this comes from the fact that young children do differentiate between minimally and phonetically similar words of the input. Even a word that has only one neighbor must still require fine-grained coding on the part of the child for accurate recognition.

Although these views about whether children use global or finegrained recognition strategies remain at odds, it is clear that the structure of words in the lexicon appears to be critically linked to the nature of a child's phonological representations. Taken together, these findings support that a

word's frequency and its neighborhood density play a similar role in fully developed and developing lexicons. In the developing language system, sensitivity to phonotactic probability emerges early, with phonotactic probability influencing perception in a manner similar to adults.

In perceptual tasks, 9-month-old infants listen longer to lists of words composed of common sound sequences than to those composed of rare sound sequences (Jusczyk et al. , 1994). Moreover, infants appear to acquire phonotactic probability rapidly in controlled listening conditions (Aslin, Saffran, & Newport, 1998; Saffran, Aslin, & Newport, 1996). After listening to strings of nonsense syllables for a short period of time, 8-month-old infants are able to discriminate syllable sequences that commonly co-occur from those that rarely co-occur. That is, syllables that commonly co-occurred in the speech 0 LANGUAGE, SPEECH, AND HEARING SERVICES IN SCHOOLS • Vol. 33 • 24–37 • January 2002 sample were treated as a whole word; syllables that rarely co-occurred were not treated as a whole word. The evidence indicates that infants may learn the likelihood of occurrence of sound sequences in the ambient language, and then they use this to parse continuous speech into individual words. Sensitivity to phonotactic probability continues intochildhood, as shown in metalinguistic, perceptual, and production tasks. In metalinguistic tasks, children and adolescents are able to differentiate sound sequences that re legal in their language from those that are illegal (Messer, 1967; Pertz & Bever, 1975). Children, like adults, seem to have intuitions about phonotactics (e. g. , Vitevitch et al. , 1997). Perceptual and production studies provide evidence that children are also sensitive to the more finegrained distinction of common versus rare

sound sequences. Relative to perceptual evidence, children rapidly extract the phonotactic probabilities of continuous strings of nonsense syllables. Like infants, children treat strings of syllables that commonly co-occur as an entire word and strings of yllables that rarely co-occur as a part of a word (Saffran, Newport, Aslin, Tunick, & Barrueco, 1997). In production, children are more accurate at producing sound sequences that are permissible in the ambient language than those that are not (Messer, 1967). Moreover, children are more accurate at repeating common rather than rare sound sequences (Beckman & Edwards, 1999). Likewise, when given a list of nonwords to remember, children recall more nonwords if the list contains common sound sequences than if it contains rare sound sequences (Gathercole, Frankish, Pickering, & Peaker, 1999).

In childhood, sensitivity to phonotactic probability remains and appears to influence spoken word processing in a manner that parallels the fully developed adult system. The effects of word frequency, neighborhood density, and phonotactic probability on language perception and production in the developing system parallel those in the fully developed system. In terms of lexical variables, across the lifep, processing of frequent words was facilitated relative to infrequent words, and processing of words from dense neighborhoods was inhibited relative to words from sparse neighborhoods. In terms of phonological variables, cross the lifep, common sound sequences were recognized and produced more rapidly than were rare sound sequences. Given the similarity between the adult and child findings, it appears that the two-representation model can be applied to perception and production by children. APPLICATION TO LEARNING Because the two-

representation model captures perception and production by children, it may also provide insights into learning by children. In the following two sections, insights of the two-representation model for sound change and word learning will be offered and evaluated relative to current findings.

The studies reviewed focus on interactions between the lexicon and phonology in preschool and school-age children who have lexicons with many more than 50 words. These investigations provide evidence of whether lexical-phonological interactions continue in development beyond the 50-word stage. Promoting Sound Change When a sound is unknown, the child presumably will have no ambient, or adult-like, phonological representation for the target sound. In some cases, treatment may be needed to promote sound change. The goal of treatment then is to create an ambient phonological representation for the nknown sound, often by presenting the target sound in words and providing feedback regarding production accuracy. Given the absence of an ambient phonological representation, lexical processing is predicted to dominate sound learning in this treatment context. Thus, lexical representations may influence the success of phonological treatment. In particular, treatment of the sound in frequent words should promote sound change relative to infrequent words. Furthermore, embedding the sound in words from dense neighborhoods should inhibit learning when compared to treatment of the sound in words from sparse neighborhoods.

An experimental treatment study by Gierut, Morrisette, and Champion (1999) examined the role of lexical variables in phonological treatment (see also Morrisette & Gierut, in press). Twelve children with functional

phonological delays, aged 3; 0 (years; months) to 7; 4, participated in an alternating treatments design to promote sound change. The characteristics of word frequency and neighborhood density were manipulated experimentally. Experimental conditions included treatment of all possible combinations of frequent/ infrequent words from dense/sparse neighborhoods. Each child was taught two sounds affiliated with the lexical haracteristics of the assigned conditions. For example, a child assigned to the frequent versus infrequent condition was taught one sound in frequent words and another sound in infrequent words. Treated sounds were excluded from the pretreatment inventory and were produced with 0% accuracy. Generalization accuracy in production of the treated sounds to untreated words and contexts was measured as the dependent variable and submitted to statistical analysis. Treatment conditions and corresponding results are shown in Table 1. Results revealed that for the lexical characteristic of ord frequency, phonological treatment using frequent words induced significantly greater generalization learning than did treatment of infrequent words. For neighborhood density, treatment in words from sparse neighborhoods induced significantly greater generalization learning than did treatment in words from dense neighborhoods. When the frequency conditions were compared to the density conditions, treatment in both frequent and infrequent words resulted in significantly greater generalization learning than did treatment in words from dense neighborhoods. Further, treatment in frequent and infrequent words resulted in reater or equivalent generalization learning than treatment of words from sparse neighborhoods. Overall, the characteristic of word frequency was most salient in inducing phonological change as compared to neighborhood density. Moreover, in

every comparative Storkel • Morrisette: The Lexicon and Phonology 31 condition, frequent words consistently facilitated sound change, whereas words from dense neighborhoods consistently failed to promote generalization learning. These results were replicated by Morrisette and Gierut (in press) and are consistent with the predictions of the two-representation model.

Frequent words in the language consistently emerged as facilitating spoken word processing and learning, whereas words from dense neighborhoods in the language consistently emerged as inhibiting spoken word processing and learning. Moreover, phonological learning by preschool children was influenced by the lexicon, paralleling previous findings from much younger children. Novel Word Learning Applying the two-representation model to novel word learning, a child presumably will have no corresponding lexical representation for a newly encountered word. In the absence of a lexical representation, the two-representation odel predicts that phonological processing will be most influential. Thus, phonological processing is hypothesized to influence the creation of a lexical representation for the novel word. Because phonological processing is facilitated for common over rare sound sequences, children should learn novel words composed of common sound sequences more rapidly than they should those composed of rare sound sequences. Storkel and Rogers (2000) provided a direct test of this hypothesis that phonotactic probability should influence word learning. Typically developing school-age children from three age groups, age 7, 10, and 11, participated in a onword learning task, where half of the nonwords were composed of common sound sequences and half were composed of

rare sound sequences. The target nonwords were associated with unfamiliar objects. Children were exposed to the nonword-object pairs in a lecture format, and referent identification was tested immediately following exposure. The results showed a significant interaction between phonotactic probability and age. The two older groups of children learned more common than rare sound sequences; the youngest group of children showed no difference in learning common versus rare sound sequences.

This interaction between phonotactic probability and age was not predicted and was further investigated in a second study (Storkel, 2001). In Storkel (2001), word learning by preschool children was investigated in a multi-trial word learning paradigm. In particular, nonword learning was assessed in several tasks emphasizing either form or referent learning at multiple points in time. Preschool children were exposed to nonwords: Half were composed of common sound sequences and half were composed of rare sound sequences. The nonwords served as names for nonsense objects. The nonword-object pairs were mbedded in a story containing multiple story episodes with learning being assessed after each episode. Results showed that across measures of learning and exposures, preschool children learned more nonwords composed of common rather than rare sound sequences. Across the two studies, younger and older children seemed to learn novel words composed of common sound sequences more rapidly than they did those composed of rare sound sequences, supporting the predictions of the two-representation model. As in language perception and production tasks that are dominated by phonological processing, word learning was facilitated for common ound sequences relative to rare. Phonological characteristics

appeared to play a role in word learning by preschool and school-age children, complementing previous findings with younger children. Phonology appeared to influence lexical development beyond the 50-word stage. Moreover, various aspects of phonology seem to impact development of the lexicon, including the child's phonetic inventory and the phonotactic probability of the novel word (Leonard et al. , 1981; Schwartz & Leonard, 1982; Storkel, 2001; Storkel & Rogers, 2000). CLINICAL IMPLICATIONS The finding of a continued interaction between the exicon and phonology in children who have surpassed the 50-word threshold has clinical implications for children with functional phonological delays and children with specific language impairment. Children with functional phonological delays reportedly have a primary delay in the acquisition of phonology. Given the evidence documenting an interaction between the lexicon and phonology, lexical characteristics may play a role in promoting sound change. In contrast, children with specific language impairment appear to exhibit delays in lexical acquisition (e. g. , Dollaghan, 1987; Oetting, Rice, & Swank, 1995; Rice,

Buhr, & Nemeth, 1990; Rice & Woodsmall, 1988). Phonological variables may provide insights in the diagnosis and treatment of delays in word learning. Children With Functional Phonological Delays The results of Gierut and colleagues (1999) indicate that lexical variables of target words do appear to influence the Table 1. Experimental results of the Gierut et al. (1999) study. Treatment condition Generalization results Frequent versus infrequent Frequent > infrequent Dense versus sparse Sparse > dense Frequent versus dense Frequent > dense Frequent > dense Infrequent versus dense Infrequent > dense

Frequent versus sparse Frequent = sparse Infrequent versus sparse Infrequent ?? sparse Note. The symbol ">" indicates " greater than" (e. g. , treatment of sounds in frequent words resulted in significantly greater generalization learning than infrequent words). The symbol "? " indicates " greater than or equivalent" (e. g. , treatment of sounds in infrequent words resulted in greater or equivalent generalization learning than sparse words). The symbol "=" indicates " equivalent" (e. g. , treatment of sounds in frequent words resulted in generalization learning that was equivalent to sparse words). 2 LANGUAGE, SPEECH, AND HEARING SERVICES IN SCHOOLS • Vol. 33 • 24–37 • January 2002 process of sound change in treatment for children with functional phonological delays. When children were taught sounds in frequently occurring words, they made significant gains in their production accuracy of the target sound. In contrast, when children were taught sounds in words from dense neighborhoods, they failed to learn the treated sound. This suggests that phonological treatment should focus on frequent words in the language and avoid the use of words from dense neighborhoods. These results have direct linical implications for the kinds of words that should be selected for phonological treatment. A sample of treatment words is presented in Table 2. These words were adapted from the Morrisette and Gierut (in press) study and are consistent with procedures for the selection of treatment words in the Gierut et al. (1999) study. In this sample, the target fricative /f/ was taught in the word-initial position of frequent words in the language. Word frequency counts were obtained from KucUera and Francis (1967); neighborhood density values came from a computational database of 20, 000 English words (Nusbaum et al. 1984). Frequency counts and density values are more generally available for clinical

use through the online Neighborhood Database at http://www. artsci. wustl. edu/ ~msommers. Operational definitions for frequent versus infrequent and dense versus sparse neighborhoods were consistent with previous investigations of word frequency in phonological acquisition (e. g. , Morrisette, 1999). Frequent words were selected based on a word frequency count greater than 100. Thus, all of the words in Table 2 have a word frequency greater than 100. Further, because a word has both a frequency and a density, the words were alanced for neighborhood density. Half of the words came from dense neighborhoods, with 10 or more neighbors, and half of the words came from sparse neighborhoods, with fewer than 10 neighbors. Following from the Gierut et al. (1999) and Morrisette and Gierut (in press) studies, treated words were pictured on a computer screen and elicited through drill activities. Children attended three 1-hour treatment sessions each week and proceeded through two phases of treatment— imitation and spontaneous production. During the imitation phase, the child named the treated words following a clinician's model.

Imitation continued until the child achieved 75% production accuracy of the target sound across two consecutive sessions or until seven sessions were completed, whichever came first. During the spontaneous phase, the child named the treated words without a model. This phase continued until the child achieved 90% production accuracy of the target sound across three consecutive sessions or until twelve sessions were completed, whichever came first. Feedback related to the accuracy of the child's production of the target sound was provided during both phases. Generalization learning for each child was monitored hrough spontaneous picture-naming tasks or

probes. These probes were designed to sample the treated sound and other untreated sounds that were excluded from the child's pretreatment sound inventory in untreated words and across contexts. Probes were administered throughout treatment, immediately following treatment, and at 2 weeks and 2 months posttreatment. Percentages of accuracy were then calculated and plotted as generalization learning curves. Thus, based on results from Gierut et al. (1999), it is predicted that phonological treatment using the frequent words illustrated in Table 2 would result in generalization f /f/ to untreated words and contexts. It should be noted that although half of the frequent words selected were from dense neighborhoods, the consistent variable was word frequency. Treatment programs consisting of words that are all from dense neighborhoods should be avoided. Based on the Gierut et al. (1999) study, treatment in words from dense neighborhoods resulted in minimal or no learning of the treated sound. Children With Specific Language Impairment The results of Storkel (2001) suggest that the phonological characteristics of novel words influence lexical acquisition. Thus, clinically, it may be important to consider honotactic probability in the diagnosis and treatment of delays in lexical acquisition in children with specific language impairment. These children may have difficulty learning phonotactic probability due to either perceptual processing deficits (Ellis Weismer & Hesketh, 1996, 1998) or limited lexical exemplars resulting from delays in language acquisition. Children with specific language impairment may fail to show a learning advantage for common over rare sound sequences. In support of this hypothesis, Storkel reported that increased vocabulary size was correlated with an increased learning advantage for ommon over rare sound sequences in children with ageappropriate lexical development.

Delays in word learning and a decreased effect of phonotactic probability may go hand in hand. As a result, it may be necessary to examine the influence of phonotactic probability on word learning in this population. Unfortunately, standardized measures of vocabulary may not be sensitive to the factors that affect word learning because these tests examine the products of learning rather than the process itself. Therefore, clinicians may need to construct tasks that investigate the process of word learning to provide further insights into the factors hat contribute to a particular child's poor word learning ability. Here, guidance is provided by past experimental Table 2. Sample of frequent treatment words. Word Word frequency Neighborhood density fine 161 28 full 230 15 feed 123 19 far 427 18family331 0 field 274 9 final 156 6 forward 115 0 Note. Neighborhood density counts in bold indicate words from dense neighborhoods. Storkel • Morrisette: The Lexicon and Phonology 33 studies that have employed procedures that may be adapted for clinical use. In particular, the procedures used in Storkel (2001) may be appropriate. This multi-trial word earning paradigm was administered individually in one 30- minute session with a follow-up 10-minute session to examine retention. Thus, the time commitment is similar to other standardized test protocols. Moreover, Storkel and Rogers (2000) successfully administered their word learning task to groups of students in a classroom. There are several important steps in constructing a measure of word learning: (a) identifying the stimuli to be learned, (b) exposing the child to the stimuli, and (c) measuring learning. Each step will be described in turn. Stimuli. Identification of the stimuli to be learned nvolves choosing nonwords or unknown real words and associating these with referents. In Storkel (2001), nonwords were selected as stimuli so

that the phonological characteristics could be controlled. Specifically, all nonwords were composed of early acquired consonants that were articulated correctly by the participating children. This guarded against the influence of misarticulation on word learning (Leonard et al. , 1981; Schwartz & Leonard, 1982). Half of the nonwords were composed of common sound sequences and half were composed of rare sound sequences. Calculation of phonotactic probability is complex and equires access to a database; however, several published studies provide lists of common versus rare nonwords (e. g. , Jusczyk et al. , 1994; Storkel, 2001; Storkel & Rogers, 2000; Vitevitch & Luce, 1999) or words (e. g. , Vitevitch & Luce, 1999). The nonwords used in Storkel are shown in Table 3. The nonwords were paired with object referents to parallel real words. Novel objects were invented or adapted from published children's stories. Objects were selected in pairs from the same semantic category. Each object from a semantic pair was associated with either a common or a rare sound sequence.

In this way, semantic and conceptual factors were similar across the levels of phonotactic probability. A description of the objects is provided in Table 3. Exposure. For exposure, the nonword-object pairs were embedded in a story containing three story episodes. Pictures were adapted from children's stories (Mayer, 1993) to show two main characters interacting with one another and with the nonsense objects. Semantically paired objects were shown in the same picture, with each being associated with a different main character. A story narrative was created to accompany the story pictures. The narrative is shown in the Appendix.

Note that the exposure sentences were matched across common and rare sound sequences. For example, in the first episode, the exposure sentence for the common sound sequence /pin/ is " My favorite is the pin" and for the rare sound sequence /mOId/ is " My favorite is the mOId. " This matching of sentences was intended to equate syntactic factors across the levels of phonotactic probability. Another feature of the story narrative was that the number of times the nonwords were repeated varied across the episodes. That is, the children heard each nonword one time in Episode 1, but three times in Episodes 2 and 3.

Given that children with specific language impairment reportedly need more exposures to learn novel words, it may be necessary to increase the number of repetitions of the nonwords for this clinical population. This could be accomplished by revising the story narrative or by having the child listen to the narrative twice. Measurement. Storkel (2001) measured learning after each story episode. Three measures of learning were obtained: referent identification, form identification, and picture naming. In the referent identification task, a nonword was presented and the child attempted to select he object from a field of three picture choices that included the target, the semantically related referent, and a semantically unrelated referent presented in the story. For the target nonword /pin/, the child saw pictures of both candy machines and a picture of one of the pets. In the form identification task, an object was presented and the child attempted to select the nonword from a field of three Table 3. The phonetic transcription of the common and rare sound sequences and their corresponding referents as

invented or adapted from published children's stories. Form characteristics Referent characteristics

Common Rare Category Item 1 Item 2 w I t n aU b Toys punch toy cork gun (Geisel & Geisel, (Geisel & Geisel, 1958, p. 53) 1958, p. 45) h ? p g i m Horns orange trumpet yellow hand-held downward orientation tuba (Geisel & Geisel, (Geisel & Geisel, 1954, p. 50) 1954, p. 50) p i n m OI d Candy machines red candy + 1 chute blue candy + 2 chutes (invented) (invented) k oU f j eI p Pets green gerbil with antenna purple mouse-bat (DeBrunhoff, 1981, p. 132) (Mayer, 1992, p. 43) 34 LANGUAGE, SPEECH, AND HEARING SERVICES IN SCHOOLS • Vol. 33 • 24–37 • January 2002 choices. The choices paralleled those of the referent dentification task. For example, the child was shown a picture of one of the candy machines and heard three possible names, /pin/, /mOId/, and /koUf/. As each nonword was played, the investigator pointed to one of three squares. The child then pointed to the square associated with his or her answer. In the picture-naming task, an object was presented and the child attempted to produce the nonword. Again, the child might see a picture of one of the candy machines, but this time be asked to produce the nonword associated with the object with no choices or prompting provided by the investigator.

Following administration of these procedures, proportion correct can then be computed for common versus rare sound sequences at each test point (Episode 1, Episode 2, Episode 3) for each measure of learning (referent identification, form identification, picture naming). Difference scores can then be computed by subtracting proportion correct for rare sound sequences from proportion correct for common sound sequences. If there is

an advantage of common over rare sound sequences, the resulting number will be positive. This would parallel the findings for typically developing children (Storkel, 2001; Storkel & Rogers, 2000).

If there is no difference between common and rare sound sequences, then the resulting number will be zero. If there is a disadvantage of common relative to rare sound sequences, the resulting number will be negative. In either of these last two cases, the result would differ from those reported for typically developing children. This would suggest that one contributing factor to the child's difficulties with word learning may be difficulty using phonological information to support word learning. CONCLUSION The findings reviewed support the hypothesis that the lexicon and phonology seem to continue to influence one nother even after the 50-word threshold has been surpassed. In particular, the relationship in preschool and school-age children appeared to be bidirectional in nature, with the lexicon influencing phonological acquisition and phonology influencing lexical acquisition. The tworepresentation model of word processing held promise in capturing this relationship. Thus, models of spoken word processing may hold potential for understanding the process of language acquisition. From a clinical perspective, this theoretical model may guide the diagnosis and treatment of phonological or lexical delays in children. ACKNOWLEDGMENTS

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