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Abstract

Purpose

Children with dyslexia have speech production deficits in a variety of spoken language contexts. In this article, we discuss the nature of speech production errors in children with dyslexia, including those who have a history of speech sound disorder and those who do not, to familiarize speech-language pathologists with speech production-specific risk factors that may help predict or identify dyslexia in young children.

Method

In this tutorial, we discuss the role of a phonological deficit in children with dyslexia and how this may manifest as speech production errors, sometimes in conjunction with a speech sound disorder but sometimes not. We also briefly review other factors outside the realm of phonology that may alert the speech-language pathologist to possible dyslexia.

Results

Speech-language pathologists possess unique knowledge that directly contributes to the identification and remediation of children with dyslexia. We present several clinical recommendations related to speech production deficits in children with dyslexia. We also review what is known about how and when children with speech sound disorder are most at risk for dyslexia.

Conclusion

Speech-language pathologists have a unique opportunity to assist in the identification of young children who are at risk for dyslexia.

Ben is in second grade and has always enjoyed school. His teachers have consistently reported that he is quite bright and engaged in the classroom setting. His parents note that Ben has always enjoyed being read to at home, but since late kindergarten he has resisted trying to read on his own or aloud to mark off his assigned "home reading time" for school. They have talked with his teachers about his resistance to read at home. Although his teachers have noted that Ben tends to lag behind his peers in reading skills, they have not been overly concerned because of his classroom engagement. Ben was seen by a school-based speech-language pathologist (SLP) from 3 to 6 years of age for a speech sound disorder that significantly impacted his overall speech intelligibility. At age 6, all error patterns had remediated except for /r/ in all positions of words, so he was discharged from therapy. Now in second grade, Ben's resistance to participating in reading activities in class and at home has become increasingly worrisome. He was recently referred for a special education evaluation to determine the presence of a reading disability. Results revealed that Ben has relatively strong oral language comprehension and expression but has weak phonological awareness and significant difficulty in decoding words. The special education team determined that Ben exhibits characteristics consistent with a learning disability and are now recommending intensive instruction to remediate Ben's deficient word-reading skills.

This true case example[1] is a common scenario regularly played out in many educational settings. It often takes 2-3 years of a child failing to respond to reading instruction before he or she is identified with dyslexia (often referred to as a specific learning disability in school-based settings) and can begin receiving much-needed individualized instruction to support reading acquisition. Ben exhibited early risk factors, such as a speech sound disorder, that placed him at risk for reading difficulty long before he was struggling with reading in the classroom. Children with dyslexia are at risk for long-term educational and social-emotional consequences, including poor self-esteem and poor self-perception of social and academic competence (Polychroni, Koukoura, & Anagnostou, 2006; Snowling, Muter, & Carroll, 2007; Terras, Thompson, & Minnis, 2009). Consequently, optimizing early identification of children with dyslexia has been a central goal for educators and researchers for

decades. In this article, we highlight how SLPs are uniquely suited to play a pivotal role in improving early identification of children with dyslexia because of their expertise in speech and language and their interaction with children before the start of formal reading instruction.

The SLP's Impact on Children With Dyslexia

Approximately 9% of school-age children in the United States have dyslexia (Katusic, Colligan, Barbaresi, Schaid, & Jacobsen, 2001; Pennington & Bishop, 2009). Dyslexia is defined as "a specific learning disability that is characterized by difficulties in accurate and/or fluent word recognition and by poor spelling and decoding abilities. These difficulties typically result from a deficit in the phonological component of language.... Secondary consequences may include problems in reading comprehension...and vocabulary and background knowledge" (Lyon, Shaywitz, & Shaywitz, 2003, p. 2). At first glance, it may appear that assessing and treating dyslexia may be outside the scope of practice for SLPs and instead fall more fully under the purview of a reading specialist or other educator. We, too, believe that reading specialists and other educators are key players for remediation of decoding and spelling skills as children learn to read. It is crucial, however, to consider the full scope of how dyslexia is characterized and recognize the important role SLPs play in the prevention, identification, and remediation of children with dyslexia.

Since 2001, it has been the position of the American Speech-Language-Hearing Association (ASHA) that SLPs play a "critical and direct role in the development of literacy for children and adolescents with communication disorders" (ASHA, 2001, p. 1). This role includes the identification of children who are at risk for reading and writing problems, such as dyslexia. As outlined in ASHA's position statement, "the connections between spoken and written language are well established and spoken language provides the foundation for the development of reading and writing" (ASHA, 2001, p. 1). Children with dyslexia commonly have a history of poor oral language skills in early childhood (Bishop & Adams, 1990; Magnusson & Nauclér, 1990; Scarborough, 1990; Snowling & Melby-Lervåg, 2016). In addition, weak word-reading skills have cascading influences on key language skills outside the phonological domain, such as the acquisition of vocabulary knowledge and reading comprehension. This becomes particularly evident around the third to fourth grades when students make the well-known shift from learning to read to reading to learn (Chall, 1983). As a result, children with dyslexia are at particular risk for experiencing a detrimental Matthew effect, a phenomenon wherein reading deficits impede a child's ability to improve his or her language skill through reading texts (Duff, Tomblin, & Catts, 2015; Stanovich, 1986). Furthermore, as reviewed by Adlof and Hogan (2018), there is an established relationship between developmental language disorder (DLD) and dyslexia. DLD is characterized by a deficit in any subcomponent of language such as phonology, morphology, syntax, vocabulary, and/or pragmatics (see Bishop, Snowling, Thompson, Greenhalgh, & CATALISE-2 Consortium, 2017, for a review). Thus, children with DLD are at significant risk for dyslexia if phonological weaknesses are part of their profile. Importantly, however, some children with DLD do not show phonological weaknesses and thus do not exhibit dyslexia (Catts, Adlof, Hogan, & Weismer, 2005). We refer the reader elsewhere for further discussion on the relationship between dyslexia and oral language skills (Adlof & Hogan, 2018; Scarborough & Dobrich, 1990; Snowling, Bishop, & Stothard, 2000; Storch & Whitehurst, 2002)

But what is the relation between dyslexia and speech production, apart from language ability? Because dyslexia involves a deficit in phonology, it is plausible that individuals with dyslexia likewise show difficulty with speech production in some capacity. Speech production is, after all, heavily reliant on an intact phonological system. Indeed, research shows that individuals with dyslexia exhibit a spectrum of speech production deficits, spanning the gamut from more severe impairments that are properly characterized as a speech delay or speech sound disorder to subclinical deficits involving word-specific errors, such as phonological confusion during speech

production (e.g., mispronouncing "animal" as "aminal" and "stethoscope" as "steposcope" long after it is age appropriate).

The purpose of the current article is to review the nature of speech production deficits in children with dyslexia, particularly as it relates to errors that may alert the SLP to the risk for dyslexia in young children. We further provide concrete recommendations that SLPs may readily incorporate into clinical practice to more fully support the identification and/or remediation of children with or at risk for dyslexia. We believe a more complete understanding of speech production skills and how they relate to dyslexia will help SLPs more easily recognize their role in the prevention, identification, and treatment of children with dyslexia. We first provide the reader with a brief review of the role that phonology plays in dyslexia, including evidence for a phonological deficit in children with dyslexia. Second, we review speech production error patterns made by individuals with dyslexia, regardless of the presence or absence of a speech sound disorder. Third, we review the relation between speech sound disorder and dyslexia, particularly as this pertains to identifying young children with speech sound disorder who are most likely to develop dyslexia. Next, we look beyond phonological deficits and discuss other prominent theories of deficit for children with dyslexia that may further assist SLPs in the identification and management of children with dyslexia. Finally, we provide concrete clinical recommendations to help clinicians more confidently apply the breadth of their knowledge to identify and remediate children with dyslexia.

The Role of Phonology in Children With Dyslexia

Dyslexia is a disorder that is primarily characterized by deficits in the understanding and use of the phonological system for literacy skills (e.g., decoding and encoding; Lyon et al., 2003). The phonological deficit hypothesis offers a long-standing explanation for the difficulties most commonly experienced by children with dyslexia (McCardle, Scarborough, & Catts, 2001; Stanovich & Siegel, 1994; Vellutino, Fletcher, Snowling, & Scanlon, 2004). The classic manifestation of the phonological deficit in dyslexia culminates as difficulty in mapping speech sounds onto letters during the decoding process. Importantly, however, individuals with dyslexia have difficulty with a number of other phonologically based skills that provide further evidence of a weak phonological system. One of the strongest indicators of phonological weakness is poor phonological awareness (Farquharson, Centanni, Franzluebbers, & Hogan, 2014; Swan & Goswami, 1997), referring to one's metalinguistic knowledge of the sound structure of language. Phonological awareness can be reflected at the word and syllable level (e.g., rhyming, syllable segmentation) or at the phoneme level, which include abilities such as phoneme blending (e.g., "What word do these sounds make? /s/ /p/ /u/ /n/.") or phoneme deletion (e.g., "Say the word 'split' without/p/.") Poor literacy outcomes have long been linked to children with poor phonological awareness (Bruck, 1992; Wagner & Torgesen, 1987). Importantly, even after learning to read, individuals with dyslexia continue to show poor phonological awareness, particularly for tasks that require phoneme-level sensitivity (Pennington, Orden, Smith, Green, & Haith, 1990; Snowling, Nation, Moxham, Gallagher, & Frith, 1997; Wilson & Lesaux, 2001).

In addition to known deficits in phonological awareness, those with dyslexia commonly manifest other deficits reflective of a weak phonological system, including poor phonological memory (Brady, Shankweiler, & Mann, 1983), poor speech perception (Rosen, 2003), and poor letter sound decoding skills (Stanovich & Siegel, 1994). Taken together, children with dyslexia exhibit poor phonological processing skills across the board (Lyon et al., 2003; Snowling et al., 1997; Vellutino et al., 2004; Wagner & Torgesen, 1987). As defined by Scarborough and Brady (2002), phonological processing refers to the "the formation, retention, and/or use of phonological codes or speech while ...speaking, listening, remembering, learning, naming, thinking, reading, or writing" (p. 318). Although it is clear that dyslexia manifests with deficits in phonology across a variety of skills and tasks, the underlying mechanism(s) that drives this deficit is still debated.

Long-standing research has reported that phonological representations appear weak, underspecified, and/or absent in children with dyslexia (Boada & Pennington, 2006; Elbro & Jensen, 2005; Farquharson et al., 2014). These abstract mental representations in the phonological system are an important component of how we store information about individual words in long-term memory (Goswami, 2000; Scarborough & Brady, 2002; Sutherland & Gillon, 2005). Such information may include the phonemes comprising the word, the stress pattern of the word, and/or any other phonologically relevant information for a given word. Phonological representations appear to be acquired and refined over time as language develops (Scarborough & Brady, 2002). Importantly, phonological representations are not the only mental representation for words in long-term memory. For example, a "semantic" representation provides meaning of the word in the lexicon (Perfetti & Hart, 2002). For children with dyslexia, the creation of phonological representations appears to be disrupted (Alt et al., 2017; Brady et al., 1983; Melby-Lervåg & Lervåg, 2012; Swan & Goswami, 1997). As children acquire new words, they must rely on phonological working memory to create, retain, and retrieve a phonological code that is not yet associated with a semantic representation. This process of phonological encoding has been an oft-reported deficit for children with dyslexia (Brady et al., 1983; Elbro & Jensen, 2005; Swan & Goswami, 1997), which likely has negative implications for learning to read and produce complex words. For example, this deficit may affect a child's ability to encode and retrieve challenging words in a science class, where vocabulary is often complex.

Speech Production Error Patterns in Children With Dyslexia

Because dyslexia is characterized by a core deficit in phonology (Stanovich & Siegel, 1994; Vellutino et al., 2004), it follows that individuals with dyslexia may produce errors during speech production, an ability that relies heavily on phonology. Indeed, the relation between spoken language and dyslexia has been of interest for many years. As far back as the early 20th century, it was noted that children with word-reading deficits often presented with a history of oral language problems early in childhood (Orton, 1925). Numerous researchers have since corroborated this finding and similarly reported that children with dyslexia commonly have a history of "spoken language" or "verbal" deficits (Gallagher, Frith, & Snowling, 2000; Lambrecht Smith, Roberts, Locke, & Tozer, 2010; Scarborough & Dobrich, 1990; Snowling, 1981). However, prior research has not always been clear about what was meant by "spoken language" or "verbal" deficits. It is possible this terminology alternatively may have referred to deficits of speech production (i.e., articulation), oral language, or both. Below, we review literature that characterizes speech production in both young children at risk for dyslexia as well as older children and adults who have dyslexia.

In early development, young children with familial risk for dyslexia have shown significantly poorer speech production accuracy relative to children without familial risk (Carroll, Mundy, & Cunningham, 2014; Carroll & Snowling, 2004; Elbro, Borstrom, & Petersen, 1998; Scarborough, 1990). These studies have noted that even in toddlerhood, children with familial risk of dyslexia who eventually develop dyslexia produce more consonantal errors (Lambrecht Smith et al., 2010; Scarborough, 1990) and use slower speaking rates (Smith, Roberts, Smith, Locke, & Bennett, 2006) than their peers at familial risk for dyslexia who do not develop the disorder. Additional speech production deficits have been implicated among children, adolescents, and adults with dyslexia with respect to phonetic accuracy during speech production (Bertucci, Hook, Haynes, Macaruso, & Bickley, 2003; Catts, 1986, 1989; Catts, Fey, Zhang, & Tomblin, 2001), articulatory speed (Duranovic & Sehic, 2013; Fawcett & Nicolson, 2002), speaking rate (Catts, 1989), and speech motor planning/ programming (Peter, Lancaster, Vose, Middleton, & Stoel-Gammon, 2017). Of note, the speech errors in those with dyslexia are atypical and do not follow the pattern of systematic misarticulations or distortions characteristic of a clinically diagnosed speech sound disorder.

Catts (1986) sought to explicitly characterize speech production patterns in children with dyslexia in the absence of a diagnosed speech sound disorder. He found that children ages 12;7 to 15;9 (years;months) produced more speech production errors than their peers during a picture-naming task (e.g., rhinoceros, ambulance), when repeating multisyllabic words (e.g., aluminum, sympathize), and when repeating short phrases (e.g., the priest blessed the bread). These errors were characterized as word- or phrase-specific misarticulations (e.g., saying amunium for aluminum), as opposed to the systematic distortions typical of children with speech sound disorder (e.g., /r/ is produced as /w/ in all instances). Catts hypothesized that some of these errors were the result of difficulty in encoding phonological information (e.g., omitting phonemes, substituting the wrong phoneme) but attributed other errors to the children's difficulty with accessing phonological memory because the children were aware that the production they attempted was not correct (e.g., laughing when a word came out incorrectly). He concluded that children with dyslexia may have an adequate phonological representation to recognize that what they produced did not match the intended phonological target. This study replicated an earlier finding from Snowling (1981) that showed that children with dyslexia produce an increasing number of speech production errors or misarticulations, but only when words become more phonologically complex (e.g., producing consonant cluster vs. singletons, producing words of increasing length). Importantly, both Catts (1986) and Snowling (1981) noted these errors were not systematic distortions children were making in their speech but rather occurred in specific words and/or when the speech task became more challenging.

Speech Sound Disorder in Children With Dyslexia

Similar to children with dyslexia, a core deficit in the phonological system has been implicated in children with speech sound disorder (Anthony et al., 2011; Pennington & Bishop, 2009; Sutherland & Gillon, 2007). Children with speech sound disorder have a clinical delay or difference in speech sound acquisition that cannot be explained by cognitive, sensory, or structural deficits (Shriberg et al., 2010). Speech production errors in speech sound disorder are characterized by persistent and systematic deletion, substitution, and/or distortion of speech sounds resulting in decreased intelligibility as compared to same-age peers (Shriberg, Austin, Lewis, McSweeny, & Wilson, 1997). In addition to their overt errors in speech production, children with speech sound disorder have shown deficits for a variety of other phonological tasks, including phonological awareness (Bird, Bishop, & Freeman, 1995; Carroll & Snowling, 2004; Preston, Hull, & Edwards, 2013; Rvachew & Grawburg, 2006), phonological memory (Couture & McCauley, 2000; Farquharson, Hogan, & Bernthal, 2017; Munson, Edwards, & Beckman, 2005), spelling (Bird et al., 1995; Carroll & Snowling, 2004; Clarke-Klein & Hodson, 1995), and word reading itself (Apel & Lawrence, 2011; Overby, Trainin, Smit, Bernthal, & Nelson, 2012). Importantly, children with speech sound disorder have been shown to exhibit deficits in these tasks, even when controlling for their poor speech production accuracy (Anthony et al., 2011; Rvachew, Ohberg, Grawburg, & Heyding, 2003; Sutherland & Gillon, 2005, 2007) and/or even after their speech sound errors have been remediated (Raitano, Pennington, Tunick, Boada, & Shriberg, 2004). This suggests that phonological deficits impact an underlying level of phonological representation that goes beyond their overt speech production errors.

A large body of work has shown that children with speech sound disorder are at increased risk for having difficulty in learning to read (Anthony et al., 2011; Bird et al., 1995; Carroll & Snowling, 2004; Hayiou-Thomas, Carroll, Leavett, Hulme, & Snowling, 2017; Larivee & Catts, 1999; Peterson, McGrath, Smith, & Pennington, 2007; Raitano et al., 2004; Rvachew, 2007). Approximately 18% of preschool-age children with isolated speech sound disorder (absent of a co-occuring language impairment) have reading difficulty in mid-elementary school (Lewis, Freebairn, & Taylor, 2000). In a separate line of work, an estimated 25% of school-age children with a family history of dyslexia have a history of speech sound disorder in early childhood (Pennington & Lefly, 2001). Thus, speech sound disorder and dyslexia are highly comorbid.

The comorbidity of speech sound disorder and dyslexia is not well understood for several reasons. First, one inherent challenge to studying these populations concerns the ages at which symptoms of speech sound disorder and dyslexia manifest. Children with speech sound disorder are typically identified during the early preschool years due to low intelligibility resultant from speech production errors. Once these children are identified, an SLP begins targeting the child's speech production errors in therapy, well before reading instruction begins. It is not uncommon for many of these children, with the provision of adequate speech therapy, to resolve most of their overt speech errors by the beginning of reading instruction in early elementary school (Baker & McLeod, 2011). Indeed, that is often a primary goal of therapy: to remediate speech production errors before the start of formal education. It is during the early elementary grades that reading deficits associated with dyslexia manifest for children who are failing to respond to quality reading instruction. Thus, dyslexia is typically diagnosed in the early to mid-elementary grades. Just as children with speech sound disorder are resolving their speech production errors, those children with dyslexia are on the cusp of being identified. As a child is undergoing evaluation for dyslexia, knowing that he or she has a history of speech sound disorder would provide useful diagnostic information concerning that child's underlying phonological system. Unfortunately, because of the age disparity between when children with speech sound disorder and children with dyslexia are diagnosed and treated, it is common for a child's history of speech sound disorder to be unknown to the personnel conducting the evaluation.

Second, as mentioned in the previous section, many children with dyslexia have poor speech production as compared to age-matched typically developing readers (e.g., Catts, 1989; Snowling, 1981; Snowling & Melby-Lervåg, 2016), particularly when words are long or phonologically complex (Catts, 1989; Peter et al., 2017; Snowling, 1981). The quantity of their errors, however, may not be sufficient to warrant a clinical diagnosis of speech sound disorder, and thus, these children may not be under the direct care of an SLP. On the reverse side, some children with speech sound disorder show poorer reading outcomes when compared to their age-matched peers with typical speech production, even though their weak literacy skills may not fully qualify them for a formal diagnosis of dyslexia (Hayiou-Thomas et al., 2017). These children may have related subclinical deficits, such as poor phonological awareness, but may not require intensive reading intervention (Overby et al., 2012). This may place these children at increased risk for reading comprehension deficits in the later grades subsequent to their weak phonological skills. In both cases-subclinical speech production deficits in children with dyslexia and subclinical reading deficits in children with speech sound disorder-the potentially interesting overlap between these two disorders is missed because the visibility of one deficit may be more apparent than the other.

Third, the comorbidity between dyslexia and speech sound disorder is often mediated by oral language skills (see Pennington & Bishop, 2009). For example, in one sample of children, 75% of preschool-age children with speech sound disorder and language impairment developed dyslexia (Lewis et al., 2000), and 18% of preschool-age children with isolated speech sound disorder (absent of language impairment) developed dyslexia. Similar converging findings have led many to conclude that a speech sound disorder alone is not necessary or sufficient to result in dyslexia in all children (Bishop & Adams, 1990; Larivee & Catts, 1999; Nathan, Stackhouse, Goulandris, & Snowling, 2004; Pennington & Bishop. 2009; Raitano et al., 2004; Snowling et al., 2000). We argue, based on literature discussed above, that although comorbid speech and language impairments are a major risk factor for dyslexia, isolated speech sound disorder also poses an increased risk for dyslexia and should not be ignored (Hayiou-Thomas et al., 2017; Lewis et al., 2011). Children with isolated speech sound disorder are at risk for being overlooked for dyslexia risk precisely because they do not have a co-occurring language impairment that would otherwise alert the SLP to further investigate reading skills.

Finally, characteristics of a child's speech sound disorder-severity of the disorder, persistence of the disorder, and errors associated with the disorder-are linked to risk for reading difficulties (Bird et al., 1995; Larivee &

Catts, 1999; Preston et al., 2013; but see Shriberg et al., 2005). In terms of severity, the more severe or persistent the speech sound disorder, the more likely the child will have a reading disability. This finding is highlighted in children with childhood apraxia of speech, a speech sound disorder associated with motor programming deficits and which tends to show a poor response to treatment (Lewis, Freebairn, Hansen, Iyengar, & Taylor, 2004). In terms of persistence, children with speech sound disorder beyond the age of 6 years, regardless of initial severity (Hayiou-Thomas et al., 2017), are at increased risk for reading difficulty (Nathan et al., 2004; Raitano et al., 2004). Indeed, one of the most significant risk factors for dyslexia in children with speech sound disorder is whether or not they are still producing speech production errors at the onset of reading instruction (Bird et al., 1995; Hayiou-Thomas et al., 2017; Raitano et al., 2004). In terms of error types, children who produce atypical or unusual speech errors (e.g., non-developmental phonological processes such as initial consonant deletion, backing) are at greater risk for later reading difficulty as compared to children who produce more typical speech errors (Hayiou-Thomas et al., 2017; Preston et al., 2013). Taken together, these findings help provide guidance for SLPs regarding factors that increase the risk for dyslexia in children with speech sound disorder.

Beyond the Phonological Deficit in Children With Dyslexia

Although research suggests deficits in phonology play a key role in dyslexia, we acknowledge that a phonological deficit may not be the sole contributor to reading difficulty. In a large population-based analysis of children with dyslexia, Pennington et al. (2012) investigated the roles of phonological awareness, processing and/or naming speed, and language as determinants for dyslexia. Specifically, they tested whether a singular phonological deficit accounted for dyslexia in some, most, or all cases of dyslexia. Using statistical modeling, Pennington et al. (2012) concluded that it was individual differences in children that determined whether a singular deficit in phonological awareness or multiple cognitive deficits (e.g., phonological awareness + language) best accounted for a child's risk of dyslexia. That is, there was not a definitive model of dyslexia that fit for all or even the majority of children. Although these findings shed further light on the complex nature of dyslexia in children, more research is necessary to further elucidate the contribution of additional cognitive deficits such as naming/processing speed or language to the presence or absence of dyslexia risk. In related work, Pennington (2006) proposed that the multiple-deficit hypothesis further helps explain the high incidence of comorbidity among dyslexia and other disorders such as speech sound disorder, DLD, or attention-deficit/hyperactivity disorder. For speech sound disorder, Peterson, Pennington, Shriberg, and Boada (2009) proposed that a multiple deficit hypothesis provides the best explanation for when and how speech sound disorder co-occurs with dyslexia. Similar to the findings of Pennington et al. (2012), it appears that phonological deficits may interact with other factors (e.g., nonverbal cognitive ability, phonological awareness, oral language skill) to determine whether a child develops dyslexia.

So, what are other factors that could potentially contribute to a multiple-deficit view of dyslexia? Beyond the key areas of deficit in the phonological domain, psycholinguistic components also play an important role, which refer to the underlying factors that allow individuals to acquire, use, and understand language. In a case study review, Cabbage, Farquharson, and Hogan (2015) investigated two such psycholinguistic factors-speech perception and working memory-to determine whether these constructs were deficient for children with speech sound disorder and/or dyslexia. They found that the underlying phonological processing skills of children with speech sound disorder with or without dyslexia are quite varied and not necessarily predicted by overt speech production patterns. That is, the children produced similar overt errors but displayed distinct deficit profiles for the psycholinguistic constructs of speech perception and working memory.

As reviewed in this article, those with dyslexia produce increasing numbers of speech production errors as word length and complexity increases. This occurs even in the absence of a co-occurring speech sound disorder.

Although underlying deficits in phonology may explain these errors, it is possible that deficits in broader domains beyond the speech mechanism, such as generalized deficits in motor skills, may also play a role. Indeed, children with dyslexia have clear deficits in gross motor skills (Fawcett & Nicolson, 1999; Ramus, 2003) and procedural learning (Nicolson & Fawcett, 2011; Stoodley, Harrison, & Stein, 2006; Vicari, Marotta, Menghini, Molinari, & Petrosini, 2003), neither of which are easily explained by a singular deficit in phonology. Motor deficits may appear as general deficit in motor coordination or balance (Nicolson & Fawcett, 2011), whereas deficits in procedural learning manifest as difficulty in acquiring skills or behaviors without explicit teaching. In reading instruction, generally students are exposed to systematic instruction of the correspondence between speech sound to letter mappings, and then knowing this basic information, children "figure out" how to read mostly on their own (Share, 1995). Is it possible that children with dyslexia, because of a procedural learning deficit, have more difficulty with the implicit learning required to master the reading process? Procedural learning deficits have been implicated for children with dyslexia and some children with speech sound disorder (Peter et al., 2017), specifically those with childhood apraxia of speech. Although an exhaustive review of the literature in this area is beyond the scope of this article, we nevertheless want to raise awareness to other factors beyond phonology that may be associated with dyslexia.

Clinical Implications

Taken together, the information above has substantial clinical utility. In this section, we highlight specific and practical ways SLPs can recognize and assist with the prevention, identification, and remediation of children with dyslexia in various clinical settings, including schools and private practice. Pediatric SLPs, regardless of clinical setting, are on the frontline for identifying preschool-age children who may be at risk for dyslexia and/or assisting in the evaluation of older children who are struggling with reading. In some cases, children exhibit multiple risk factors that may alert the SLP to a child's risk for dyslexia. For example, a child who has a history of significant developmental delays in addition to a significant speech sound disorder is likely to be already on the SLP's radar as at risk for reading difficulty. In these cases, the child is often receiving services from several professionals on a multidisciplinary team and is thus being monitored across several disciplines, including academic preparedness. But what about children who are receiving primarily and, in some cases, only speech and/or language services? In Figure 1, we offer an example of the referral process for a kindergartener who is experiencing some difficulties in learning letter names and sounds. In this example, it is assumed that the referral is made to a student support team and that the SLP would be a member of this team.

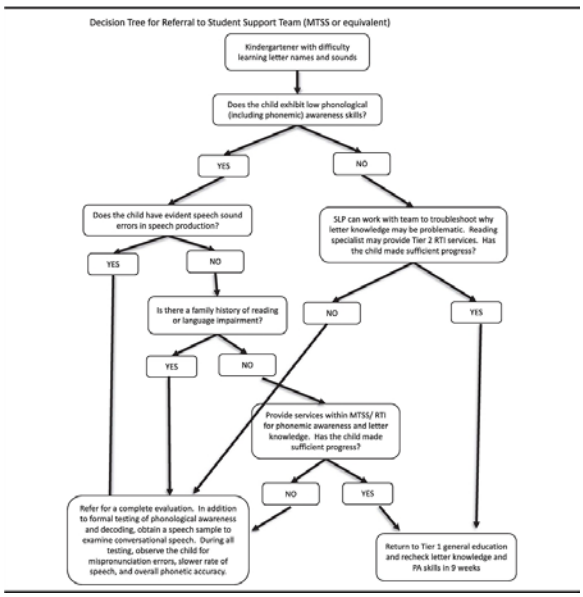
Case History

Dyslexia is a disorder that is neurobiological in origin and is highly inheritable in families (Yu, Zuk, & Gaab, 2018). Thus, children with a familial risk for dyslexia have a higher likelihood of developing dyslexia (Astrom, Wadsworth, & DeFries, 2007; Snowling & Melby-Lervåg, 2016). Relatedly, the prevalence of dyslexia is higher among children with speech sound disorder who also have a family history of dyslexia (Hayiou-Thomas et al., 2017). Thus, we recommend that SLPs ensure that any case history or intake protocol includes an inquiry into the child's family history of reading difficulty. Note that asking this question may insinuate to parents that they have "caused" their child's dyslexia. To alleviate this burden, SLPs can provide information to parents on the neurobiological nature of dyslexia.

Individuals with dyslexia, regardless of speech therapy history, often have difficulty in producing words of increasing length of phonological complexity (Catts, 1986; Snowling, 1981). The SLP can raise awareness for this difficulty by helping teachers and other practitioners watch for this marker in children. This does not suggest that children are suspected of having dyslexia if they have difficulty in producing complex or multisyllabic words; it merely serves as an additional point of consideration for children who may be at risk. Thus, it would be appropriate for a generalized developmental history questionnaire to include a question regarding whether a

child has difficulty in producing specific words, such as saying "steposcope" for "stethoscope," etc., or notes any pronunciation errors children make during assessment of classroom tasks. Importantly, many young children make these types of errors (e.g., saying "pasghetti" for "spaghetti"), but it is the persistence of these errors that is the key to concern for dyslexia.

Figure 1. Decision-making tree for a young child referred for academic difficulty in the classroom. Each question addresses a risk factor associated with dyslexia and ultimately directs the student support team (multitier system of supports [MTSS] or equivalent) to recommended outcomes; SLP = speech-language pathologist; RTI = response to intervention; PA = phonological awareness.



Phonological Skills

An assessment of phonological awareness is essential to fully examine a child's phonological system including a full assessment of speech production error patterns and/or phonological processes. Phonological awareness encompasses multiple skills that reflect an awareness of the sound structure of language, including rhyming, blending, and segmentation tasks (at both syllable and phoneme). There are numerous commercial phonological awareness assessments available to practitioners, but we believe that informal measures of phonological awareness can yield equally useful information about a child's phonological awareness skills. Magnusson and Nauclér (1990) reported that rhyming skills and the ability to identify phonemes were the most important metaphonological skills for a preschool-age child to have, as these skills predicted reading and spelling abilities in first grade. This was true even for children diagnosed with a language disorder, as well as those with severe speech sound disorder. As reported previously, tasks that require phoneme-level sensitivity are particularly problematic for children (and adults) with dyslexia (Pennington et al., 1990; Snowling et al., 1997; Wilson & Lesaux, 2001). Thus, it is important for any assessment of phonological awareness to include tasks that assess phoneme-level sensitivity such as phoneme blending and phoneme segmentation.

Given the phonological underpinnings of dyslexia, it is critical to fully examine the breadth of phonological skills in children who have speech sound disorder. Historically, we have classified children with speech sound disorder into those with articulation or phonological disorders, with the assumption that there are divergent underlying deficits for these populations. That is, articulation disorders are assumed to be the result of a sensorimotor deficit of some kind. By contrast, phonologically based speech sound disorders are assumed to be the result of a deficit in the underlying cognitive phonological representation for the phonemes used in speech production and thus cannot be explained by sensorimotor deficits. Although this distinction has been popular in the field for

some time now, the dichotomization of these disorders may be more difficult to distinguish clinically than previously assumed (Farquharson, 2015). As a result, we suggest a full examination of phonological skills in all children with speech sound disorder, regardless of suspected origin, to ascertain the functioning of the underlying phonological system.

Importantly, when assessing phonological awareness in children with speech sound disorder, it is critical to include receptive measures of phonological awareness in the assessment to prevent the interference of the child's speech sound production errors from masking true phonological awareness skills. A child who has multiple phonological process patterns, such as consonant cluster reduction or fronting, may not be able to verbally demonstrate the breadth of his or her phonological awareness skills if he or she is required to respond verbally. For example, the child may be asked to produce a word with the same beginning sound as "spoon." The child may respond with /tar/. In this case, it is unknown whether the child intended to say /star/, which would be correct, or if the child intended another target such as /kar/ or /tar/, both of which would be incorrect. Instead, the child may be shown three pictures (e.g., pig, ball, star) and asked to point to the picture that begins with the same sound as "spoon." This example demonstrates the complex nature of assessing phonological awareness in children with speech sound disorder. When a child's speech production errors are not accounted for in scoring, children's phonological awareness skills may be underestimated. Thus, SLPs should be mindful of the child's speech production error patterns when scoring expressive phonological awareness measures.

Given that children with dyslexia, regardless of speech sound disorder, have difficulty producing words of increasing length and complexity, we recommend incorporating multisyllabic word production and/or nonword repetition to assess speech production. Such a measure will also allow for an examination of phonological memory and phonological encoding skills, which are often weak in children with dyslexia. Assessment tools that are used for differential diagnosis of children with childhood apraxia of speech often include subtests of multisyllabic word production. Indeed, the speech errors among those with dyslexia can appear similar to those evidenced by individuals with childhood apraxia of speech (Peter et al., 2017). Likewise, performance on a nonword repetition task provides insight into phonological processing and phonological encoding for increasingly complex words. Children with weak phonological systems produce more errors repeating nonwords than their typically developing peers (Melby-Lervåg & Lervåg, 2012; Munson et al., 2005).

Importantly, we recommend the assessment of phonological processing skills both when the child is initially assessed for services and when being discharged from speech services. That is, even if a child's speech production errors have fully corrected, there may be continuing deficits in broader phonological skills, such as phonological awareness. Therefore, a measure of phonological awareness is also recommended as part of exit testing. This does not mean, necessarily, that a child with poor phonological awareness should remain on the caseload of an SLP; rather, it means that the SLP has an important role on the literacy team to advise other team members for risk of dyslexia (ASHA, 2001).

Additional Considerations

It is within the scope of practice of the SLP to also investigate a child's word-reading skills directly. Again, commercial measures are useful for determining a child's word reading ability in relation to age- and grade-matched peers, but age-appropriate informal measures of word reading also provide important insight into a child's decoding abilities. By having a child read during a therapy activity, the SLP may gather informal data regarding a child's word-reading skill. For example, is the child using strategies that are successful? Does it seem that weak decoding or low levels of fluency are impacting the child's reading comprehension? It may be the case that a child acquires compensatory strategies that aid in the development of a sight word vocabulary (e.g., words such as "said" and "the"), which does not require systematic decoding. Thus, an assessment that more deeply probes a child's ability to use decoding strategies to read nonwords (e.g., fape, kneet) is critical to

measure a child's ability to apply phonics rules outside of any linguistic context. Lastly, because phonological skills through reading contribute to vocabulary acquisition, children with dyslexia often exhibit mild deficits in vocabulary. As such, a standardized vocabulary measure may be a prudent addition to a comprehensive assessment battery. In the Appendix, we provide a sample assessment checklist that may be used to evaluate a child similar to our initial case study, Ben. Please note that any commercial assessment tool mentioned is simply provided as an example of an appropriate option, but clinicians are encouraged to use the assessment tools available to them.

Once a child is identified as having dyslexia, the involvement of the SLP continues to be necessary and critical. For children who are receiving speech therapy services for a speech sound disorder and/or language impairment, the SLP should incorporate phonological awareness activities into therapy and take opportunities to incorporate orthography into treatment whenever possible (Gillon, 2005; Nation, Angell, & Castles, 2007; Saletta, Goffman, & Hogan, 2016; Sutherland & Gillon, 2007). Baron et al. (2018) found that including orthography during a word-learning task with children with dyslexia facilitated learning of novel words. This suggests that, despite a word reading deficit, children with dyslexia can still benefit from including orthography when targeting speech and language learning. Even if the SLP is not providing direct services to a child with dyslexia, he or she continues to play a role in supporting language development in that child (see Figure 1). Children with dyslexia are at risk for low vocabulary because of limited access to language through text (Duff et al., 2015; Stanovich, 1986). Thus, SLPs play an important role in educating parents and teachers about facilitating language growth in multiple language areas. The SLP may consult with the classroom teacher regarding ways to adapt classroom curricula to ensure children with dyslexia are able to access information in ways beyond text only (e.g., access to audiobooks, use of text-to-speech technology). Furthermore, SLPs play an important role in helping parents understand ways to maximize the home literacy environment to promote language growth, such as reading aloud with their children to introduce and teach new vocabulary (Petrill, Logan, Sawyer, & Justice, 2014; Tambyraja, Schmitt, Farquharson, & Justice, 2017).

Conclusion

In this article, we have explicated the role of speech production deficits in children with dyslexia in children with and without speech sound disorder. Long term, a deep understanding of speech production skills in children with dyslexia has the potential to drive the development of targeted intervention strategies that will best help protect children against the impact of dyslexia and/or speech sound disorder on their academic, psychosocial, and even vocational outcomes (Carroll & Iles, 2006; Hitchcock, Harel, & Byun, 2015; McCormack, McLeod, McAllister, & Harrison, 2009; Snowling et al., 2007). SLPs possess unique and in-depth knowledge of the subsystems of language, including phonology, morphology, syntax, and semantics, and this knowledge may be used to either directly or indirectly assist in the assessment and treatment of children with dyslexia. It is not uncommon for SLPs to feel underprepared or unsupported in their desire to support children with dyslexia in their settings (Fallon & Katz, 2011; Katz, Maag, Fallon, Blenkarn, & Smith, 2010). Resources such as this special issue on dyslexia are designed to help bridge that gap to help SLPs implement effective practices for improved identification of children with dyslexia. We refer the reader to ASHA's Roles and Responsibilities of SLPs in Schools (ASHA, 2001) and other publications for further clinical recommendations for SLPs in this domain (Kamhi, Allen, & Catts, 2001).

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