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The Different Faces of Reading Disabilities:

Evidence from Case Studies

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Abstract: Children with language or phonological disorders, including those with motor speech disorders such as Childhood Apraxia of Speech (CAS), are all at risk for reading disorders. Other children who have neither known risk factors nor prior linguistic or learning difficulties have reading disorders nonetheless. Few studies have focused on specific differences in the reading profiles of children from these varied groups. These issues are explored in two case studies that highlight the differences between phonological dyslexia and literacy-related deficits that result from other conditions. The results show core differences between the two children's profiles, with the seemingly more impaired child demonstrating strengths in some relevant sub-skills in comparison to the otherwise higher-functioning girl. We stress the importance of identification and classification of reading disorders in order to provide appropriate remediation and improve chances in achieving literacy.
Key words: Childhood Apraxia Of Speech; Phonological Dyslexia; Reading Deficits; Phonological Awareness; Phonological Memory; Working Memory

INTRODUCTION

The traditional definition of dyslexia focuses on differences in reading proficiency in comparison to overall cognitive and linguistic skills (Lyon, Shaywitz & Shaywitz, 2003). However, as researchers delve more deeply into reading disorders, this definition may not hold. Moreover, readers' profiles may show many similarities at a surface level, despite different underlying profiles of reading pre-requisite skills, i.e., phonological awareness (PA), vocabulary, verbal working memory, and overall language skills (e.g., semantics and morphosyntax). Despite decades of research there are still uncertainties as to the characteristics, the subtypes, and even the most appropriate labels for the reading deficits exhibited by the subgroup of children with a history of speech and language disorders. However, these children are attending public schools and it is the obligation of educators to identify their deficits and provide support at the remedial and instructional levels. A specific challenge for educators is to recognize that individuals who have difficulty acquiring reading skills may fall into different categories such as reading deficits due to underlying language and motor-speech disorders versus reading deficits due to phonological dyslexia. The difficulty of classifying reading deficits is exacerbated by the fact that

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children with speech and language disorders and children with phonological dyslexia may demonstrate similar reading profiles despite different underlying deficits (Joanisse, Manis, Keating & Seidenberg, 2000; Catts, Adolf, & Ellis Weismer, 2006, Tunmer & Greaney, 2010). Identifying the psycholinguistic factors that may lead to reading failure holds important theoretical and clinical implications: Is dyslexia truly a distinct diagnosis from other reading disorders? Does the profile of reading disability as a secondary diagnosis differ from that of reading disability as a primary diagnosis? Can remediation for speech-language deficits that includes attention to metaphonological skills change the reading profile of the disabled reader?

Several models have been proposed to explain reading development and disorders. Most theories of reading acquisition posit a stage-like progression (Ehri, 1999), beginning with visual word recognition without understanding of grapheme-phoneme relationships (pre-alphabetic stage). Gradually, children acquire certain aspects of PA, reach automaticity in applying grapheme-phoneme knowledge, and finally combine these abilities with recognition of larger orthographic representations for efficient reading.

From a neurocgnitive perspective, the dual-route cascading model of reading (Coltheart et al., 2001; Coltheart, 2006) considers both sub-lexical and lexical routes for word recognition. The sub-lexical route applies grapheme-phoneme mappings to read nonwords and unfamiliar words. The lexical route maps visual forms onto established orthographic representations for reading familiar “sight” words. Children with disorders may not acquire access to both routes at the usual pace or in the typical manner.

Cognitive-linguistic approaches have resulted in a componential model of text comprehension. This construct, described by Gough & Tunmer (1986) as “the Simple View of Reading,” is considered to be a well-defined and time-tested view of contributory factors. Reading comprehension, according to the Simple View, is in part dependent upon ‘code-related’ skills (important for decoding) and in part on ‘language-related’ skills (related to listening comprehension). Both parts can be further broken down into important identifiable factors. ‘Code-related’ skills (Kamhi, 2009) draw on initial phonological representations as the basis of future decoding and of the ability to transfer information from the phonemic level into orthographic units. These skills include PA, phonological memory, and working memory (WM) capacity, as parts of verbal working memory (VWM). PA has been given the most attention by researchers (Goswami & Bryant 1990; Muter, Hulme, Snowling, & Taylor, 1998; Nation & Hulme, 1997; Hoien, Lundberg, Stanovich & Bjaalid 1995). The relationship of WM to reading, particularly to reading comprehension, has also been a topic of intense research (Cain, Oakhill, & Lemmon, 2004). Results suggest that WM influences reading comprehension independent of decoding (Oakhill, Cain, & Bryant, 2003; Swanson, Howard, & Saez, 2006).

Foundational oral language skills such as the lexicon and knowledge of morphosyntax facilitate reading comprehension as ‘language-related’ skills. The interdependence of language-related and code-related skills is seen in their association with PA. PA is highly abstract, representing conscious awareness of smaller linguistic units (syllables, onsets, rimes, phonemes) (Snowling et al., 2000). It has been shown to be grounded in strong vocabulary (Walley, Metsala, & Garlock, 2003; Dickinson, McCabe, Anastasopoulos, Peisner-Feinberg, & Poe, 2003). Typical language developing children show this relationship between vocabulary and PA early on (Silven, Niemi, & Voeten, 2002), with resulting advantages in reading and spelling acquisition (Stackhouse & Wells, 1997; Catts & Kamhi, 1999). Children who experience difficulty performing PA tasks may have less refined phonological representations (Raitano, Pennington, Tunick, Boada, & Shriberg, 2004) with less phonological information stored in the lexicon (Metsala, 1999). WM and phonological memory (PM) are also strongly linked to the development of and performance on PA tasks (Hulme, Snowling, Caravolas, & Carroll, 2005; Yopp, 1998; Oakhill & Kyle, 2000), as well as having substantial influences on vocabulary development (Baddeley, 2003; Gathercole, 2006). In addition, there appears to be an association between speech perception and production skills and the development of PA (Mann & Fay, 2007). Difficulty forming, storing, or accessing specific phonological representations may result in a smaller lexicon as well as vice versa. Thus, reading is dependent upon both ‘code-related skills’ and ‘language-related skills’ and the absence of one may impede the development of the other (Storch & Whitehurst, 2002).

Children with speech and language disorders are more likely to struggle with literacy. Such disorders include specific language impairment (SLI) as well as childhood apraxia of speech (CAS). Numerous studies report reading deficits among children with CAS (Snowling & Stackhouse, 1983; Lewis, Hansen, Iyengar, & Taylor, 2004). The same is true for children with SLI, who may show deficits in underlying code-related skills similar to those of children with developmental phonological dyslexia. Researchers, clinicians, and educators have struggled to find exclusionary criteria that will discriminate between children with dyslexia and children with different underlying deficits who may demonstrate similar reading profiles (Joanisse et al., 2000). Recent research does support a distinction between SLI and dyslexia as different diagnoses, despite some overlapping symptoms. Results have emphasized the roles of semantic and grammatical skills in reading disabilities associated with an SLI profile (Bishop & Snowling, 2004; Catts et al., 2006). In contrast, core difficulties in dyslexia are seen within code-related skills, i.e., severe deficits in the area of phonological processing (Frith, 1997). The inference is that it is important to identify the differences in reading profiles in children with dyslexia and children with other forms of speech and language disorders, as it will lead to different remedial strategies.

There is a paucity of research studies comparing children with phonological processing disorders that affect linguistic development from an early age to those whose phonological processing disorders are not identified until the literacy years. Establishing and distinguishing between the psycholinguistic profiles of children with primary speech disorders, including CAS in particular, and children with developmental dyslexia is an important area of research with strong educational implications.

Childhood Apraxia of Speech (CAS) is a motor speech disorder characterized by impaired on-line programming and planning of speech movements without significant muscle weakness or muscle tone differences (Ozanne, 2005; Velleman & Strand, 1994; Velleman, 2003), resulting in articulatory sequencing difficulties, vowel deviations, and inconsistent speech errors in word repetition. Children with CAS represent a very heterogeneous group: not all of them exhibit the same symptoms of the disorder, nor do they exhibit the same symptoms over time (Shriberg et al., 2003). However, there are commonalities in the profiles of deficits in children with CAS including restricted phonemic inventories; reduced perception and production of vowels (Maassen, Groenen & Crul 2003), syllables (Marquardt, Sussman, Snow & Jacks, 2002), rhymes (Marion, Sussman, & Marquardt, 1993), and phoneme sequences – especially in nonwords (Bridgeman & Snowling, 1988); and impaired expressive language. Children with CAS are at high risk for reading disorders (Lewis et al., 2004; Moriarty & Gillon, 2006; Stackhouse & Snowling, 1992). Furthermore, there is evidence that, due to imprecise phonological representations, children with CAS may be at higher risk for written language deficits than children with other speech and language disorders (McNell, Gillon, & Dodd, 2009). Research also shows that, despite years of treatment, children with CAS typically continue to show deficits in phonological awareness skills and therefore have poorer reading outcomes than children with other speech and language disorders (Lewis et al., 2004; Stackhouse & Snowling, 1992). The nature and sources of these ongoing phonological awareness difficulties have not been adequately studied. Thus, it is unknown whether they result solely from poor motor foundations – yielding incomplete or variable phonological representations – or whether cognitive foundations, such as phonological memory and working memory capacity, are also impaired in this population.

Dyslexia is the most widely investigated written language disorder. One of the prominent characteristics of dyslexia is a specific deficit in word recognition despite adequate instruction and intact general cognitive abilities (Lyon, Shaywitz & Shaywitz, 2003). In parallel with the literature on acquired reading disabilities (Coltheart et al., 1980), children with specific reading disabilities have been classified into two types: phonological dyslexia (PD) and surface dyslexia (SD). PD is associated with deficits in sub-lexical processing, resulting in specific problems reading nonwords and regular words, with more success in reading common irregular "sight" words (Rack et al., 1992; Snowling, 1980). This profile is typically associated with broader phonological impairments (Frith, 1997). For instance, children with developmental PD consistently show difficulties in PA tasks such as phoneme counting and deletion (Bruck, 1992; Stanovich et al., 1997, Snowling, 2000). In addition, individuals with PD have difficulty with rapid automatized naming (RAN) and non-word repetition tasks, signifying deficits in phonological memory storage and retrieval (Tijms, 2004).

To date, no studies of the roles of PM or WM capacity in the literacy outcomes of children with CAS have been reported. Nor have the literacy outcomes of children with CAS been compared to those of children with phonological dyslexia, despite the assumption of a common underlying phonological processing difficulty. The present study addresses the patterns of reading development of two children with similar reading comprehension skills, but radically different psycholinguistic profiles. One child, with a diagnosis of CAS and borderline IQ, achieved an age-appropriate reading status after years of remediation. The other was missed by her school system as a clear case of phonological dyslexia because of her above average IQ, language, and certain reading skills. We maintain that despite similar performance on reading comprehension, there are core differences in the children's word recognition and grapheme-phoneme mapping abilities, despite the fact that both exhibit phonological processing deficits. We address the ensuing reading abilities in relationship to other skills requiring phonological coding, such as PA, RAN and VWM (phonological memory and working memory capacity) as well as language skills. We also discuss the subjects' performance in terms of stage models of reading acquisition (Ehri, 1999) and in the context of the dual-route cascading model of reading (Coltheart et al., 2001; Colheart, 2006). Finally, we address the role of deficits in sub-lexical processing as it relates to reading comprehension in the Simple View of Reading (Gough and Tunmer, 1986).

METHOD

PARTICIPANTS

The participants were two girls with similar performance levels in reading comprehension. L (Note: we use random letter for our participants) was 11;4 and a 5th grader in a mainstream private school setting without support services at the time of her comprehensive literacy assessment. She had diagnoses of borderline cognitive skills and CAS, by specialists in childhood motor speech disorders (including the second author). She had been in speech-language therapy, with a focus on speech production, receptive and expressive language, attention, preliteracy and literacy skills since the age of 27 months. Consistent with common patterns of phonological processes seen in children with CAS, L showed specific deficits in sound production (i.e., /r/ and /s/), cluster reduction as well as vowel diviations (Shriberg, Aram & Kwiatkowski, 1997a; Velleman, 2003). Between the ages of 6;4 and 11;6 targeted intervention was provided at the University of Massachusetts – Amherst Center for Language, Speech and Hearing (CLSH).

K was 9;4 at the time of her first comprehensive literacy assessment and finishing 3rd grade in a suburban public school setting in the vicinity of the University of Massachusetts-Amherst . She had no history of previous speech or language deficits and indeed was performing above the average level in all academic areas, including reading. However, her family noticed that while K was able to successfully spell the words in classroom quizzes, she demonstrated significant difficulty with spontaneous (i.e., unstudied) spelling to dictation and in writing samples. She was administered parts of the *Phonological Awareness Test* (*PAT*, Robertson & Salter, 1997) in school by a speech-language pathologist at the request of the family. The test was not administered in its entirety, but the results of the administered subtests fell between above average (75th %ile) and borderline low average (19th %ile); thus K was deemed not to qualify for support services in school. A formal evaluation of K's oral and written language skills was conducted six months later at the CLSH as requested by her mother.

PROCEDURES

The test battery administered to both girls within the CLSH included assessments in the areas of general language skills (receptive and expressive), skills that are essential for the development of sub-lexical processing, such as RAN/RAS, PM (as tapped by non-word repetition), WM, and PA, as well as literacy skills, including single word reading (regular, irregular, and nonwords), word spelling (regular/irregular) in isolation and in sentence contexts, and finally, reading fluency and reading comprehension. All tests were administered as per standardized instructions, most in quiet clinical settings at the CLSH over two sessions, one week apart. For the *Nonword Repetition Task,* each word was read by the examiner at a regular pace and the responses were recorded manually and on a SONY ICD-MX20 digital voice recorder for transcription and scoring to ensure intra-judge accuracy in recording the responses manually and to conduct intra-judge reliability measurements. For the sentence presentation, as part of the CLPT, the examiner read each sentence at a steady pace, and followed each sentences with the phrase "Is this true or not?" The answers were hand recorded on a special form (see Gaulin & Campbell, 1994) for scoring, as well as recorded on the same digital voice recorder. Two masters level speech-language pathology students served as independent raters and rescored the tasks. Inter-rater reliability using Cohen's kappa coefficient was .87, representing "almost perfect" inter- rater reliability (Landis & Koch, 1977) In a few cases individual tests were administered in other settings (e.g., at school) or had been previously given. These exceptions will be noted in the Results section.

MATERIALS

All the tests administered during the evaluation were standardized measures commonly used for language, literacy and phonological processes assessments. The phonological memory and working memory capacity were assessed by experimental measures that have been consistently used for research purposes.

General Language Skills

The *Peabody Picture Vocabulary Test-III* (*PPVT-III,* Dunn & Dunn, 2001) was used to assess vocabulary knowledge in the receptive modality. This widely used standardized measure of vocabulary assessment is also highly correlated with verbal IQ.

The *Clinical Evaluation of Language Fundamentals – Fourth Edition (CELF-4*; Secord, Semel & Wiig, 2003) was used as a standardized measure of general language skills. Four subtests from the CELF-4, that measure core areas of language abilities in the Receptive and Expressive domains were administered: *Concepts and Directions* measures the ability to follow oral directions of increased procedural and linguistic complexity**;** *Word Classes* that assess client's knowledge of semantic relationship between the words; *Recalling Sentences* to measure the ability to repeat sentences increasing in syntactic complexity; and *Formulated Sentences*, that require the use of certain words and phrases in full sentences. Scoring is based on the correctness of syntactic structures and the meaningful use of the words/phrases presented.

Verbal Working Memory

Two experimental measures were used to assess verbal working memory (VWM). The *Nonsense Word Repetition Task* (NWRT, Montgomery, 1995) was administered as a measure of phonological memory (PM). The task uses 12 nonsense words each at four word lengths, ranging from monosyllabic (e.g., "dep") to four-syllables (e.g., "shedubicate") and requires the client to repeat each nonsense word immediately after hearing it. The scores are total number correct and percent correct.

The *Competing Language Processing Task* (*CLPT*; Gaulin & Campbell, 1994) is an oral adaptation of a written span measure developed by Daneman and Carpenter (1980) to assess WM capacity. The CLPT consists of 4 practice and 42 test sentences and yields scores for comprehension (True/False) and Recall, i.e. ability to repeat the last words in the set of just heard sentences after verifying their truthfulness. The test sentences sets range in length from one to six sentences, with two sets at each length. The highest number of correctly recalled words is an index of WM capacity. The scoring system is the same as for the NWRT.

Sub-lexical Processing

The *Rapid Automatized Naming and Rapid Alternating Stimulus Test* (RAN/RAS, Wolf & Denckla, 2005) assesses the ability to quickly and accurately name rows of letters, colors and numbers (RAN), rows of letters mixed with numbers, and rows of letters mixed with both numbers and colors (RAS). The RAN tests utilize five high frequency stimulus items randomly repeated 10 times and arranged in five rows for a total of 50 items. The automaticity of the retrieval process is considered to be a strong predictor of successful reading.

The *Lindamood Auditory Conceptualization Test – Third Edition* (*LAC-3*, Lindamood and Lindamood, 2004) is a highly abstract measure of sub-lexical processing and requires the examinee to associate colored blocks to sounds and then manipulate the blocks. Stimuli are nonwords only and thus do not invoke lexical processing. There are five subtests: *Phoneme Identification,, Tracking Phonemes, Counting Syllables*, *Tracking Syllables* and finally *Tracking Syllables and Phonemes.* The test requires substantial visual attention and memory resources. It utilizes raw scores for individual subtests that are combined to form a standard score and age/grade equivalents.

The *Phonological Awareness Test (PAT*; Robertson & Salter, 1997) contains three sections – *Phonemes, Graphemes* and *Decoding*. Only the *Phonemes* section actually assesses PA. Two subtests from the *Phonemes* section were administered: *Isolation*, to assess the ability to identify phonemes in the initial, medial or final positions of one-to-three syllable words, and *Blending*, that asks the client to blend individual syllables or phonemes into words (e.g., /bas-ket/). (Note: PAT was administered to L a year prior to her final evaluation, at the age of 10;6, and administered to K in her school setting).

The *Sound-Symbol Knowledge* subtest of the *Word Identification and Spelling Test* (*WIST*; Wilson and Felton, 2004) was administered to further assess sub-lexical processing. This subtest contains two parts. *Letter Sounds* assesses the ability to provide all possible sounds for individual consonants, consonant digraphs, long and short vowels, r-controlled vowels, diphthongs, and letter combinations associated with common sound patterns *(*e.g*., -olt, -sion).*

The *Graphemes* section of the PAT utilizes the same process and asks the client to produce phonemes corresponding to various graphemes.

Reading at the one-word level

The *Decoding* section of the *PAT* asks the client to read aloud non-words containing various syllable structures and sound combinations.

The *Pseudo Word* portion of the *WIST*'s *Sound-Symbol Knowledge* subtest has 50 non-words that require application of letter-sound correspondence within regular word patterns.

The *Word Identification* section of the *WIST* assesses the client's ability to read regular words (100 total) and irregular (sight) words (30 total), drawn from the Dolch (1948) list of high frequency words and fall within the top 300 most frequent words in English print (Kucera & Francis, 1967).

Spelling at the one-word and sentence level

The *Regular Words* and *Irregular (sight) Words* section of the *WIST* was used to assess spelling abilities through dictating 100 regular and 30 irregular words

The *Sentence Spelling* subtest of the *WADE* focuses on spelling sentences with simple syntactic structures.

Reading accuracy, fluency and comprehension

The Gray Oral Reading Test – Fourth Edition (*GORT-4*; Weiderholt & Bryant, 2001) was administered to both participants to assess their ability to read short passages aloud and answer comprehension questions. Measures include accuracy (number of deviations from the text), rate (time to read each passage), fluency (combined score for accuracy and rate), and comprehension (number of questions answered correctly). Fluency and comprehension scores are added to create an Oral Reading Quotient.

RESULTS

The results are presented in comparative format, despite the fact that our participants were of different ages, 11;4 and 9;4, at the time of the testing, to highlight specific underlying differences between the psycholinguistic and reading profiles of the two subjects. A review of previously published case studies supports our format; e.g., Valdois, Bosse, Ans, Carbonnel, Zorman, David, & Pellat (2003) compared the performance of two adolescent boys exhibiting different subtypes of dyslexia whose ages were 14;8 and 13;1, roughly the same age difference as in our participants.

Language Skills, PM and WM capacity (CELF-4, PPVT-III, NWRT, CLPT). The results of the general language skills tests and the tasks assessing PM and working memory capacity are delineated in Table 1. As the results show, there were striking differences in the general language skills and both aspects of VWM between the two participants.

Table 1: Language and Verbal Working Memory Skills

Area of Assessment	Subtests	SS	%ile
		K / L	**K / L**
Language			
CELF-4	Core Language	132 / 69	98 / 2
	Recept. Lang. (C&D, WC-R)*	134 / 70	99 / 2
	Expres. Lang. (RS, FS, WC-E)	136 / 69	99 / 2
	Language Mem. (C&D, RS, FS)	129 / 66	97 / 1
PPVT-III			93/ 32
Verbal Working Memory**			
PM (48 items)		47 / 38	98 / 79
WM (42 items : comprehension and recall)			
	True/Falls (Comp)	42 /42	100 / 100
	Recall (capacity)	26 / 14	62 / 33

* RS=Recalling Sentences; C&D=Concepts and Direction; FS=Formulated Sentences; WC=Word Classes

** PM=Phonological memory; WM =Working memory capacity; both tasks use number correct and percent correct scores.

K's language scores fell well above the average range, while L's were all either within or well below average range. Neither one demonstrated any one skill area that was strikingly different from the others. That is, L's scores were all within the below average range while K scored consistently above average in all aspects of grammatical knowledge, auditory comprehension and memory. Vocabulary skills were, in a way, a relative strength for L, as she scored in the 32nd percentile, while K's score was in the 93rd percentile. In contrast, L's total language score fell in the 5th percentile whereas K scored in the 98th percentile overall.

The results of the NWR task again showed differences in the performance of both participants with K repeating 98% and L 79% of the 48 nonwords presented to them ($\chi^2(1)=6.57$, $p=.01$). In agreement with the suggested deficits in PM among children with CAS, L missed 8 items at the 4-syllable length, while K missed only 1.

The results of the CLPT tasks, as measures of basic comprehension and WM capacity, showed that neither participant had any difficulty verifying the truthfulness of the statements. In contrast, they achieved very different scores on the recall part of the test, with K recalling 26 out of the 42 administered items (62%), and L recalling only 14/42 items (33%). The difference was significant ($\chi^2(1)=5.78$, $p=.01$), indicating K's better WM capacity. The results of this test placed K in the 12-years-of-age range, while L scored within the 6-year-old range according to the norms provided by Gaulin & Campbell (1994). Moreover, L's WM capacity was significantly below the mean percent of retrieved words by a group of sixteen 10-12 year-old children with SLI (M=57.9, SD=10.93; range 29-67, $\chi^2(15)=9.4$, $p=.001$) (Zaretsky, 2003).

Literacy Predictors (Sub-lexical Processing)

The results of LAC, as a measure of PA, revealed specific deficits for both participants, with a lower and more varied performance by L. Both girls did relatively well on identifying isolated phonemes, but started to have some difficulties with tracking phonemes, counting and tracking syllables, and especially tracking both phonemes and syllables, as this taps a combination of PA and working memory skills. The last subtest was not administered to L because her score on the previous subtest was lower than 4.

The results of the RAN/RAS provided another clear contrast between the two girls. Significant differences were observed on the RAN part of the test, with K scoring much higher on all subtests (t=3.44, df=10, p=.0006). None of the RAN parts differ significantly for both participants, but naming colors was equally difficult for both, and reflected the highest score for L and the lowest score for K.

The results of the *Phonemes* section of the PAT subtests again showed the differences between our participants. The PAT had been administered to K at her school prior to the evaluation at the CLSH as an attempt to show that she did not have deficits in PA and therefore did not have a reading disability. Indeed, her combined score for the *Isolation* and *Blending* subtests fell within the 75th percentile. However, within the *Isolation* subtest she scored in the 12th percentile for identifying phonemes in initial position, 11th in the medial and 19th in the final position, which represent results well below the average range. She met with much higher success on the *Blending* subtest, scoring in the 56th and 75th percentiles for blending syllables and phonemes. Thus, the combined score was quite misleading. For the same subtests, L scored in the severely below average range, i.e., in the 5th, 4th, and 1st percentiles for *Isolation* of initial, medial and final phonemes respectively, and in the 2nd and 3rd percentile respectively for blending syllables and phonemes. Thus, in contrast to K, L found isolation slightly less difficult than blending; holding the individual sounds in memory while performing an operation on them (blending them) was extremely challenging for her. The differences between the scores obtained by the participants were significant (t=2.42, df=8, p=.04). Table 2 represents the participants' scores for this part of the assessment.

Table 2: Sub-lexical Processes as Literacy Predictors

Area of Assessment	Subtests	RS	SS	%ile	AE	GE
		K / L	**K / L**	**K / L**	**K / L**	**K / L**
LAC	Isolated Phonemes	16 /15				
	Tracking Phonemes	10 / 5				
	Counting Syllables	10 / 8				
	Tracking Syllables	7 /<4				
	Tracking Syll. & Phon.	1 / (1)*				
	Sum of Raw Scores	**44 / 38**	**108/83**	**70/13**	**10;9/8;9**	**5-7/2-3**
RAN/RAS	Objects		107 /88	68 / 21	10;9 / 8;6	
	Colors		91 / 91	27 / 27	7;6 / 9;3	
	Numbers		100 / 83	50 / 13	9;0 / 7;6	
	Letters		94 / 87	35 / 19	8;0 / 7;9	
	Letters and Numbers (RAS)		111 / 88	77 / 21	11;0 / 8;6	
	Letters, Numbers, Colors		93 / 81	32 / 10	8;0 / 7;3	
PAT	**Isolation (phonemes)**					
	Initial		87 / 71	2 / 5		
	Medial		81 / 66	11 / 4		
	Final		91 /<50	19 / 1		
	Blending					
	Syllables		104 / 50	56 / 2		
	Phonemes		111 / 62	75 / 3		
	Combined Score		**112 / 51**	**75 / 3**		

Knowledge of Grapheme-phoneme Correspondence

The knowledge of graphemes and their corresponding sounds was assessed through the *Grapheme* section of the *PAT* and the *Letter Sounds* subtest of the *WIST*. The results again highlighted the differences in the abilities of our two participants to provide appropriate sounds for all types of graphemes. While both participants achieved scores well below average for letter-sound knowledge on the PAT (K's total score fell within the 13th percentile and L's score fell within the 4th percentile), they showed different patterns of deficits. Both participants had difficulty providing sounds for consonants, but L had a more difficult time with long and short vowel sounds, which is a characteristic of CAS. Both participants had better success with vowel digraphs. There was a surprising difference in their abilities to provide sounds for r-controlled vowels with L scoring significantly higher (L – 23rd percentile vs. K – 3rd percentile), perhaps due to her long-term phonological intervention focusing on /r/ and /r/ sound combinations.

The results of the *WIST* showed a similar pattern of performance; although it fell below average, K's score was higher than that of L. The difference between their ability to accurately provide sounds corresponding to vowels, vowel digraphs and diphthongs was significant ($\chi^2(3)=3.67$, $p=.01$), with K providing more sounds than L. Both girls' scores fell well below their age and grade levels: K at a kindergarten level (<6;1), while L was above kindergarten level.

Reading at the One-word Level

The decoding skills are measured by both the *PAT* and the *WIST*. The latter provides a much broader picture through assessment of reading both regular and irregular words, as well as regular non-words. Regular and irregular words are part of the *Word Identification* subtest, while non-word reading falls within the *Sound-Symbol Knowledge* subtest. Full information on the girls' *WIST* performance (i.e., Word Identification, Spelling and Sound-Symbol Knowledge) can be found in Figure 1.

Reading at the one-word level highlighted striking differences between our participants. L's score fell at the 65th percentile, with an age-equivalent of 12;7, above her chronological age. In contrast, K's score was in the 14th percentile, with an age-equivalence of below 6;1, three years below her chronological age. L was reading at a grade 6 functioning level for both regular and irregular words, but K read regular words below the 2nd grade level and irregular words at the 6th grade level. Non-word reading proved to be difficult for both participants, putting them both below a grade 2 equivalence. Thus, only reading regular words significantly differentiated our participants ($\chi^2(2)=4.89$, $p=<.0001$).

Spelling at the One-word and Sentence Levels

Results of the spelling tasks on the *WIST* (regular and irregular words) and the *WADE* (sentence level) again yielded an advantage for L: L's total spelling score placed her in the 19th percentile (9;7 age-equivalent) with the ability to spell regular words at the 3rd grade level and familiar irregular words at the 6th grade level. K's total spelling score, in contrast, placed her in the 9th percentile (6;1 age equivalent) with spelling of regular words below the 2nd grade level and spelling of irregular words at the 2nd grade level. The differences between the two participants' spelling scores (regular and familiar irregular words) were significant ($\chi^2(2)=7.63$, $p=<.0001$ and $\chi^2(2)=3.59$, $p=.003$ respectively).

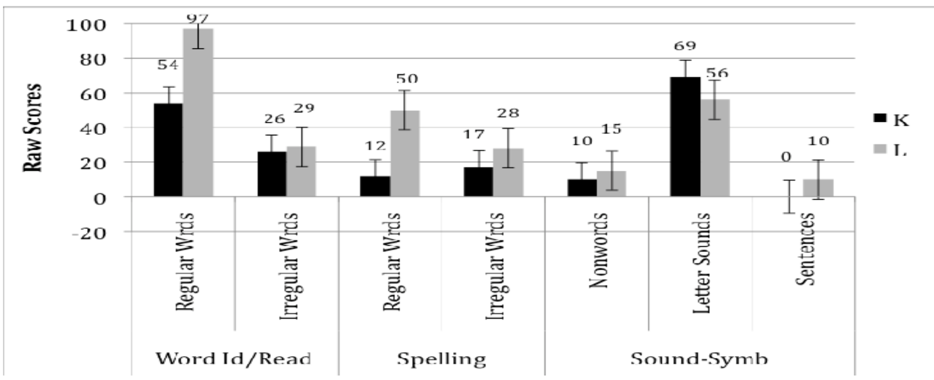


Figure 1: WIST Reading, Spelling, and Sentence Writing (WADE)

Notes: We provide the raw scores, i.e., actual number of correct items out of total items administered (see test description). The difference between the participants' regular word reading scores was significant at p=<.0001; Regular and irregular word spelling scores were significantly different at p=<.0001 and p=.003, respectively; The total difference in letter sound knowledge is due to significantly better identification of vowels by K (p=.01)

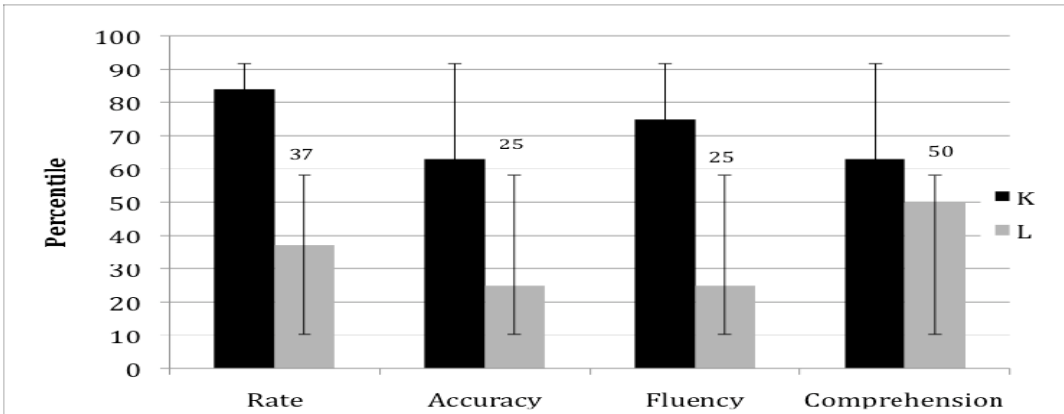
L was able to correctly spell 10 out of 25 sentences (i.e., 40% of total items), while K could not spell any sentences without mistakes and the administration of the *Sentence Spelling* subtest was discontinued. (Figure 1.)

Reading Accuracy, Fluency and Comprehension

The GORT-4 provided a picture of the reading skills of both participants. L's scores for accuracy, rate and fluency fell at the 25th, 37th and 25th percentiles respectively (all within -1 SD below the mean, with M=10 and SD=3). However, L achieved a comprehension score at the 50th percentile. (See Figure 2.) The deviations from print included mostly omissions of function words (e.g., *then*, *an*), mis-readings and substitutions of words (e.g. *southeast* for *southwest*, *pernanent* for *permanent*). Her age-equivalency was stable across all components of the test (10;0 – 11;0 years of age).

K, on the other hand, scored above average for every measure of the test, with rate at the 84th percentile, accuracy at the 63rd percentile, fluency at the 75th percentile and comprehension at the 63rd percentile (Figure 2). Her age-equivalencies were between 9;3 and 10;6 years old. Her mistakes were substitutions of function words (e.g. *out* for *from*, *back* for *down)*, additions and changes of inflections (e.g., plural *-s*, 3rd person singular *–s*, *-ed* for *-ing*), and word substitutions (e.g., *bared* for *barbed*, *area* for *era*, *relieve* for *believe*), signifying inattention to word structure at the orthographic level.

The differences between the two participants' mean percentiles obtained on all subparts of the GORT-4, illustrated in Figure 2, were significant (t=4.71, df=6, p=.003).



Note: A significant difference was observed between the means of all scores at p=.003.

Figure 2: Reading rate, accuracy, fluency and comprehension (GORT-4)

Spelling Analysis

To get a better understanding of the two girls' ability to utilize phoneme-grapheme mapping skills for spelling words with regular patterns, we analyzed the words that were spelled to dictation by both participants. L's spelling patterns were consistent with her diagnosis of CAS; spelling mistakes mirrored past and present speech production deficits, specifically with the production of nasals, liquids, and vowels. She also exhibited sequencing problems. L was more aware of word beginnings, resulting in 100 % accuracy on initial sounds. She also relied on familiar word patterns, applying a 'whole word' strategy. For example, '*compliment*' was spelled as '*complaint*', with sensitivity to the word edges only.

As L was receiving ongoing speech-language therapy that targeted sound production, phoneme-grapheme mapping and syllabification, treated skills were evident: L was able to identify the sound patterns and applied strict phoneme-grapheme conversion, rather than word-specific rules, for spelling these patterns. For example, she spelled *'location'* as *'lokashing'*, and *'decide'* as *'decied'*.

Most of the mistakes made by K in spelling were omissions and substitutions of consonant and vowel sounds. She was successful at spelling CVC and CCVC words, e.g., *sun, box, glass*, and spelled correctly one of the words with a welded sound pattern (i.e., *wild).* However, she often omitted the second consonant from consonant clusters, even with complex blends, such as the word *strong* spelled as *srong.* She spelled *inspect* as *insped,* demonstrating difficulties in applying strict grapheme-phoneme mapping. For short vowel representations, K often drew on her good knowledge of taught spelling patterns, e.g., diphthongs and digraphs. For example, she spelled *led* as *lead*. We compared K's spelling to that of a group of typically-developing children assessed in the beginning and the end of the kindergarten year who had been given a list of twelve monosyllabic words with the same phonological structure found in the monosyllabic words in the *WIST* spelling subtest. The kindergartners made the same mistakes in cluster representations as K at the beginning of the year, but by the end of the year showed a great deal of awareness of the sub-lexical structure of the words, producing correct consonant cluster strings in initial and final position (T1 vs. T2 initial position - $t=-3.34$, $df=90$, $p= .001$; T1 vs. T2 final position – $t=-2.2$, $df=90$, $p=.03$). At the end of the kindergarten year, these typically-developing children were able to correctly write 9.5 out of 12 words on the average, while K was only able to spell a total of 12 regular words out of 100 correctly.

Next, we looked at the participants' sensitivity to syllabic and onset-rime units versus whole-word activation, which is part of spelling development (Perry & Ziegler, 2004). K appeared to approach spelling on a whole word level, i.e., activating the whole word, or lexical level, rather than applying strict phoneme-grapheme mapping. She often retained the lengths of the words but changed the graphemes. Omissions and substitutions were also evident. The analysis of the spelling produced by L revealed a pattern of letter sequencing mistakes, perhaps reflecting the motor planning difficulties consistent with her diagnosis of CAS.

However, L's overall ability to spell was much better. (Refer to Figure 1)

DISCUSSION

The aim of the present study was to highlight the differences between phonological dyslexia and literacy deficits that may result from other phonologically-related conditions. The differences between the participants' profiles, with the seemingly more impaired child nonetheless demonstrating strengths in some relevant subskills in comparison to the otherwise higher-functioning girl, showcase the difficulties faced by educators in recognizing and classifying children with reading deficits. We also examine the efficacy of treatment in the acquisition of reading skills even for severe cases of speech and language disorders, as well as the danger that may lay ahead for a child who may be denied remedial strategies based on high performance at a surface level.

L presented with many risk factors absent from K's profile: decreased cognition and a severe, persistent motor speech disorder, as well as decreased skills in language, working memory capacity, rapid naming, and phonological awareness, especially on tasks requiring mental manipulation of phonemes. K, on the other hand, had clear signs of developmental phonological dyslexia (PD): She had pronounced difficulty reading nonwords and severe discrepancies in reading regular vs. irregular words. Her success in reading regular words was limited mainly to words that have high frequency in elementary school texts. Her additional weaknesses in PA and word spelling are also consistent with developmental PD. As in other cases of developmental PD (e.g., Valdois et al., 2003, Tree and Key, 2006), difficulties with PA may be a contributing factor to K's impaired sub-lexical processing, despite the fact that her VWM skills (which support PA) were intact. K's weaknesses in PA were apparent on sound isolation within words and following the movement of sounds in syllables. However, K did not show deficits in phonological short-term memory or working memory capacity (Baddeley, 2003), which commonly underlies reading and spelling disorders. An association between phonological memory, working memory capacity, and reading acquisition is seen in acquiring letter-sound mapping rules as well as storing individual sound segments for future blending during phonological recoding (Alloway et al., 2004). For example, L's deficits in working memory capacity were obvious and likely contributed to her difficulties with blending, as seen in the results of the PAT subtests.

With respect to the deficits in phonological memory among individuals with developmental PD, it has been proposed that poor readers may resort to visual strategies rather than use phonological coding (Stainbrink and Klatte, 2008). Moreover, Stainbrink and Klatte (2008) suggest that the problem may not be deficits in phonological memory, but rather inefficient use of it and reliance on long-term memory. In the present case it appears that good VWM skills support K's oral language but do not support the level of sound processing required for decoding. Her weaknesses in processing word-level phonemic information make it difficult to learn grapheme-phoneme mapping rules, thus her struggle on tasks requiring sound provision for individual letters and numerous errors attempting to read aloud simple VC and CVC nonwords. L., on the other hand, is a clear case of an individual with substantial deficits in VWM, resulting in poor support for language and PA. However, her relatively strong performance on PM tasks, due to years of remediation, may be a factor in her relatively good acquisition of grapheme-phoneme mapping. Even with deficits in providing sounds for individual letters, she still is able to apply the grapheme-phoneme mapping rules required for reading regular and irregular words. L's deficits in reading nonwords are consistent with the diagnosis of CAS.

The literature on developmental PD also suggests that RAN should be impaired as one component of sub-lexical processing deficits. Szenkovits and Ramus (2005) argued that deficits in sub-lexical processing could be at the level of input or output, with RAN falling within the output continuum of this hypothesis. However, these authors contend that lexical and sub-lexical output deficits imply possible deficits at either level. In addition, RAN relies on memory (Wolf, et al., 2000): RAN assesses the phonological loop of working memory, while RAS is more likely dependent on working memory capacity (Amtmann, et al., 2007). Taken together, these constraints may explain the timing deficit in dyslexic children, as it requires sustained coordination of orthographic-phonological processing. Therefore, the discrepancies observed in K's performance on RAN/RAS, i.e. better retrieval of lexical items, may suggest several interpretations. First, it may be an example of faulty sub-lexical processing in the presence of well-developed lexical skills, suggesting a possible dissociation between lexical and sub-lexical processing at the input and output levels. postulates second possibility is that her strong VWM skills at this time support an appropriate retrieval speed. Given the same assumptions (Amtmann, et al., 2007; Szenkovits & Ramus, 2005; Wolf, et al., 2000), we can explain L's performance on RAN/RAS based on weak sub-lexical and lexical processing.

Both children demonstrated difficulty in sub-lexical processing and subsequent deficits in the application of grapheme-phoneme mapping, as seen in their reading and spelling patterns. Their ability to read high-frequency irregular words (i.e., "sight words") was comparable with respect to raw scores; a relative strength for both. Yet, L's reading of regular words was at a similar level as her reading of sight words. With regards to the K's scores on the *Word Identification* section, it was apparent that she was able to utilize stored orthographic representations to identify familiar sight words. Given that many regular words are not high frequency, she had to rely on faulty sub-lexical processing in an attempt to read them, but showed a remarkable ability to recognize words that are regularly taught in school. L, on the other hand, was able not only to identify sight words, but also apply grapheme-phoneme correspondence to read regular words with a much better success than K, despite her deficits in matching individual phonemes to graphemes.

With regard to stage models of reading development (e.g., Ehri, 1999), K's deficiencies in sub-lexical processing point to arrested development in the alphabetic stage. However, K's adequate sight word reading suggests that success in the alphabetic stage may not be essential for building up orthographic representations for very common words. Similarly, K's spelling of sight words, though limited, was superior to her spelling of less familiar regular words. This again implies that orthographic representations can develop despite quite limited sub-lexical processing. Although L's spelling of sight words was better than her spelling of regular words, the difference between L's performance on these two tasks was much smaller than the chasm between K's ability to spell sight words versus regular words. This pattern of performance suggests that L is progressing through the alphabetic stage, albeit at a slower rate than is expected at her chronological age.

Our analyses of our participants' performance also supports the two-route model for reading/spelling: K's performance on sub-lexical tasks, which rely on grapheme-phoneme mappings, differed strikingly from her performance on lexical tasks, which require direct activation of stored, whole-word orthographic representations. This is consistent with the dual-route cascading model of reading (Coltheart et al., 2001) i.e., with the notion that spelling can employ either sub-lexical strategies or activate whole-word orthographic representations (Perry and Ziegler, 2004). In the case of K, weak sub-lexical skills were compensated by the application of strong lexical strategies. Apparently, at this point in her literacy development, these strategies were sufficient to allow for success in reading/spelling familiar words. With a great deal of exposure to these words, she had been able to build up whole-word orthographic representations. In the case of L, there is direct evidence of availability of both routs, lexical and sub-lexical, despite a rather weak activation of both.

The orthographic representations of common words along with strengths in oral language allowed K to demonstrate above average reading fluency and reading comprehension (results of the *GORT-4).* In terms of the "Simple View of Reading" (Gough and Tunmer, 1986), K combined adequate decoding (via lexical strategies) with strong listening comprehension to support reading comprehension, so K's deficiencies in sub-lexical processing had not hampered decoding enough to impact reading comprehension. It seems quite evident that K's strong listening comprehension contributed greatly to her success in comprehending what she read. Her exceptional receptive vocabulary skills (*PPVT-III*) and general language knowledge (*CELF-4*), combined with strong VWM, boosted K's ability to understand text at and above grade level. Although she produced some omissions, misreading of inflections and substitutions of function words, her strong vocabulary and understanding of grammatical structures allowed her to process the meaning of passages and answer comprehension questions. Therefore, her oral language skills proved to be beneficial in compensating for her weak sub-lexical processing to extract sufficient information from the text for comprehension. Moreover, her performance supports the argument that dyslexia should be defined and identified based on decoding deficits (Tunmer and Chapman, 2007).

In contrast, L's performance on the GORT-4 was markedly low average across accuracy, fluency, and rate measures, but her reading comprehension was, surprisingly, at the average level for her age. This suggests that both lexical and sub-lexical routes for reading were available to L, even if neither one was specifically strong.

Despite strong cognitive skills and her lack of deficits in any of the linguistic areas, K was significantly more impaired for reading and spelling regular words (and non-words) than for reading sight words. Thus, she seemed to have a highly specific, severe deficit in the learning of phoneme-grapheme correspondence rules. As such, she is an example of a child who meets the standard definition of phonological dyslexia (Frith, 1997; Harm & Seidenberg, 1999, as cited in Joanisse et al., 2000).

Bishop & Snowling (2004) stated that, "children with severe selective reading impairment in the context of otherwise normal oral language are likely to have a different neurobiological….profile, and also a different outcome, from those who have more global impairments affecting all aspects of oral as well as written language" (p. 879; see also Morris et al., 1998). This statement is also consistent with the proposed idea of the "narrow view of reading" (Kamhi, 2009), which separates word recognition/decoding skills from reading comprehension. It follows that skilled reading is based on the ability to represent "phonological information segmentally… " and that impairment in phonological segmentation "interferes with the acquisition of word recognition skill, but it especially affects the capacity to use knowledge of spelling–sound correspondence" (Joanisse et al., 2000, p. 51).

It should be pointed out that K's limitations in sub-lexical processing are very likely to impede reading comprehension once she faces more advanced texts containing less familiar key words critical to understanding the meanings of passages: she will likely struggle to identify words not commonly found in her spoken vocabulary for which she has not had enough exposure to build up orthographic representations. Although visual skills were not assessed directly, K's ability to utilize the knowledge of complex graphemes, such as digraphs, trigraphs, and diphthongs, that are taught explicitly supports the argument that strong memory and visual skills can be used to compensate for other deficits. It is also in agreement with the Valdois et al. (2003) finding that visual deficits are not part of the profile of PD.

The case of L, a child with CAS and cognitive deficits, on the other hand, serves as a good example of how focused, intensive treatment can allow a student with many risk factors to achieve reading skills within the appropriate age and grade levels despite continuous struggles in the areas of language, phonological awareness, retrieval and working memory. Previous research suggested that targeting specific areas of deficits in children with speech and language disorders, such as metaphonologically-based training, produced a trend for longer lasting effects on the development of PA in severely phonologically impaired children than traditional articulation therapy alone (Hesketh, Adams, Nightingale & Hall, 2000). Gillon's (2002) PA intervention for children with phonological disorders resulted in sustainable gains on word recognition and phoneme-grapheme mapping, including spelling of nonwords. Outcomes of intervention that simultaneously targeted speech production, PA and decoding skills in children with CAS were positive (Moriarty & Gillon, 2006). PA awareness intervention also improves PM in children with speech-language impairment: post-treatment nonword repetition and PA tasks were not statistically different from those of untreated TD groups (van Kleeck, Gilla, & Hoffman, 2006). The case of L provides additional support for these previously-reported research outcomes, specifically in view of her relatively strong performance on NWRT.

CONCLUSIONS

The main purpose of this comparison of two reading-impaired children is to caution against the tendency of some evaluators to pay attention to scores (behaviors) and ignore the particular cognitive origins of the behavior that produced those scores. This trend was particularly evident in the school's interpretation of K's performance on the PAT, which did not identify a profile of developmental phonological dyslexia. It is true that diagnostically K's overall performance is confusing, because she applies alternative cognitive abilities to solve the problems presented by the test. This results in subtle disturbances at a surface level. However, a systematic analysis of K's poor results at the sub-lexical level, in comparison to her good performance on tasks that require integrative resources, suggested that the better scores were arrived at by means of compensatory abilities, built on her clear cognitive strengths and therefore masking her true underlying deficits in specialized reading-related cognitive components. Literature in reading acquisition points to some common patterns of deficit in young struggling readers, although they may not be quite as extreme as those of K (Roberts and Scott, 2006; Catts, et al, 2006). Marinac & Harper (2009) cautioned professionals working in the field of education about identifying developmental disabilities by default, when classic diagnostic symptoms for a specific disorder are not readily available. In the case of K, even subtle specific reading deficits should not have gone undiagnosed and untreated in an educational setting because they can greatly affect the likelihood of success in later reading and spelling development.

LIMITATIONS OF THIS STUDY

The limitation of this study is clearly in the number of participants. It is an important goal for future research to extend this study to more participants with similar profiles of reading but with different etiologies, assessing them using measures of language, PA, verbal working memory, automaticity of retrieval, phoneme-grapheme mapping and decoding and encoding skills. Until a set of comprehensive profiles of disabled readers with different patterns of both risk factors and cognitive-linguistic deficits is established, educators will be challenged to determine underlying causes, identify appropriate remediation strategies, and advocate for the full range of children with reading deficits.

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