Handbook of Child Language Disorders:

Perception and Production

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Introduction

If one was to ask a lay person to describe a symptom of a language disorder, the typical answer would probably focus on a phonological error ("wabbit" for *rabbit*); on a problem related to academic performance, such as difficulty in learning to read; or on a specific named disorder that is associated also with deficits in areas other than language, such as autism-spectrum disorder, or attention deficit hyperactivity disorder. The general public's knowledge of language disorders of an unknown origin is, in general, quite limited. This is true despite the fact that such language impairments are relatively common, with recent prevalence estimates of approximately 7.42 % from a population-based sample in the Midwestern United States (Tomblin, Records, Buckwalter, Zhang, Smith, & O'Brian, 1997). Even within the study of functional language impairments, there are great discrepancies in the specific topics that have been studied. Within this research area, a much larger proportion of research has examined morphology, syntax, and academic problems of children with language impairment, than has examined these children's speech perception, speech production, and their knowledge of higher-level aspects of the sound structure of language. Yet the latter are arguably the foundations on which knowledge of more abstract aspects of language, such as syntax, are based. Sounds are one of the media through which language is conveyed. Deficits in knowledge of sounds may a contributing, maintaining, or even a causal factor in language impairments. Thus, the topic of this chapter—a review of studies of what children with language impairments know about the knowledge of sounds—is a topic that is both understudied and poorly understood, as well as a topic that can explain much about the nature of a commonly occurring childhood communicative disorder.

There is ample evidence that the task of acquiring knowledge of the sound structure of language is highly protracted, and begins quite early in life. Children begin to recognize some familiar words, such as their names, by 4 to 5 months of age (Mandel, Jusczyk, & Pisoni, 1995) and begin to produce words around their first birthday. While most typically-developing children produce most or all of the sounds in their native language in a way that listeners perceive to be accurate by about 5 or 6 years or age (Smit, Freilinger, Bernthal, Hand, & Bird, 1990), more subtle measures of speech perception and production suggest that the phonological system is not adult-like until about age 10 or 12 (e.g., Kent & Forner 1980; Goffman, 2004; Hazan & Barrett, 2000; Smith, 1978).

A discussion of the protracted nature of phonological development must begin with a description of phonological *knowledge*. Phonological knowledge is far from monolithic. Knowledge of the sound structure of language includes many different sub-types of knowledge. This includes knowledge of the physical instantiation of phonological categories -- i.e., *perceptual knowledge* of the acoustic characteristics of speech sounds and their perceptual consequences, and *articulatory knowledge* of the motoric, tactile-kinesthetic, and proprioceptive characteristics of speech sounds. Phonological knowledge also involves more abstract higher-level knowledge of the ways that words can be divided into sounds, and sounds can be combined into meaningful sequences in words. In our previous work (e.g., Munson, Edwards, and Beckman, 2005b), we have referred to this as *higher-level phonological knowledge*. Perceptual, articulatory, and higher-level knowledge all refer to people's knowledge of the way that sounds are used to convey linguistic meaning. One last kind of phonological knowledge, *social-indexical knowledge*, refers to individuals' knowledge of the way that variation in speech production is used to convey social identity and social-group membership.

The different types of phonological knowledge can be illustrated by the knowledge that people have of the sound /r/. People have perceptual knowledge that /r/ is characterized by a low third-formant frequency, as illustrated in studies in which people identify synthetic stimuli varying in third-formant frequency as /r/ if the stimuli have a low F3 and /l/ if the stimuli have a high F3 (e.g., Munson & Nelson, 2005). People also have articulatory knowledge that /r/ can be produced either with a bunched tongue root or with a retroflex movement of the tongue tip, and that different configurations can be used to reduce acoustic variability in this sound (Guenther et al., 1999). People also have higher-level knowledge that /r/ does not occur in any word-initial clusters following /v/, and that /vrɑtʃ/ is not a possible word of English. Finally, people have knowledge of the ways that variation in /r/ production can be used to convey social-group membership. For example, British English speakers presumably have tacit knowledge that labiodental variants of /r/ are more likely to be produced by middle-class women than middle-class men or working-class people (Foulkes & Docherty, 2000). A full characterization of knowledge of /r/ includes all of these different types of knowledge.

This chapter will focus on the development of the first three kinds of phonological knowledge in children with language impairment relative to their typically developing peers, simply because there is little or no research on the acquisition of social-indexical knowledge in children with language impairments relative to their typically developing peers. However, in our conclusions we will speculate on how deficits in the acquisition of social-indexical knowledge might interact with the pragmatic problems frequently observed in children with language impairment.

In this chapter, we will consider primarily the phonological knowledge of children with language impairments of an unknown origin and, to a lesser extent, children with a related and sometimes co-occurring disorder, dyslexia. There are several reasons for this. First, there is a well-established, though small, body of research on phonological acquisition for these children. In contrast, there has been relatively little research on this subject in children with other genetically or neurologically based language impairments, such as autism, Williams syndrome, or Fragile X. This discussion will exclude children with broad cognitive deficits, such as developmental disability or Down Syndrome. It will also exclude children with hearing impairment. Our motivation for this is twofold. First, the prevalence of many of these disorders is considerably lower than that of PLI. Second, children with language problems associated with cognitive deficits often have concomitant hearing deficits and speech motor deficits and therefore a discussion of phonological acquisition for these children is considerably more complex. To illustrate, consider two recent findings. Seung and Chapman (2000) found that 11 of their 33 participants with Down syndrome failed a hearing screening, but did not differ from the 22 individuals who passed the screening on a psycholinguistic measure closely related to language performance, digit span. Marler, Elfenbein, Ryals, Urban, and Netzloff (in press) found a high rate of sensorineural hearing loss in individuals with Williams Syndrome, who are generally characterized as having relatively good language abilities in the absence of low full-scale IQ scores.

In this chapter, we will use the term *primary language impairment* (or PLI) rather than the more commonly used term *specific language impairment* (SLI) to describe children whose primary problem is with language acquisition and who have age-appropriate non-verbal IQ's, social-emotional skills, and oral-motor ability (following Kohnert & Windsor, 2004; Windsor & Kohnert, 2004). Children with PLI often show deficits in non-linguistic auditory and visual tasks relative to their typically developing peers (e.g., Kohnert & Windsor, 2004). The word *specific* in the label *specific language impairment* wrongly implies that these children's deficits are specifically limited to tasks involving language. Readers should keep in mind that the diagnostic criteria for PLI are identical to those described for SLI: the failure to achieve age-appropriate language skills in the absence of a condition that would otherwise cause a language impairment.

Perceptual knowledge

Speech Perception

In this first section, we focus on speech perception in children with language impairments relative to their typically peers, an area of research that goes back more than 20 years. The interest in speech perception began with the early work of Tallal and colleagues (e.g., Tallal & Piercy, 1973, 1974, 1975; Tallal & Stark, 1981). These researchers found that school-age children with language and/or learning disorders had more difficulty than typically-developing age peers in the discrimination of non-speech tones and in the discrimination of both synthetic speech consonants embedded in CV syllables, and in brief synthetic vowels. Crucially, children with language impairment performed more poorly than their typically developing age peers when the distinction hinged on brief acoustic cues, such as formant transitions, voice onset time, or even steady state formants for vowels if they were of sufficiently brief duration. This finding has since been replicated by a number of researchers using a variety of experimental paradigms and a variety of stimulus types (e.g., Leonard, McGregor, & Allen, 1992; Tallal & Piercy, 1974, 1975; Tallal & Stark, 1981; Stark & Heinz, 1996; Sussman, 2001). A number of researchers have hypothesized that these observed auditory processing deficits are causally related to language impairment. For example, Leonard et al. (1992) suggested that the inability to perceive rapidly changing acoustic information might underlie the grammatical deficits of children with PLI, as these acoustic parameters are potentially the cues used to perceive some grammatical morphemes. For example, two commonly occurring allomorphs of the English past-tense "–ed" morpheme are word-final -/t/ and -/d/, the perception of which would be based primarily on perception of formant transitions.

This view has been challenged in recent studies. Recent research has suggested that the observed speech perception deficits of children with PLI may have more to do with the nature of the stimulus and the memory demands of the task than on the perception of brief acoustic cues. Coady, Kluender, and Evans (in press) and Coady, Evans, Mainela-Arnold, and Kluender (2005) found that children with PLI performed similarly to typically developing age peers when natural speech rather than synthetic speech was used, when the stimuli were real words rather than nonsense words, and when the memory demands of the task were lessened. This finding is consistent with the claim of Gillam, Hoffman, Marler, and Wynn-Dancy (2002) that the performance of children with PLI is disproportionately affected by task difficulty relative to the performance of chronological-age peers. Nevertheless, this research has served as an impetus to understand how speech perception deficits are related to language impairment, whether these deficits are considered as an underlying cause of the language impairment, as in the work of Tallal and colleagues (e.g., Merzenich, Jenkins, Johnston, Schreiner, Miller, & Tallal, 1996), or as a symptom of a more general processing problem, as in the work of Miller, Leonard, and Kail (2001) and Windsor and Kohnert (2004), among others.

Still other researchers have argued that these studies underestimate the speech perception deficits of children with PLI, because these studies measure speech perception in quiet. A recent study by Ziegler, Pech-Georgel, George, Alario, and Lorenzi (2005) compared speech perception by children with SLI in conditions of steady background noise to ones in which the background noise fluctuated. This methodology is commonly used in studies of auditory perception in individuals with hearing impairment (e.g., Nelson, Jin, Carney, & Nelson, 2004) to examine whether observed speech perception deficits are due to peripheral auditory perception deficits, or more central speech processing problems. Ziegler et al. found that children with PLI performed more poorly than their typically developing peers. This was related to severity of language impairment. However, the group difference did not interact with noise type: they perceived speech better in fluctuating noise than in static noise, suggesting a more central deficit in associating acoustic signals with phonological categories rather than a peripheral auditory processing problem. More generally, Ziegler et al. criticized previous studies of speech perception in PLI for using optimal listening conditions which may underestimate the speech-perception deficit of children with PLI.

While some researchers have suggested that differences in speech perception observed in school-age children with language impairment relative to typically developing peers might be a consequence of the language disorder, rather than a cause, recent research suggests that such differences in speech perception are evident as early as the first year of life, even before children begin to produce words. Two recent prospective studies are relevant here. In a longitudinal study of 28 infants, Tsao, Liu, and Kuhl (2004) found a correlation between performance on a vowel discrimination task at 6 months of age and word production and comprehension at 13 months and at 16 months. Speech perception performance at 6 months was also correlated with production of irregular forms and grammatical complexity at 24 months. In another prospective study, Benasich and Tallal (2002) examined younger siblings of children with PLI relative to siblings of children with typical language development. Across the two groups of children, they found that performance on a non-speech auditory discrimination task at 7.5 months predicted subsequent language performance at 16 and 24 months for measures of both language comprehension and production.

Nonspeech Auditory Processing

In addition to differences in speech perception relative to their typically developing peers, recent studies have suggested that children with PLI may differ from their typically developing peers on a range of auditory perception tasks that do not utilize speech signals. The general focus of psychophysical studies since the foundational study of Tallal and Stark (1973) has been to identify possible difficulties in the perception of acoustic parameters that carry crucial acoustic cues to speech sounds. A finding that children with PLI have difficulty perceiving acoustic parameters in non-speech stimuli considerably strengthens the hypothesis that general perceptual difficulties may underlie language difficulties.

Wright et al. (1997) examined auditory temporal processing in eight children with PLI, to examine whether the deficits in rapid auditory processing for speech found by Tallal and colleagues could also be demonstrated for non-speech stimuli. Wright measured detection thresholds for pure-tone stimuli presented simultaneous to, prior to, or after broad-band noise with different spectral characteristics. The crucial condition in this study was the *backward masking* condition. In this condition, a tone is presented immediately prior to an interval of noise. A large, statistically significant group difference was found for detection thresholds in the backward masking condition: the tone needed to be louder in this condition for the PLI children to detect it. This difference was not present when the spectral characteristics of the noise and those of the tone were considerably different. Wright et al. claimed that these findings supported Tallal's earlier conjecture that the perception of brief auditory stimuli is impaired in children with PLI. Wright and Zecker (2004) expanded on this finding with a larger, more heterogeneous group of children, including children with PLI (including the eight children in Wright et al., 1997), children with dyslexia, and children with central auditory processing disorder, as well as age-matched peers with normal language and academic achievement. Again, typically developing children could detect a less-intense tone in the backward-masked condition than the children in any of the other groups.

Wright and colleagues' result has been replicated in a number of studies. Marler, Champlin, and Gillam (2002) and Marler and Champlin (2005) further showed that children with PLI have abnormal neurophysiologic responses in the backward-masking condition. Marler, Champlin, and Gillam (2001) examined detection thresholds in backward masking conditions by children with PLI undergoing computer-based auditory training programs (either Fast ForWord or Laureate Learning Systems software) and typically developing controls not receiving treatment. They found no association between participation in these programs and improvement in backward-masking thresholds. Thresholds decreased on successive trials, for both groups of children, suggesting that performance on the backward-masking task is at least partly dependent on task familiarity.

The auditory perception problems of children with PLI may extend beyond temporal perception. McArthur and Bishop (2004) examined frequency discrimination in teenagers and young adults with PLI and peers with typical language achievement. McArthur and Bishop argued that many previous findings regarding the purported auditory temporal processing deficit in children with PLI may be due to their decreased ability to perceive fine differences in frequency. They demonstrated that frequency detection thresholds were lower for people with typical language achievement than for a subgroup of people with PLI who had poor phonemic awareness. In a subsequent study, Bishop and McArthur (2005) showed that some of the children with PLI in the McArthur and Bishop (2004) study had atypical neurophysiologic responses to auditory stimuli, though this didn't coincide perfectly with the subset who demonstrated poor frequency discrimination. In follow up measures taken 18 months later, the frequency discrimination of many of the children with PLI improved, though a large proportion of the group continued to have atypical neurophysiologic responses to stimuli. Bishop, Adams, Nation, and Rosen (2005) examined the perception of brief glide stimuli (i.e., pure tone stimuli that change in frequency). They found that duration and frequency-range thresholds did not differ significantly between the two groups, though they did differ in a linguistic task, perceiving words in noise.

In general, the studies reviewed in this section seem to converge on the notion that at least some children with PLI have deficits in at least some aspects of auditory perception. The interpretation of this finding is qualified, however, by a number of factors. First, not all findings have been replicable across studies, suggesting that small differences in identification criteria used for PLI, or the inclusion of children with a variety of different language impairments (i.e., both PLI and dyslexia) may lead to different results. Second, as discussed by McArthur and Bishop (2004), it is not clear that the tasks that have been used in the classic studies on the psychophysical abilities measure what they purport to measure. For example, McArthur and Bishop argue that tasks that have been purported to measure temporal-processing abilities may in fact have been measuring frequency perception.

Finally, and perhaps most importantly, is the possibility that the group differences may reflect task learning rather than psychophysical abilities. Classical research on the psychophysical abilities of adults has examined asymptotic performance on listening tasks. This requires that individual listeners participate in numerous listening sessions to determine threshold performance. The long times required to determine these thresholds in these studies make them inappropriate for children with language impairment, who often show decreased attention. Consequently, thresholds are often determined using procedures that are relatively quick, and potentially affected by lapses in attention. The group differences may reflect attention or task learning, rather than differences in psychophysical abilities. This possibility is underscored by Marler et al.'s (2001) finding that backward-masked thresholds in children decreased with successive trials. It is possible that, with increased familiarity with a task, the auditory perception of children with PLI may reach levels that are comparable to those of children with typical development. Only one study has examined this possibility systematically. McArthur and Bishop (2004) examined the association between performance on a frequency-detection task and performance on tasks that measure basic-level cognitive processes involved in their task: attention, perception, and temporal-order perception. Though some group differences were found on these measures, McArthur and Bishop argued that "although temporal order and paired association may account for some variance in [frequency detection] thresholds, this amount is too small to explain the poor [frequency detection] thresholds of the [children with PLI demonstrating poor frequency detection]" (p. 537). A challenge for future studies is to further delimit the extent to which group differences in auditory perception are related to task familiarity and other basic-level cognitive processes.

Another challenge for future research is to identify the extent to which individual differences in auditory processing contribute to the heterogeneity in language abilities that is characteristic of the population of children with PLI, beyond what can be predicted by basic-level cognitive processes. Few studies have examined this, and the results of these studies do not find a consistent relationship between psychophysical abilities and language performance, as measured with standardized instruments. For example, Bishop, Bishop, Bright, Janes, Delaney, and Tallal (1999) found that a measure of auditory perception, performance on the *Tallal Auditory Repetition Test*, did not predict scores on a standardized language test as well as scores on another task, nonword repetition. Much previous research has shown that children with PLI perform more poorly than their typically developing peers on nonword repetition tasks (e.g., Ellis Weismer, Tomblin, Zhang, Buckwalter, Chynoweth, & Jones, 2000). It is well documented that children with PLI very often have lower nonverbal IQ scores than age- and language-matched peers with typical language development, even when children with scores below a cutoff (i.e., 85) are excluded. As argued by Rosen (2003), these subtle, sub-clinical differences in nonverbal IQ may account for auditory-processing differences between children with PLI and TD, rather than the differences in language abilities. In short, the findings reviewed in this paragraph support Rosen's (2003) argument that the auditory processing deficits observed in some children with PLI may be co-occurring deficits, rather than a causal deficit.

Relating speech perception to language skills

Two hallmark symptoms of PLI in English-acquiring preschool children are: 1) vocabulary problems, as exemplified by late talking (a delay in when first words are produced), difficulties with word-learning, and a smaller productive vocabulary size than typically developing peers at any age (e.g., Dollaghan, 1987; Oetting, Rice, & Swank, 1995); and 2) morphological deficits, as exemplified by a protracted period for morphological acquisition, especially for morphemes related to verb tense (for a summary of this work, see Leonard, 1998). In this section, we consider how these difficulties in word learning and morphological acquisition might be related to early problems in speech perception, such as those observed by Tsao et al. (2004) and Benasich and Tallal (2002).

A large body of research on infant speech perception provides some insight into why early deficits in speech perception might lead to delays in word learning. One of the primary language-learning problems that children must solve in their first year of life is how to pick out words–which they don't yet know—from the continuous stream of speech. This task is made easier by child-directed speech with its larger pitch range, shorter utterances, and simpler syntactic structure, but the problem still remains. Research on speech perception in the first year of life provides much insight into how infants gradually develop the abilities they need in order to delimit words from running speech. By about 9 to 10 months of age, children prefer listening to words with the preferred English strong-weak stress pattern (Jusczyk, Cutler, & Redanz, 1993); they prefer listening to words that contain sequences with permissible phonotactic sequences (Jusczyk, Friederici, Wessels, Svenkerud, & Jusczyk, 1993); and they prefer to listen to sequences with high rather than low phonotactic probabilities (Jusczyk, Luce, & Charles-Luce, 1994). Children are able to exploit these preferences so that they can segment continuous speech into words sometime between 6 and 9 months of age, using phonotactic information (Friederici & Wessels, 1993; Mattys, Jusczyk, Luce, & Morgan, 1999). If children have difficulty with speech perception in their first year of life, then these difficulties might make it more difficult for them to segment out words from running speech and this difficulty, in turn, could lead to a delay in word learning. There exist any number of deficits in speech perception that might make word learning problematic and relatively few of these deficits have been studied children with PLI. While we know that children with language deficits may have difficulty with distinguishing between minimal pair consonant or vowel segments even as early as six months of age (e.g, Leonard, McGregor, & Allen, 1992; Tallal & Piercy, 1974, 1975; Tallal & Stark, 1981; Stark & Heinz, 1996; Sussman, 2001; Tsao, et al., 2004), we know very little about whether children with PLI have other difficulties in speech perception, such as learning which contrasts are relevant in the ambient language (e.g., Werker & Tees, 1984) or determining the statistical patterns in the ambient language so that they can efficiently segment continuous speech into word-sized units (e.g., Saffran, 2001).

Werker, Fennell, Corcoran, and Stager (2002) provide some experimental evidence relevant to the prediction of a relationship between speech perception and word learning. They examined the auditory word discrimination skills of children in their second year of life, at a time when there is a wide range in vocabulary size, even for typically developing children. Werker et al. (2002) found that most 14-month-old infants were unable to distinguish between minimal pairs such as /bɪ/ and /dɪ/ in a word-learning task, although they were able to do so in a simpler speech perception task, and in a word-learning task using the phonetically dissimilar nonwords /lɪf/ and /næm/. In contrast, many 17-month-old and most 20-month-old infants could do so. Werker et al. (2002) found that across the whole age range of 14 to 20 months, productive vocabulary size was correlated with the ability to distinguish between minimal pair words on the word learning task. In addition, they found that infants with a productive vocabulary of at least 25 words or a receptive vocabulary of at least 200 words were successful on this task. Werker and Curtin (2005) interpreted these results within their model of infants' and toddlers' speech perception and word learning (PRIMIR). In the PRIMIR model, there are three multidimensional planes that underlie speech perception and word learning: a general perceptual plan, a word form plan, and a phoneme plane. Information on the phoneme plan develops gradually, based on regularities that emerge from the multi-dimensional clusters on the word form plane. This model predicts an interaction between word learning and phonological development, as observed by Werker et al. (2002). As predicted by the PRIMIR model, children who knew more words have a more highly developed phoneme plane and children with a more highly developed phoneme plane were better word learners.

Research on infant speech perception predicts that children who have perceptual difficulties early on will have difficulty picking words out of running speech and thus will be delayed in word learning. Furthermore, the PRIMIR model predicts that children with delayed word learning will have delayed phonological development as well because phonological development interacts with word learning. These findings address the first hallmark symptom of PLI, namely, difficulties in word learning.

The second hallmark symptom of PLI in English-speaking children is difficulty in the acquisition of morphology. The deficits in word learning that are observed for English-speaking children with PLI may be related to their deficits in morphological acquisition. There is some evidence that at least some aspects of morphological acquisition are related to vocabulary size. For example, Marchman (1995) found that the best predictor of when English-speaking children begin to over-generalize the regular past tense (*goed* instead of *went*) is the number of verbs in productive vocabulary. Even for regular morphemes, there is evidence that children need a critical mass of lexical forms to robustly abstract the appropriate allomorphic alternation. The past tense morpheme /ɪd/ is much lower in frequency than its allomorphs /t/ and /d/, and it is the last of the "regular" past tense allomorphs to be acquired (Marchman, Wulfeck, & Ellis Weismer, 1999). Similarly, the plural morpheme /ɪz/ is lower in frequency than its allomorphs /s/ and /z/ and it is the last of the "regular" plural allomorphs to be acquired (Derwing & Baker, 1980). One interpretation of these findings is that children need a "critical mass" of lexical items in order to make a morphological generalization (Marchman & Bates, 1994). Marchman and Bates have simulated these results with a connectionist model in which learning shifts qualitatively from memorization to systematic generalization as a function of vocabulary size. This view of morphological learning predicts that children with smaller vocabularies will have difficulties with the acquisition of morphology, and this is precisely what is observed for English-speaking children with PLI. In short, deficits in building a lexicon may mediate the causal relationship between speech perception deficits and morphological deficits in children with PLI: early speech perception deficits make the task of acquiring words challenging, and the resulting smaller-sized vocabulary may limit the robustness of the morphological generalizations that children with PLI can make.

The second area in which speech perception deficits may relate causally to language impairment concerns children with dyslexia. Dyslexia is defined broadly as a deficit in comprehending and producing written language. Like PLI, it is often diagnosed using exclusionary criteria (i.e., poor reading ability in the absence of a deficit that would otherwise compromise reading). It is commonly observed that PLI and dyslexia overlap, though the estimates are higher in clinically referenced samples (e.g., Catts, 1993) than in a population-based sample in the Midwestern United States (Catts, Adolf, Hogan, & Ellis Weismer, in press). The question of whether children with dyslexia have deficits in speech perception was examined by Manis, McBride-Chang, Seidenberg, Keating, Doi, Munson, and Peterson (1997). Manis et al. found that children with dyslexia had atypical identification functions for a *bath-path* continuum relative to typically achieving peers. More recently, Joanisse, Manis, Keating, and Seidenberg (2000) found that speech perception deficits occurred in children with dyslexia only if they had a concomitant oral-language impairment. Joanisse et al.'s study provides further evidence for a link between speech perception and language abilities. It further suggests that speech perception deficits in children with dyslexia may be mediated by oral language abilities, rather than directly attributable to the reading impairment.

Articulatory knowledge

The studies reviewed thus far all deal with only one of the four types of phonological knowledge, perceptual knowledge. Another type of phonological knowledge is articulatory knowledge. Relatively few studies have examined speech production directly in children with PLI. Although there is a low comorbidity rate between primary language impairment and phonological disorder (Shriberg, Tomblin, & McSweeny, 1999) at kindergarten entry, the few studies that have been conducted suggest that children with PLI may have speech production deficits relative to their typically developing peers. One example of this is shown by McGregor and Leonard (1994), who showed that children with PLI repeated initial unstressed pronouns and articles less accurately than initial stressed content words. That is, initial syllables were more likely to be deleted in weak-strong sequences like *they RUN* than in strong-strong sequences like *DOGS RUN* (where words in caps indicate stressed words). This is consistent with the behavior of younger, typically developing children (as reviewed in Gerken, 1996), and may indicate that the well-established tendency for children with PLI to omit articles and function-word subjects has a basis in difficulties with speech production, rather than in deficits in abstract grammatical knowledge.

Further evidence of speech production deficits in children with PLI comes from studies of articulatory variability. Goffman (1999, 2004) showed that children with language impairments have greater kinematic variability in lip movement than typically developing age-matched children when producing nonsense sequences. Both groups of children produced greater kinematic variability in weak-strong sequences than in strong-weak ones. This finding was replicated in a recent study by Goffman, Heisler, and Chakraborty (in press), who further showed that these differences occur in different phrase positions. Heisler, Goffman, and Younger (2004) also found that children with SLI show more kinematic variability in tasks in word-learning tasks. Crucially, the children with PLI in Goffman's studies did not have frank pronunciation problems; their increased kinematic variability does not appear to be secondary to categorical phonological errors of the type seen in children with articulation and phonological impairments. Goffman's findings suggest that children with PLI have less mature motor control than their typically developing peers.

Finally, some research has shown that children with PLI differ from their TD peers in general motor skills. Bishop (1990) found that children with PLI performed more slowly than TD children on a timed peg-moving task. Johnson, Stark, Mellits, and Tallal (1981) showed that children with PLI were slower than TD peers in executing rapid finger movements. Together, these findings suggest that the articulatory variability noted by Goffman may relate to a more general motor deficit in children with PLI.

Higher-level phonological knowledge

In the PRIMIR model of speech perception and word learning (Werker and Curtin, 2005), higher-level phonological knowledge is highly inter-related with word learning. One prediction that this model makes is that children with smaller vocabularies will have difficulty with higher-level phonological knowledge, such as being able to robustly abstract consonant and vowel categories from their usual consonant-vowel, vowel-consonant, and consonant-consonant contexts. This hypothesis was tested by Munson, Kurtz, and Windsor (2005). Munson, Kurtz, & Windsor (2005) examined nonword repetition in three groups of children. The primary group of interest was a group of 16 school-age children with primary language impairment. These children were compared to two groups of children who were acquiring language typically, a group of children who were matched to the children with PLI on chronological age (CA group) and a group of children who were matched on the basis of an estimate of expressive vocabulary size (the VS group). Munson, Kurtz, & Windsor (2005) examined accuracy of production of high- and low-probability nonwords (i.e., nonwords that contained either all high-frequency or all low-frequency two-phoneme sequences). Previous work (Edwards, Beckman, & Munson, 2004; Munson, Edwards, & Beckman, 2005a) argued that the difference in repetition between high- and low-frequency sequences of phonemes is related to the robustness of children's higher-level phonological knowledge. High-frequency sequences of phonemes, such /mp/, can be repeated accurately by resorting to knowledge in existing lexical items (as in *simple, camper,* etc.). In contrast, low-frequency sequences like /mk/, which occur in no known lexical items, can be repeated accurately only if the child's higher-level phonological knowledge includes knowledge of individual phonemes, like /m/ and /k/, in addition to knowledge of the sound structure of known words.

Analyses of variance showed that all three groups of participants produced the high-probability nonwords more accurately than the low-probability ones. Interestingly, the effect of probability was *larger* for the children with PLI relative to their CA controls and was not significantly different for the children with PLI relative to their VS controls. Thus, Munson, Kurtz, & Windsor (in press) found evidence that children with language impairments have less-robust higher-level phonological knowledge than their peers with typical development. These deficits appear to be due entirely to the smaller size of their vocabularies, as shown by the fact that the size of their frequency effect did not differ from that of their VS matches, and by the fact that an estimate of vocabulary size predicted the difference in repetition accuracy between high-and low probability nonwords. Munson, Kurtz, & Windsor (in press) conjectured that the larger phonotactic-probability effect seen in children with language impairments is related to their word-learning difficulties: children with LI may experience more difficulty than their age peers in learning higher-level phonological knowledge from lexical items. Consequently, the robust 'scaffold' that phonological representations serve in word-learning is not available to them, and their subsequent word-learning suffers.

Further evidence for higher-level phonological knowledge deficits can be seen in studies of spoken-word recognition by children with PLI. Dollaghan (1998) examined the ability of children with PLI to recognize spoken words from which acoustic information had been removed. The ability to accurately recognize words with information removed is facilitated if children have higher-level phonological knowledge that words are comprised of strings of phonemes, as this allows them to relate a partial input to a lexical representation in memory (Garlock, Walley, & Metsala, 2001; Walley, 1988). Typically developing children with larger-sized lexicons recognize gated words more accurately than those with smaller-sized lexicons (Edwards, Fox, & Rogers, 2002; Munson, 2001). Dollaghan (1998) found that children with PLI did not require more acoustic information than their typically developing peers to recognize familiar words, but did require significantly more information to recognize unfamiliar words. This finding complements Munson, Kurtz, and Windsor's finding by providing further evidence children with PLI have a deficit in higher-level knowledge of the phonemic structure of words.

Conclusions

With the notable exception of work on speech perception in children with PLI, there is a paucity of research on other aspects of phonological knowledge. Even in the area of speech perception, research has focused on whether children with PLI can perceive lower-level phonetic contrasts, rather than on whether they also have difficulty in abstracting higher-level phonological knowledge, such as phonotactic information. In addition, there are relatively few studies on articulatory and higher-level phonological knowledge in children with PLI relative to age controls or vocabulary-size controls. Furthermore, to our knowledge, there is virtually no research on the acquisition of social-indexical knowledge in children with PLI. Social-indexical knowledge refers to knowledge of how linguistic variation is used to convey and perceive membership in different social groups. Social-indexical knowledge encompasses a variety of different factors, including social class, race, gender, and regional dialect. Social-indexical variation can relate to any aspect of linguistic structure, including phonology, syntax, morphology, and the lexicon. Though previous studies have shown the pervasive influence of social-indexical variability on speech production and perception in adults and children (see Foulkes, 2005, for a review), very little research has examined how social-indexical knowledge may be impaired in children with SLI. However, there is some evidence that children with another commonly occurring communication disorder, phonological disorder, have decreased knowledge of social-indexical variability (Nathan and Wells, 2001). It is well established that children with SLI show a host of deficits in social skills and social communication (e.g., Brinton, Fujiki, & McKee, 1998, Brinton, Fujiki, Spencer, & Robinson, 1997; Marton, Abramoff, & Rosenzweig, 2004). It is possible that a causal or maintaining factor for these concomitant impairments is a decreased ability to perceive and convey social roles and social-group membership through variation in speech production. This is a potentially rich area for future research.

To summarize, while there are many critical gaps in our understanding of phonological knowledge in children with PLI, the research to date suggests that children with PLI have deficits in perceptual knowledge, articulatory knowledge, and higher-level phonological knowledge relative to their typically developing age peers. In this chapter, we have suggested that the observed deficits in perceptual knowledge, in particular, could lead to difficulties with word learning which, in turn, could lead to difficulties in the acquisition of morphology. Our account of the relationship between speech perception and language acquisition differs from that of others (e.g., Merzenich et al., 1996; Sussman, 2001; Wright et al., 1997). These other accounts have generally proposed a fairly direct link between deficits in speech perception and deficits in language acquisition (for example, children with PLI will have difficulty learning grammatical morphemes if they have difficulty processing rapidly changing temporal information). In contrast, we have proposed that the lexicon plays a crucial role in the acquisition of both phonological knowledge and morphological knowledge. In this account, deficits in speech perception will result in difficulties in word learning, which in turn will make the acquisition of robust phonological representations more difficult. This proposal is consistent with theories that posit continuity between processing and knowledge of language (e.g., MacDonald & Christiansen, 2002). Such an account of PLI has many implications, both theoretically and clinically.

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References

Benasich, A. A. & Tallal, P. (2002). Infant discrimination of rapid auditory cues predicts later language impairment. *Behavioural Brain Research*, *136*, 31-49.

Bishop, D. V. M. (1990). Handedness, clumsiness, and developmental language disorders. *Neuropsychologia*, *28*, 681-690.

Bishop, D. V. M., & McArthur, G. (2005). Individual differences in auditory processing in specific language impairment: a follow-up study using event-related potential and behavioural thresholds. *Cortex*, *41*, 327-341.

Bishop, D. V. M., Adams, C., Nation, K., & Rosen, S. (2005). Perception of transient nonspeech stimuli is normal in specific language impairment: Evidence from glide discrimination. *Applied Psycholinguistics*, *26*, 175-194.

Bishop, D. V. M., Bishop, S., Bright, P., James, C., Delaney, T., & Tallal, P. (1999). Different origin of auditory and phonological processing problems in children with language impairment: evidence from a twin study. *Journal of Speech, Language, and Hearing Research*, *42*, 155-168.

Brinton, B., Fujiki, M., & McKee, L. (1998). Negotiation skills of children with specific language impairment. *Journal of Speech, Language and Hearing Research*, *41*, 927-940.

Brinton, B., Fujiki, M., Spencer, C., & Robinson, L. A. (1997). The ability of children with specific language impairment to access and participate in an ongoing interaction. *Journal of Speech, Language and Hearing Research*, *40*, 1011-1025.

Catts, H. (1993). The relationship between speech-language impairments and reading disabilities. *Journal of Speech and Hearing Research*, *36*, 948-958.

Catts, H., Adolf, S., Hogan, T., & Ellis Weismer, S. (in press). Are specific language impairment and dyslexia distinct disorders? *Journal of Speech, Language, and Hearing Research*.

Coady, J. A., Kluender, K. R., & Evans, J. L. (in press). Categorical perception of speech by children with specific language impairments. *Journal of Speech, Language, and Hearing Research*.

Coady, J. A., Evans, J. L., Mainela-Arnold, E., & Kluender, K. R. (2005). Children with specific language impairments perceive speech most categorically when tokens are natural and meaningful. Manuscript submitted for publication.

Derwing, B. L., and Baker, W. J. (1980). Rule learning and the English inflections (with special emphasis on the plural). In G. D. Prideaux, B. L. Derwing, and W. J. Baker (Eds.), *Experimental linguistics: Integration of theories and applications* (pp. 247-272). Ghent: E. Sotry-Scientia.

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

Dollaghan, C. (1998). Spoken word recognition in children with and without specific language impairment. *Applied Psycholinguistics, 19*, 193-207.

Edwards, J., Beckman, M. E., & Munson, B. (2004). The interaction between vocabulary size and phonotactic probability effects on children's production accuracy and fluency in nonword repetition. *Journal of Speech, Language, and Hearing Research*, *47*, 421-436.

Edwards, J., Fox, R. A., & Rogers, C. (2002). Final consonant discrimination in children: Effects of phonological disorder, vocabulary size, and phonetic inventory size. *Journal of Speech, Language, and Hearing Research*, *45*, 231-242.

Ellis Weismer, S., Tomblin, J., Zhang, X., Buckwalter, P., Chynoweth, J., Jones, M. (2000). Nonword repetition performance in school-age children with and without language impairment. *Journal of Speech, Language, and Hearing Research, 43*, 865-78.

Foulkes, P. (2005) Sociophonetics. In Brown, K. (Ed.), *Encyclopedia of Language and Linguistics, 2nd Edition*. Amsterdam: Elsevier Press.

Foulkes, P., & Docherty, G. (2000). Another chapter in the story of /r/: 'labiodental' variants in British English. *Journal of Sociolinguistics,* 4, 30-59.

Friederici, A., & Wessels, J. (1993). Phonotactic knowledge of word boundaries and its use in infant speech perception. *Perception & Psychophysics*, *54*, 287-295

Garlock, V., Walley, A., & Metsala, J. (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.

Gerken, L. A. (1996). Prosodic structure in young children’s language production. *Language, 72,* 683–712.

Gillam, R., Hoffman, L., Marler, J., & Wynn-Dancy, M. (2002). Sensitivity to increased task demands: contributions from data-driven and conceptually driven informationl processing deficits. *Topics in Language Disorders*, *22,* 30-48.

Goffman, L. (1999). Prosodic influences on speech production in children with specific language impairments and speech deficits: kinematic, acoustic, and transcription evidence. *Journal of Speech, Language, and Hearing Research, 42*, 1499-1517.

Goffman, L. (2004). Kinematic differentiation of prosodic categories in normal and disordered language development. *Journal of Speech, Language, and Hearing Research, 47,* 1088-1102.

Goffman, L., Heisler, L., & Chakraborty, R. (in press). Mapping prosodic structure onto words and phrases in children's and adults' speech production. *Language and Cognitive Processes.*

Guenther, F., Espy-Wilson, C., Boyce, S., Matthies, M., Zandipour, J., & Perkell, (1999). Articulatory tradeoffs reduce acoustic variability during American English /♦/ production. *Journal of the Acoustical Society of America, 105,* 2854-2865.

Hazan, V., & Barrett, S. (2000). The development of phonemic categorization in children aged 6-12. *Journal of Phonetics, 28,* 377-396.

Heisler, L., Goffman, L., & Younger, B. (2004). *The Influence of Word Learning on Speech Production for Children with Specific Language Impairment.* Poster presented at the Symposium for Research on Child Language Disorders, Madison, WI.

Joanisse, M., Manis, F., Keating, P., & Seidenberg, M. (2000). Language deficits in dyslexic children: speech perception, phonology, and morphology. Journal of Experimental Child Psychology, 77, 30-60.

Tallal, P., Stark, R., Kallman, C., Mellits, D. (1981). A reexamination of some nonverbal perceptual abilities of language-impaired and normal children as a function of age and sensory modality. *Journal of Speech & Hearing Research, 24,* 351-357.

Jusczyk, P, Cutler, A., & Redanz, N. (1993). Infants' preference for the predominant stress patterns of English words. *Child Development, 64,* 675-687.

Jusczyk, P., Friederici, A., Wessels, J., Svenkerud, V., & Jusczyk, A. (1993). Infants' sensitivity to the sound patterns of native language words. *Journal of Memory and Language, 32,* 402-420.

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

Kent, R., & Forner, L. (1980). Speech segment durations in sentence recitations by children and adults. *Journal of Phonetics, 8*, 157-168.

Kohnert, K., & Windsor, J. (2004). The search for common ground: Part 2. Nonlinguistic performance by linguistically diverse learners. *Journal of Speech, Language, and Hearing Research, 47*.

Leonard, L. B. (1998). *Children with Specific Language Impairment*. Cambridge, MA: MIT Press.

Leonard, L. B. McGregor, K. K. & Allen, G. D. (1992). Grammatical morphology and speech perception in children with specific language impairment. *Journal of Speech and Hearing Research, 35*, 1076-1085.

MacDonald, M. C. & Christiansen, M. H. (2002). Reassessing working memory: A comment on Just & Carpenter (1992) and Waters & Caplan (1996). *Psychological Science, 109*, 35-54.

Mandel, D., Jusczyk, P., Pisoni, D. (1995). Infants' recognition of the sound patterns of their own names. *Psychological. Science* 6, 315 18.

Manis, F., McBride-Chang, C., Seidenberg, M., Keating, P., Doi, L., Munson, B., & Peterson, A. (1997). Are speech perception deficits associated with developmental dyslexia? *Journal of Experimental Child Psychology, 66*, 211-235.

Marchman, V. (1995). *Lexical development and morphological productivity: Vol. 13. A longitudinal follow-up*. Paper presented at the Biennial Meeting of the Society for Research in Child Development, Indianapolis, IN.

Marchman, V. & Bates, E. (1994). Continuity in lexical and morphological development: A test of the critical mass hypothesis. *Journal of Child Language, 21*, 331-366.

Marchman, V., Wulfeck, B., & Ellis Weismer, S. (1999). Morphological Productivity in Children with Normal Language and SLI: A Study of the English Past Tense. *Journal of Speech, Language and Hearing Research, 42*, 206-219.

Marler, J., & Champlin, C. (2005). Sensory processing of backward-masking signals in children with language-learning impairment as assessed with the auditory brainstem response. *Journal of Speech, Language, and Hearing Research, 48*, 189-203.

Marler, J., Champlin, C., & Gillam, R. (2001). Backward and simultaneous masking measured in children with language-learning impairments who received intervention with Fast ForWord or Laureate Learning Systems software. *American Journal of Speech-Language Pathology, 10*, 258-268.

Marler, J., Champlin, C., & Gillam, R. (2002). Auditory memory for backward masking signals in children with language impairment. *Psychophysiology, 39*, 767-780.

Marler, J., Elfenbein, J., Ryals, B., Urban, Z., & Netzloff, M. (in press). Sensorineural hearing loss in children and young adults with Williams Syndrome.

Marton, K., Abramoff, B., & Rosenzweig, S. (2004). Social cognition and language in children with specific language impairment. *Journal of Communication Disorders, 38*, 143-162.

Mattys, S., Jusczyk, P., Luce, P., Morgan, J. (1999). Phonotactic and prosodic effects on word segmentation in infants. *Cognitive Psychology, 38*, 465-494.

McArthur, G., & Bishop, D. V. M. (2004). Frequency discrimination deficits in people with specific language impairment: reliability, validity, and linguistic correlates. *Journal of Speech, Language, and Hearing Research, 4*7, 527-541.

McGregor, K., & Leonard, L. B. (1994). Subject pronoun and article omissions in the speech of children with specific language impairment: a phonological interpretation. *Journal of Speech and Hearing Research, 37*, 171-81.

Merzenich, M. M., Jenkins, W., Johnston, P., Schreiner, C., Miller, S., & Tallal, P. (1996). Temporal processing deficits in language-learning impaired children ameliorated by training. *Science, 271*, 77-81.

Miller, C. A., Kail, R., Leonard, L. B., & Tomblin, J. B. (2001). Speed of processing in children with specific language impairment. *Journal of Speech and Hearing Research, 44*, 416-433.

Munson, B. (2001). Relationships between vocabulary size and spoken word recognition in children aged 3-7. *Contemporary Issues in Communication Disorders and Sciences, 28*, 20-29.

Munson, B., Edwards, J., & Beckman, M. E. (2005a). Relationships between nonword repetition accuracy and other measures of linguistic development in children with phonological disorders. *Journal of Speech, Language, and Hearing Research, 48*, 61-78.

Munson, B., Edwards, J., & Beckman, M. E. (2005b). Phonological knowledge in typical and atypical speech-sound development. *Topics in Language Disorders, 25*, 190-206.

Munson, B., Kurtz, B. A., & Windsor, J. (2005). The influence of vocabulary size, phonotactic probability, and wordlikeness on nonword repetitions of children with and without specific language impairment. In press in *Journal of Speech, Language, and Hearing Research, 48*.

Munson, B., & Nelson, P. B. (2005). Phonetic identification in quiet and in noise by listeners with cochlear implants. In press in *Journal of the Acoustical Society of America, 118.*

Nathan, L., & Wells, B. (2001). Can children with speech difficulties process an unfamiliar accent? *Applied Psycholinguistics, 22,* 343-361.

Nelson, P. B., Jin, S.-H., Carney, A. E., & Nelson, D. (2004). Understanding speech in modulated interference: Cochlear implant users and normal-hearing listeners. *Journal of the Acoustical Society of America, 113,* 961-968.

Oetting, J., Rice, M., & Swank, L. (1995). Quick incidental learning (QUIL) of words by school-age children with and without PLI. *Journal of Speech, Language, and Hearing Research, 23,* 434-445.

Rosen, S. (2003). Auditory processing in dyslexia and specific language impairment: is there a deficit? What is its nature? Does it explain anything? *Journal of Phonetics, 31*, 509-527.

Saffran, J. (2001). Words in a sea of sounds: The output of statistical learning. *Cognition, 81*, 149-169.

Seung, H.-K., & Chapman, R. (2000). Digit span in individuals with Down syndrome and in typically developing peers: temporal aspects. *Journal of Speech, Language, and Hearing Research, 43*, 609-620.

Shriberg, L. D., Tomblin, J.B., & McSweeny, J. L. (1999). Prevalence of speech delay in 6-year-old children and comorbidity with language impairment. *Journal of Speech, Language, and Hearing Research, 42*, 1461-1481.

Smit, A. B., Freilinger, J. J., Bernthal, J. E., Hand, L., & Bird, A. (1990). The Iowa articulation norms project and its Nebraska replication. *Journal of Speech and Hearing Disorders, 55*, 779-798.

Smith, B. (1978). Temporal aspects of English speech production: a developmental perspective. *Journal of Phonetics, 6*, 37-67.

Stark, R. E. & Heinz, J. M. (1996). Vowel perception in children with and without language impairment. *Journal of Speech and Hearing Research, 39*, 860-869.

Sussman, J. E. (2001). Vowel perception by adults and children with normal language and specific language impairment: Based on steady states or transitions? *Journal of the Acoustical Society of America, 109*, 1173-1180.

Sussman, J.E. (1993). Perception of formant transition cues to place of articulation in children with language impairments. *Journal of Speech and Hearing Research, 26*, 1286-1299.

Tallal, P. & Piercy, M. (1973). Defects of nonverbal auditory perception in children with developmental aphasia. *Nature, 241*, 468-469.

Tallal, P. & Piercy, M. (1974). Developmental aphasia: Rate of auditory processing and selective impairment of consonant perception. *Neuropsychologia, 12*, 83-93.

Tallal , P. & Piercy, M. (1975). Developmental aphasia: The perception of brief vowels and extended stop consonants. *Neuropsychologia, 13*, 69-74.

Tallal, P. & Stark, R. E. (1981). Speech acoustic cue discrimination abilities of normally developing and language impaired children. *Journal of the Acoustical Society of America, 69*, 568-574.

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.

Tsao, F.-M., Liu, H.-M., & Kuhl, P. K. (2004). Speech perception in infancy predicts language development in the second year of life: A longitudinal study. *Child Development, 75*, 1067-1084.

Walley, A. C. (1988). Spoken word recognition by young children and adults. *Cognitive Development, 3,* 137-165.

Werker, J. F., Fennell, C. T., Corcoran, K. M., & Stager, C. L. (2002). Infants' ability to learn phonetically similar words: Effects of age and vocabulary size. *Infancy, **3***, 1-30.

Werker, J. F., & Curtin, S. (2005). PRIMIR: A developmental model of speech processing. *Language Learning and Development*, *1*, 197-234.

Werker, J. F. & Tees, R. C. (1984). Cross-language speech perception: Evidence for perceptual reorganization during the first year of life. *Infant Behavior and Development, 7*, 49-63.

Windsor, J., & Kohnert, K. (2004). The search for common ground: Part 1. Lexical performance by linguistically diverse learners. *Journal of Speech, Language, and Hearing Research, 47*.

Wright, B., & Zecker, S. (2004). Learning problems, delayed development, and puberty. *Proceedings of the National Academy of Sciences, 101*, 9942-9946.

Wright, B., Lombardino, L., King, W., Puranik, C., Leonard, C., & Merzenich, J. (1997). Deficits in auditory temporal and spectral resolution in language-impaired children. *Nature, 387*, 176-178.

Ziegler, J. C., Pech-Georgel, C., George, F., Alario, F.-X., & Forenzi, C. (2005). Deficits in speech perception predict language learning impairment. *Proceedings of the National Academy of Sciences, 102*, 14410-14115.