Journal of Child Psychology and Psychiatry 45:4 (2004), pp 821–835

Pre-literacy skills of subgroups of children with speech sound disorders

Nancy A. Raitano,[1] Bruce F. Pennington,[1] Rachel A. Tunick,[1] Richard Boada,[1] and Lawrence D. Shriberg[2]

[1]University of Denver, USA; [2]University Wisconsin – Madison, USA

Background: The existing literature has conflicting findings about the literacy outcome of children with speech sound disorders (SSD), which may be due to the heterogeneity within SSD. Previous studies have documented that two important dimensions of heterogeneity are the presence of a comorbid language impairment (LI) and the persistence of SSD, but these factors have not been examined separately. **Method:** The current study used a 2×2 MANOVA design (with follow-up MANCOVAs) to examine how a comorbid language impairment (LI) and the persistence of SSD relate to pre-literacy skills in a sample of 5- to 6-year-old children with SSD. **Results:** Significant main effects for persistent SSD and LI were obtained, such that each factor was associated with worse performance on pre-literacy tasks, particularly those assessing phonological awareness (even with nonverbal IQ covaried). In addition, even SSD children with normalized speech without LI were found to have deficits on phonological awareness tasks relative to control participants. **Conclusions:** These results suggest that a history of SSD and comorbid LI are strong correlates of pre-literacy deficits. **Keywords:** Child speech sound disorders, language impairment, pre-literacy skills, reading disability, dyslexia. **Abbreviations:** SSD = child speech sound disorder; RD = reading disability; LI = language impairment.

Over the past several decades, numerous studies have demonstrated a relation between developmental dyslexia or reading disability (RD) and child speech sound disorders (SSD). Longitudinal studies have documented that children with RD have elevated rates of SSD and other oral language deficits as preschoolers (Scarborough, 1990; Gallagher, Frith, & Snowling, 2000; Pennington & Lefly, 2001), and, conversely, that children with SSD are at increased risk for later RD (Catts, 1993; Bishop & Adams, 1990; Snowling, Bishop, & Stothard, 2000). Research examining the relation between speech, language, and reading development has demonstrated that approximately 25% of children who develop RD have a history of SSD (Scarborough, 1990; Gallagher et al., 2000; Pennington & Lefly, 2001), and 30% of children with SSD later develop RD (Lewis, 1996). Thus, the overlap between these two disorders is greater than would be expected by chance, but is clearly not complete. One possible explanation for this heightened comorbidity may be that both disorders are due to problems in the development of phonological representations, a well-documented core deficit of developmental dyslexia (Liberman, 1973; Liberman, Shankweiler, Fischer, & Carter, 1974; Stanovich, 1988; Fowler, 1991; Snowling & Hulme, 1994; Swan & Goswami, 1997). If this is the case, why is the overlap only partial? Why do some children with SSD escape later RD, and why do some children with RD have histories of normal speech development? One reason may be the heterogeneity of SSD.

The current study examined associations among speech, language, and pre-literacy skills in a sample of 5- to 6-year-old children with idiopathic SSD. Children with SSD are delayed in the acquisition of developmentally appropriate speech sounds, resulting in reduced speech intelligibility. Idiopathic SSD is not due to known etiological factors such as cleft palate or hearing loss and is limited to disorders of speech sound production (i.e., not stuttering). Childhood speech sound disorders have been labeled and classified in a number of different ways, including *articulation disorder*, and the somewhat confusing term for literacy researchers, *phonological disorder*. The latter classification term was introduced in the mid-1990s and is retained in the current text revision of the *Diagnostic and Statistical Manual of the American Psychiatric Association* (APA, 2000). For the purposes of this paper, we use the umbrella term, SSD, as proposed by Shriberg (2002), which includes various subtypes, including *Speech Delay* (*SD*), which is reserved for children who currently make developmentally inappropriate speech errors.

This study investigated how heterogeneity within SSD is associated with pre-literacy skills by focusing on two dimensions of SSD heterogeneity – the persistence of speech production errors and the presence of a comorbid language impairment (LI). SSD persistence was examined, because it was hypothesized that if expressive phonology indexes phonological representations, then children with more persistent SSD may have more impaired phonological representations, and thus, perform more poorly on pre-literacy tasks. LI status was examined, because SSD and LI are frequently comorbid in children, particularly during preschool years (Shriberg & Austin,

Published by Blackwell Publishing, 9600 Garsington Road, Oxford OX4 2DQ, UK and 350 Main Street, Malden, MA 02148, USA

1998; Shriberg, Tomblin, & McSweeny, 1999), and because children with SSD and LI have been reported to have more impaired literacy outcomes than those with SSD but no language impairment (Catts, 1993; Bishop & Adams, 1990). Although previous research suggests that both the persistence of SSD and LI are risk factors for reading difficulties, these two dimensions of SSD symptomatology have not been clearly distinguished in previous studies, making their individual contributions to literacy outcome difficult to disentangle. By examining their individual contributions within the same sample, we hoped to augment research on subtypes of SSD and their possible relation to literacy outcome.

Before exploring possible SSD subtypes, it is important to address briefly what is known about the development of speech in young children. Learning to comprehend and produce speech in infancy is an extraordinarily difficult task that involves imitating articulatory gestures that are not readily observable and mapping these gestures onto acoustic features of the speech signal. These articulatory gestures and acoustic features are mapped onto developing phonological representations, which in turn are mapped onto meaning. Connectionist accounts (e.g., Plaut & Kello, 1999) of this dynamic developmental process implicate both bottom-up and top-down influences on the development of phonological representations, such that the accuracy of articulatory gestures hones phonological representations and the growth of vocabulary necessitates more segmented phonological representations, respectively. Such an account of the development of phonological representations has implications for the study of subtypes of SSD. Though putative subtypes of SSD exist (e.g., Shriberg, 1994), little has been done to validate SSD subtypes externally (L.D. Shriberg, personal communication, May 5, 2003). By examining the relation among persistent speech difficulties, language impairment status, and phonological representations, we may be able to augment our understanding of SSD subtypes and their relation to literacy outcome, which may help to validate externally SSD subtypes. This, in turn, has implications for understanding the development of typical and atypical reading in children.

Competing theories exist about how linguistic deficits contribute to the development of RD. Some theorists have proposed primarily phonological theories of the disorder (e.g., Jorm, 1979), while others have proposed primarily semantic-syntactic theories (e.g., Smith, 1973). While evidence exists to support both the phonological and semantic-syntactic contributions to RD, single deficit theories, such as those of Jorm and Smith, lack an interactive framework. Bishop (1997) proposes a multiple deficit, interactive view of the development of reading and language skills similar to the connectionist view of the development of phonological representations proposed by Plaut and Kello (1999). This view rejects a purely bottom-up, modular approach to the development of reading (and language) and supports an interactive approach where bottom-up and top-down influences play roles in the development of typical and atypical reading. According to this view, it is likely that both phonological skills and semantic-syntactic skills contribute to and interact in the development of typical and atypical reading. Thus, if persistent speech production errors index an underlying problem in the development of phonological representations, then SSD persistence should be a risk factor for the development of pre-literacy skills, and if the multiple deficit, interactive view of reading development is correct, then the presence of LI in children with SSD should be an additional risk factor for the development of pre-literacy skills. In what follows, previous research on the literacy outcomes of children with SSD will be reviewed, with a focus on these two risk factors.

Literacy outcomes of children with SSD

Many follow-up and prospective studies have been conducted on the literacy outcomes of children with SSD. Early follow-up studies demonstrated that individuals with a history of SSD have heightened rates of reading difficulties compared to control participants (e.g., Hall & Tomblin, 1978; Levi, Cappozi, Fabrizi, & Sechi, 1982). Although these follow-up studies demonstrated that having SSD places participants at heightened risk for literacy difficulties, the precision of early SSD diagnoses (including the presence or absence of a comorbid language impairment) in such studies is questionable. Consequently, several prospective, longitudinal studies have been conducted on this question and have confirmed that children with SSD have heightened rates of reading difficulties compared to control participants (e.g., Bishop & Adams, 1990; Catts, 1993; Bird, Bishop, & Freeman, 1995; Snowling et al., 2000). However, the findings of these studies also suggest that SSD is a heterogeneous disorder that results in somewhat varied literacy outcomes. The two aspects of SSD heterogeneity that have been examined in relation to reading outcome are the presence of comorbid LI and the persistence of speech and language disorder symptomatology. Literature on these two aspects of SSD heterogeneity will be summarized in the sections that follow.

The contributions of language impairment status to literacy outcome

The majority of studies on the literacy outcomes of children with SSD have provided convincing evidence that children with SSD and concomitant LI (SSD+LI) have higher rates of literacy difficulties than children with isolated SSD. Catts (1993) examined the literacy outcomes of first and second grade children with a history of SSD and/or LI. On

average, the group of children with SSD (with or without LI) performed worse on reading measures than control participants. However, a closer examination of the data indicated that only children with LI or SSD+LI (in contrast to children with isolated SSD) performed worse than control participants on reading measures, suggesting that LI status was an important predictor of reading outcome. Consistent with these findings, follow-up studies of a sample of children with speech and language disorders, first studied by Bishop and Edmundson (1987), indicated that children with LI-only and SSD+LI were more impaired on literacy measures than children with isolated SSD (Bishop & Adams, 1990; Snowling et al., 2000). In fact, similar to the results of Catts (1993), these studies reported that children with isolated SSD did not differ significantly from control participants on literacy measures. Several other studies have also yielded similar findings indicating that children with LI or SSD+LI have more severe literacy or phonological processing difficulties than children with isolated SSD (Larrivee & Catts, 1999; Leitao, Hogben, & Fletcher, 1997).

In contrast to the above findings, Bird et al. (1995) reported that in their sample of children with SSD and SSD+LI, the children with both isolated SSD and concomitant SSD+LI were impaired relative to control participants on literacy and phonological processing measures. In addition, the severity of the literacy and phonological processing deficits of children with SSD and SSD+LI did not differ significantly, suggesting that at least a subgroup of children with isolated SSD tended to have later literacy difficulties. Other research on children with isolated SSD has provided evidence that these children have a phonological processing deficit similar to that found in children with RD (Leitao et al., 1997; Bird & Bishop, 1992; Snowling et al., 2000), suggesting that children with isolated SSD may be at heightened risk for later literacy difficulties as well.

These divergent findings on the literacy outcomes and phonological processing skills of children with isolated SSD motivate two questions: is isolated SSD a heterogeneous disorder, and if so, what aspects of its phenotype are associated with literacy outcome? One aspect of SSD that may relate to literacy outcome, as discussed next, is the persistence of speech production errors.

The contributions of speech disorder persistence to literacy outcome

Research suggests that 75% of children with idiopathic speech sound disorders (i.e., SSD) have normalized speech by the age of 6 (Shriberg, 1994). Therefore, comparing children with persistent versus normalized (i.e., speech skills that no longer fall within the clinical range) SSD may be informative for understanding differences in the literacy outcomes of children with SSD. Specifically, if expressive phonological deficits (i.e., speech production errors) relate to the quality of underlying phonological representations, then it would follow that children with more persistent speech difficulties may be at heightened risk for RD, a disorder that is characterized by a core deficit in phonological representations (Liberman, 1973; Liberman et al., 1974; Stanovich, 1998; Fowler, 1991; Snowling & Hulme, 1994; Swan & Goswami, 1997).

Bishop and colleagues have examined how the persistence of speech and language disorders first identified at age 4 relates to literacy outcome at two time points – ages 8.5 and 15. Unlike the present study, these studies focused on the persistence of speech *and* language impairments and not on the persistence of speech production errors only (i.e., SSD persistence). In the first reading outcome study in this series, Bishop and Adams (1990) reported that eight-and-a-half-year-old children with a history of non-persistent speech/language difficulties (the 'good outcome' group in Bishop and Edmundson, 1987) tended to have better literacy outcomes than children with persistent speech/language difficulties (the 'poor outcome group'). In this study, Bishop and Adams reported that children with a non-persistent speech/language disorder performed similarly to control participants on literacy measures, suggesting that the persistence of a child's speech/language disorder may relate to the presence or severity of literacy difficulties. Snowling et al. (2000) examined this cohort of children with speech/language disorders at age 15. In contrast to Bishop and Adams (1990), at this later age, children with both persistent (poor outcome) and non-persistent (good outcome) speech/language difficulties had poorer reading skills than control participants at age 15, suggesting an increase in literacy difficulties as these children aged. However, it is not clear how many of the children with persistent speech/language difficulties had persistent speech production difficulties (i.e., persistent SSD). That is, the data reported for this study do not provide individual information associating literacy outcomes with the persistence of speech production errors versus the presence/persistence of language impairment.

In sum, the results of studies focusing on the literacy outcome of children with language impairments and persistent speech/language difficulties suggest that both LI status and the persistence of speech/language difficulties are important predictors of the presence or severity of literacy impairments in children (at least at certain ages). To date, however, the separate (and joint effects) of LI status and SSD persistence have not been examined in the same sample. Thus, the goal of the present study was to examine associations among LI status, SSD persistence, and pre-literacy skills in a crossed 2×2 ANOVA design. Specifically, this study focused on the following interrelated questions:

1. Do children with SSD (with or without LI), taken as a whole group, perform worse than age-matched control participants on pre-literacy measures, including tasks assessing phonological awareness, rapid serial naming, and letter knowledge?
2. Will LI status and SSD persistence each relate to poorer performance on pre-literacy tasks (i.e., will there be main effects of language impairment status and SSD persistence on pre-literacy measures) and will their effects be interactive?
3. Finally, do children with SSD but without either risk factor (persistent SSD or LI) have deficits in pre-literacy skills relative to age-matched control participants?

Method

Participants

One hundred forty-two 5- to 6-year-old children participated in this study. These children were part of a larger longitudinal and genetic linkage study conducted at the University of Denver examining the relation between SSD and RD. Two groups of children were recruited for this study: children with a history of childhood speech sound disorders (SSD: $n = 101$) and children with no history of speech or language disorder (Controls: $n = 41$).

Children with SSD were recruited through public and private schools in metropolitan Denver and through radio and newspaper advertisements. Children recruited through the schools were first identified by special education personnel or through mass mailings to parents of all kindergarten children in four cooperating school districts. For children recruited by special education personnel, letters were sent to their families describing the study and requesting their child's participation. Parents indicated their interest and willingness to be contacted about the study by returning a postcard with necessary contact information or by calling the study directly. For children recruited through mass school mailings or advertisements, parents were asked to contact the study directly by phone or email.

As a first gate for participation, all parents of children with SSD were given a brief phone screen: (a) to determine if a participant had current or previous SSD, (b) to determine if the child was receiving or had received speech/language therapy, (c) to rule out exclusionary medical conditions (listed below), and (d) to ensure that the child had always resided in a monolingual English-speaking home.

Control participants were recruited from the same school districts as children identified as having SSD, through newspaper advertisements, and through the University of Denver Psychology department developmental participant pool. The University of Denver developmental participant pool includes typically developing children who were recruited to be future research participants shortly after birth through a mailing distributed to new parents at Denver metropolitan area hospitals. For control participants recruited through the schools, a mailing was sent out to all children in the kindergarten of cooperating school districts asking for the participation of 5- to 6-year-old children with no history of speech or language difficulties. Parents indicated their interest in participating by contacting the study by phone or email. Similarly, newspaper advertisements were completed requesting the participation of 5- to 6-year-old children with no history of speech or language difficulties. Again, parents indicated their interest in participating by contacting the study by phone or email. Lastly, families of children recruited through the Psychology department developmental participant pool were contacted directly by study personnel.

Control participants were recruited to be similar in age, gender, and ethnicity to the SSD probands. They were also required to have always resided in monolingual English-speaking homes. As a first gate for participation, control participants were required to have (a) no history of a speech or language disorder, (b) no history of receiving speech-language therapy, and (c) none of the exclusionary medical conditions listed below. As a second gate for participation, control children were given an articulation test to assess their speech status directly. To be included in the study, control participants must have received a score above the 30th percentile on a standardized articulation test and made only developmentally appropriate speech sound errors.

Table 1 summarizes the demographic information for children in the SSD and control groups. Children in the SSD and control groups did not differ on age, gender, or ethnicity. However, the SSD and control groups did differ significantly on nonverbal IQ (NIQ; $t\,(139) = 3.82$, $p < .001$), with SSD children, on average, scoring lower than control participants. A lower nonverbal IQ has been found in many other SSD and LI study samples (e.g. Johnston, 1994), and is consistent with findings indicating that verbal and nonverbal cognitive skills are moderately related ($r = .66$ for Verbal IQ and Performance IQ on the WISC-III, Wechsler, 1991; $r = .51$–$.59$ for the Verbal and Spatial/Non-Verbal Reasoning Clusters on the DAS, Elliott, 1990; and $r = .55$ between NIQ and TOLD language composite in the current sample) and findings indicating that SSD is comorbid with LI (Shriberg & Austin, 1998).

Although attempts were made to match control and SSD participants on socioeconomic status, these groups differed on their Hollingshead Four Factor Index score (Hollingshead, 1975), such that control participants came from families with higher Hollingshead Index scores than SSD participant families ($t\,(133) = 2.08$, $p < .05$). One interpretation of this finding is that because both SSD and LI are familial (Neils & Aram, 1986; Beitchman, Hood, & Inglis, 1990; Lewis, Ekelman, & Aram, 1989), parents of children with SSD are likely to have lower levels of educational and occupational achievement, given their higher risk for language (and possibly reading) difficulties. Because both nonverbal IQ and Hollingshead ratings are closely related to the SSD phenotype, we decided not to covary them for each of the primary analyses. However, they were covaried in follow-up analyses to examine their potential association with pre-literacy skills.

Following initial comparisons between the SSD group as a whole and the control group, children in the SSD group were divided into subgroups using a 2×2 ANOVA design. Children were classified according to their SSD persistence status (persistent SSD or Normalized) and

Table 1 Means (standard deviations) for demographic variables for Control and SSD groups

	Control vs. Whole SSD		Within SSD Group				
	Control	Whole SSD	SSD Normalized No LI	SSD Persistent No LI	SSD Normalized LI	SSD Persistent LI	2 × 2 ANOVA Findings
N	41	101	49	29	13	10	–
Age in Months	67.51 (5.18)	67.53 (6.71)	68.08 (6.52)	65.52 (5.71)	70.62 (7.89)	66.70 (7.75)	Main effect persistence
DAS NIQSS[1]	111.58 (8.52)***	103.89 (11.67)	107.50 (9.14)	105.92 (11.37)	91.87 (11.29)	96.33 (11.58)	Main effect LI
Mother Years Ed[2]	16.20 (2.83)	15.64 (2.51)	16.23 (2.47)	15.31 (2.71)	15.31 (2.32)	14.00 (1.23)	n.s.
Father Years Ed[3]	15.98 (2.54)	15.57 (2.47)	16.04 (2.63)	15.00 (2.21)	15.54 (2.50)	14.75 (2.12)	n.s
Hollingshead Score	54.43 (9.08)*	50.47 (10.45)	51.54 (10.36)	49.64 (9.90)	49.04 (11.44)	49.29 (12.89)	n.s.
Male (%)	70.7	59.4	53.1	65.5	69.2	60.0	n.s.
Caucasian (%)	85.4	78.6	85.4	75.9	50.0	88.9	n.s.

* Control vs. SSD Whole Group differences, $p < .05$, *** Control vs. SSD Whole Group differences, $p < .001$.
1: Differential Ability Scales Nonverbal IQ composite.
2: Years of Maternal Education.
3: Years of Paternal Education.

their LI status (concurrent LI or no current LI). Because children were initially recruited for the study based on their SSD status, the number of participants in each of the four groups was not equal. Sample sizes in the four SSD subgroups were as follows: (a) Normalized speech without LI (Norm only; $n = 49$), (b) Persistent SSD without LI (persistent SSD only; $n = 29$), (c) Normalized speech with LI (Norm + LI; $n = 13$), and (d) Persistent SSD with LI (persistent SSD + LI; $n = 10$).

Two metrics were used to dichotomously classify participants' speech (persistent or not) and language (LI or not) status. Speech status was classified as *normal/normalized* or *persistent* using the Speech Disorders Classification System (SDCS), a computerized metric based on the type and frequency of speech production errors in a sample of conversational speech that is narrowly transcribed by research transcribers (Shriberg, 1993; Shriberg, Allen, McSweeny, & Wilson, 2001; Shriberg, Austin, Lewis, McSweeny, & Wilson, 1997a). As described in more detail below, the SDCS classifies a child as having normal/normalized speech or speech delay (SD) based on a set of decision rules developed and cross-validated on several databases (Austin & Shriberg, 1996). Children were classified as having LI if they received a standard score below 81 on at least one composite of a standardized measure of expressive and receptive language skills (consistent with other recent studies of LI, e.g., Tomblin, Records, & Zhang, 1996), as described in more detail below.

In order to assess associations between SSD persistence and LI status to demographic variables, a series of 2 (persistent or normalized) × 2 (LI or not) ANOVAs were completed. Results yielded a main effect of SSD persistence on age (F (1, 89) = 8.37, $p < .01$), such that children with persistent speech production difficulties were younger. Consequently, age was used as a covariate in all pre-literacy analyses. Consistent with recent findings reported by Campbell and colleagues (Campbell et al., 2003), a trend was also evident for SSD persistence and maternal years of education ($p < .1$), with mothers of children with persistent speech difficulties tending to have somewhat lower levels of educational achievement.

These preliminary analyses also yielded a main effect for LI status on nonverbal IQ (F (1, 89) = 14.50, $p < .001$) and a trend for an LI effect on maternal education ($p < .1$), such that children with LI had lower NIQ scores and mothers with somewhat lower levels of educational achievement than those SSD children without LI. Again, such findings were not unexpected, given the familiality of LI and its associations with verbal and nonverbal cognitive abilities. Lastly, there was a trend towards an interaction between SSD persistence and LI status with nonverbal IQ. This trend was driven by the lower nonverbal IQ of the children in the normalized, LI group. No main effect was found for persistence or LI status with ethnicity. However, additional examination of the data revealed that children with normalized speech and comorbid LI tended to be from more diverse ethnic backgrounds.

Measures and procedures

Testing took place at the University of Denver over three sessions lasting two hours each. Examiners were

doctoral students in psychology or advanced undergraduates who were experienced working with young children and administering the test protocol. As described in the following sections, participants' parents completed questionnaires that provided medical and speech-language disorder history as well.

Exclusionary measures

Medical history. Parents completed a detailed medical and developmental history questionnaire that was used to exclude children with (a) a known genetic disorder or syndrome, (b) mental retardation, (c) a pervasive developmental disorder (e.g., autism or Asperger's disorder), (d) significant birth complications, or (e) an acquired brain injury, consistent with our goal of studying idiopathic SSD.

Peripheral hearing. Hearing was assessed using pure-tone audiometry. Participants failing to pass a screening using pure tones at 25 dB HL ISO for 500, 1000, 2000, and 4000 HZ bilaterally were excluded from the study (guidelines set by American Speech-Language Hearing Association, 1990).

Peripheral speech mechanism. An Orofacial Screening Examination was completed to exclude children who had significant impairments in the peripheral speech mechanism that could be accounting for their speech difficulties (e.g., cleft palate or lip).

Nonverbal IQ. Children completed the Matrices and Pattern Construction subtests of the Differential Ability Scales (DAS; Elliot, 1990). T-scores from these two subtests were transformed to standard scores and then averaged to form a Nonverbal IQ Composite Score (NIQSS). Children receiving scores below 70 on this composite were excluded from the study.

Symptom measures

Speech production. Two speech tasks were administered to assess participants' current speech production status: the conversational speech sample used as input to the Speech Disorders Classification System, and the Goldman–Fristoe Test of Articulation (Goldman & Fristoe, 1986), a single word elicitation task.

Conversational speech sample. As described above, the Speech Disorders Classification System (SDCS) is a validated classification instrument used to categorize children (and adults) with speech disorders based on a large corpus of lifespan data of individuals with disordered and normal speech. The conversational speech samples to be coded by the SDCS software were obtained using a Sony TCM-5000EV cassette recorder and matching external microphone following recording and online glossing procedures described in Shriberg (1993). The samples were narrowly transcribed using a diacritic system and computer formatting procedures developed specifically for research on child speech disorders (Shriberg et al., 2001; Shriberg & Kent, 2003).

For the purposes of the present study, given the relatively advanced ages of participants (i.e., 5–6 years), the two disordered SDCS classifications, termed Speech Delay (SD) and Normalized Speech/Speech Delay (NSA/SD, which is intermediate between SD and Normal/Normalized Speech) were combined to form the category of Persistent SSD. Essentially, children classified as SD or NSA/SD by the SDCS are still making age-inappropriate speech sound omissions and substitutions. In contrast, a child classified as having Normal/Normalized Speech may still be making age-appropriate speech sound distortions. In addition to the categorical speech disorder assignments, the software suite provides a continuous measure indexing severity of speech delay termed the Percentage of Consonants Correct – Revised (PCC-R) (Shriberg et al., 1997b). This metric, which codes only articulatory omissions and substitutions as speech errors (i.e., not articulatory distortions), also provides a *z*-score adjusted for children's age and sex (zPCC-R).

Goldman–Fristoe Test of Articulation (GF). The GF is a single word elicitation test that provides a standardized score indexing articulation abilities. Unlike the SDCS, the GF standard score is based on the total number of speech sound production errors a participant makes, including developmentally-appropriate distortion errors. Therefore, the GF is a more liberal measure of SSD persistence.

Language. Five subtests from the Test of Language Development – Primary: Third Edition (TOLD-P:3; Newcomer & Hammill, 1997) were administered to ascertain LI status: the Picture Vocabulary, Oral Vocabulary, Grammatic Understanding, Sentence Imitation, and Grammatic Completion subtests. LI diagnoses were assigned using a modified version of the Epi-SLI system described by Tomblin et al. (1996). Children were classified as having LI if they received a standard score below 81 on one or more composites of the TOLD-P:3. The four composites utilized to assign LI diagnoses were as follows: Expressive Language Composite (includes Oral Vocabulary and Grammatic Completion subtests), Receptive Language Composite (includes Picture Vocabulary and Grammatic Understanding subtests), Semantic Composite (includes Picture and Oral Vocabulary subtests), and Syntactic Composite (includes Grammatic Understanding, Grammatic Completion, and Sentence Imitation subtests). Participants receiving a standard score below 81 on one or more the of TOLD-P:3 composites were classified as LI.

Pre-literacy measures

Phonological awareness. Four measures of phonological awareness were administered.

Rhyme judgment: The Bird and Bishop (1992) rhyme judgment task consists of 5 practice items and 14 test items during which the child must judge which of 4 words rhymes with a target word by pointing to a picture. Target and test words are spoken aloud by the examiner.

Elision: The 20-item Elision subtest of the Comprehensive Test of Phonological Processing (CTOPP;

Wagner, Torgesen, & Rashotte, 1999) requires children to omit speech sounds from stimulus items of varying sizes in order to create a new word. Sound segmentation occurs at the following levels: (a) compound words that must be broken into their component words (e.g., 'popcorn' – omit 'pop'; 2 items), (b) syllables that are parts of words (e.g., 'spider' – omit 'der'; 1 item), and (c) phonemes (e.g., 'bold' – omit 'b'; 17 items). Items are presented in increasing order of difficulty (i.e., requiring finer degrees of phonological segmentation with increasing items), with items requiring phonemic manipulations coming last. Thus, not all participants completed the phonemic items due to early ceilings in their performance.

Blending Words: The 20-item Blending Words subtest of the CTOPP requires children to piece together discrete sound units that make real words when 'blended' together. Each item is presented to the child in a standardized manner via audiotape (e.g., 'What word do these sounds make - t - oi?' Toy). Items required the synthesis of sounds at the syllabic (3 items), demi-syllabic (e.g., onset rimes; 1 item), and phonemic levels (16 items). Again, items were presented in increasing order of difficulty; thus, some participants may not have reached the phonemic items due to early ceilings.

Sound Matching: The 20-item Sound Matching subtest of the CTOPP requires children to indicate which of three words starts or ends with the same phoneme as a target word. Each of the words is pictured in a stimulus book and participants must point to the correct picture to answer each question. Although this task does not involve the manipulation of phonemes, it requires children to attend to initial and final sounds at the phonemic level in order to identify which of the three test words starts or ends with the same phoneme.

Letter Knowledge. A modified version of Treiman's letter knowledge task was used (Treiman, Tincoff, Rodriguez, Mouzaki, & Francis, 1998) to assess participants' knowledge of letter names and sounds. Children in the United States are introduced to letters (informally) in pre-kindergarten programs and begin formal training in letter knowledge in kindergarten. The majority of the children participating in this research had begun kindergarten; however, a few participants completed the test battery before beginning kindergarten. Thus, some individual differences in the amount of letter exposure within the sample existed. However, it is likely that these differences were largely accounted for when age was covaried for pre-literacy analyses. The modified version of Treiman et al.'s (1998) letter task consisted of three parts.

Letter Writing: Participants were asked to write the twenty-six letters of the alphabet in a pre-determined, random order. They received credit for correct responses in either lower or upper case print. The score for this task was the total number of letters written correctly.

Letter Name Knowledge: Participants were shown flash cards with capitalized letters presented in a random order and were asked to name the letter shown (spontaneous naming). If they were unable to spontaneously name the letter, they were then asked to choose which of two letters it was (forced choice). Scores from the spontaneous and forced choice portions of the letter recognition task were combined, with each participant's spontaneous naming score being weighted twice. Spontaneous naming scores were weighted twice in the letter knowledge composite in order to assign greater value to a child's ability to recall a letter name than his/her ability to recognize it.

Letter Sound Knowledge: After participants identified a letter, they were asked what sound it makes (spontaneous naming). If participants could not identify the correct sound, they were asked to choose which of two sounds it made (forced choice). Scores from the spontaneous and forced choice portions of the letter sound knowledge task were combined, with each participant's spontaneous naming score being weighted twice (following the rationale described for scoring the letter naming task).

Rapid Serial Naming (RSN). Scores on the Rapid Color and Object Naming subtests of the CTOPP were the total number of seconds it took the child to name all colors or objects. For all subsequent RSN analyses, reverse scores from the RSN subtests were used in order to be consistent with the manner in which other variables were measured (i.e., so that low scores reflected poor performance).

Results

Prior to conducting the primary analyses, factor analyses were performed to reduce the number of pre-literacy variables to be analyzed. The results of these analyses are presented in the section that follows.

Pre-literacy factor analyses

The nine pre-literacy variables were submitted to a factor analysis with principal components extraction and oblimin rotation. These variables were the scores from the Sound Matching, Blending Words, and Elision subtests of the CTOPP, Bird and Bishop's Rhyming task, the Rapid Color and Object Naming subtests from the CTOPP (reverse scores), and the three letter knowledge tasks.

It was hypothesized that three factors would emerge – phonological awareness, rapid serial naming, and letter knowledge – because theoretical and empirical support exists for these three somewhat separable but related forms of pre-literacy skill (see Scarborough, 1998 for a comprehensive meta-analysis). A clear three-factor solution did emerge, with the three letter knowledge tasks loading on to the first factor, the two rapid serial naming tasks loading onto the second factor, and the Rhyme, Elision, and Blending Words tasks loading on to the third factor. The Sound Matching subtest from the CTOPP cross-loaded onto the first and the third factors. This cross-loading was conceptually coherent with the three-factor solution, because the Sound Matching subtest of the CTOPP appears to tap both knowledge of sound segments in words as well as letter–sound correspondences.

Table 2 Factor structure for pre-literacy variables

	Factor 1 (Letter Knowledge)	Factor 2 (Rapid Serial Naming)	Factor 3 (Phonological Awareness)
Letter Sound Knowledge	**.929**	.108	−.136
Letter Writing	**.887**	.072	.039
Letter Name Knowledge	**.808**	.035	.180
CTOPP Sound Matching	**.516**	−.050	**.460**
CTOPP Rapid Naming–Object	−.082	**.941**	.135
CTOPP Rapid Naming – Color	.203	**.848**	−.095
Bird & Bishop's Rhyme Task	−.104	.372	**.832**
CTOPP Elision	.055	.140	**.756**
CTOPP Blending Words	.370	−.079	.615

The resulting three factors explained 78.8% of the variance in the pre-literacy variables and are summarized in Table 2. For descriptive purposes, we termed Factor 1 *Letter Knowledge (LTR)*. It had an eigenvalue of 5.03 and it explained 55.9% of the variance in the pre-literacy variables. We termed Factor 2 *Rapid Serial Naming (RSN)*. It had an eigenvalue of 1.27 and explained 14.1% of the variance in the pre-literacy variables. Finally, we termed Factor 3 *Phonological Awareness (PA)*. Although the eigenvalue for PA was only .79, it explained 8.8% of the variance in the pre-literacy variables and was conceptually distinct from LTR and RSN. Participants' factor scores from the pre-literacy factor analyses were used as the dependent variables in the group comparisons.

Group comparisons

Symptom measures. Prior to conducting analyses on the pre-literacy factors, group comparisons on symptom variables were completed. Table 3 summarizes these findings. There was converging evidence that children with histories of SSD had continued to have speech production difficulties, because the SSD group had significantly lower scores on the GF and zPCC-R than control participants (t (140) = 12.29, $p < .001$ and t (120) = 7.31, $p < .001$, respectively). In addition, the control group outperformed the SSD group on all language measures (all t's > 6.5, all p's < .001). These findings are consistent with the high degree of comorbidity between SD and LI reviewed previously.

Then analyses were completed to examine the association between SSD persistence and LI status on symptom measures within the SSD group. A 2 × 2 MANCOVA with age covaried yielded a significant main effect for SSD persistence on the two highly correlated ($r = -.85$, $p < .001$) speech measures, the GF (F (1, 89) = 40.60, $p < .001$) and the conversational speech-based, zPCC-R, (F(1,89) = 43.90, $p < .001$). Of greater interest was the finding that

Table 3 Means (standard deviations) for symptom variables for Control and SSD groups

	Control vs. Whole SSD		Within SSD Group			
	Control	Whole SSD	SSD Normalized No LI	SSD Persistent No LI	SSD Normalized LI	SSD Persistent LI	2 × 2 ANOVA Findings
Goldman–Fristoe							
Standard score	109.27 (12.52)***	83.38 (10.88)	89.45 (9.42)	75.31 (7.61)	86.85 (7.02)	72.50 (6.13)	Main effect persistence
Errors	3.61 (2.91)***	19.78 (12.71)	12.63 (7.15)	30.03 (12.87)	14.00 (6.04)	32.60 (10.56)	Main effect persistence
Conversational Speech Sample							
Percentage of consonants correct	98.05 (1.80)***	91.41 (9.21)	96.37 (2.37)	83.49 (12.28)	95.42 (2.38)	84.83 (5.35)	Main effect persistence
Percentage of consonants correct Z-score[1]	1.10 (.50)***	−.67 (2.31)	.61 (.72)	−2.67 (2.96)	.42 (.62)	−2.55 (1.03)	Main effect persistence
TOLD-P:3							
Expressive Composite[2]	113.61 (9.39)***	96.88 (15.13)	105.45 (10.42)	98.14 (10.03)	79.46 (9.79)	73.90 (9.70)	Main effect LI
Receptive Composite[3]	116.90 (8.92)***	103.75 (12.21)	108.76 (11.65)	104.34 (9.13)	92.85 (8.36)	90.33 (9.10)	Main effect LI
Semantic Composite[4]	117.41 (9.66)***	101.89 (12.80)	108.02 (11.28)	102.38 (8.15)	88.23 (8.26)	86.67 (11.53)	Main effect LI
Syntactic Composite[5]	114.00 (10.07)***	94.25 (15.12)	101.92 (11.75)	96.69 (9.42)	76.46 (6.16)	70.33 (9.58)	Main effect LI

*** Control vs. SSD Whole Group differences, $p < .001$.
[1]: Age-Corrected Percentage of Consonants Correct *Z*-Score.
[2]: TOLD-P:3 Expressive Composite Standard Score (includes Oral Vocabulary and Grammatic Completion subtests).
[3]: TOLD-P:3 Receptive Composite Standard Score (includes Picture Vocabulary and Grammatic Understanding subtests).
[4]: TOLD-P:3 Semantic Composite Standard Score (includes Oral Vocabulary and Picture Vocabulary subtests).
[5]: Syntactic Composite Standard Score (includes Grammatic Understanding, Grammatic Completion, and Sentence Imitation subtests).

severity of speech production errors, as assessed by these alternative metrics, was not significantly associated with LI status. Specifically, there was no main effect for LI status on the GF metric (F (1, 89) = 1.39, p > .2) or the zPCC-R (F (1, 89) = 0.00, p > .9), nor was there an interaction between SSD persistence and LI status (F (1, 89) = .03, p > .8 and F (1, 89) = .17, p > .6 for the GF and zPCC-R, respectively).

As expected, main effects for LI status were found for each of the four TOLD-P:3 composites: Expressive F (1, 89) = 73.91, p < .001, Receptive F (1, 89) = 25.70, p < .001, Semantic F (1,89) = 40.75, p < .001, and Syntactic F (1,89) = 72.17, p < .001. This had to be the case, as children were diagnosed with LI using the TOLD-P:3. In addition to the expected effects of LI status on the TOLD-P:3, a trend was evidenced for SSD persistence on the Expressive Composite of the TOLD-P:3 (p < .1), such that children with persistent SSD tended to have somewhat poorer scores on this task. This result was not inevitable, given our classification strategy, and it suggests that the persistence of a child's SSD relates to their expressive language skills to some degree. One could wonder whether this lower Expressive Composite score of the TOLD-P:3 for children with persistent SSD was due to their speech-based intelligibility deficits. To avoid this possible confound, efforts were made to accommodate intelligibility challenges during testing. If examiners were unsure of a child's verbal response, the examiners would ask children to indicate which of two answers was correct using a forced choice format.

Finally, group comparisons of the SSD Normalized without LI group and the Control group yielded significant differences on all symptom variables (all t's > 3.0, all p's < .001), with children with normalized SSD performing more poorly on all symptom variables than control participants. The finding that SSD normalized participants differed from control participants on the zPCC-R, (t (88) = 3.70, p < .001) and the GF (t (88) = 8.56, p < .001) is consistent with the inclusionary criteria for identifying SSD and Control participants for the study. Findings indicating that the SSD Normalized group performed less well on the language composites of the TOLD-P:3 (Expressive: t (88) = 3.87, p < .001, Receptive: t (88) = 3.67, p < .001, Semantic: t (4.20, p < .001, Syntactic: t (88) = 5.18, p < .001) were not inevitable. These results suggest that the children with a history of SSD but with normalized speech continued to evidence weaknesses not only in their speech production, but also in their expressive and receptive language skills relative to control participants with no speech history. These language findings remained significant even after nonverbal IQ was covaried, ruling out the possibility that these findings could be explained by the slightly lower nonverbal IQ reported for the SSD normalized group.

Pre-literacy measures

In order to examine group differences on pre-literacy measures, analyses were completed in several steps using the three pre-literacy factor scores described above as dependent variables. First, the SSD group as a whole was compared to the control group. Then, the contributions of SSD persistence and LI status to pre-literacy skills were examined within the SSD group using an initial 2 × 2 MANCOVA design with age covaried, followed by the same design with nonverbal IQ as a covariate. Then follow-up t-tests, controlling for family-wise error rates, were completed as necessary. Finally, children with SSD but without either risk factor (i.e., the SSD- Normalized group) were compared to control participants on pre-literacy measures. Group means for all comparisons are provided in Table 4.

SSD versus Control group comparisons. A series of t-tests were completed to compare children in the entire SSD group and the Control group on pre-literacy variables. Analyses revealed significant group differences on the PA factor, t (135) = 5.62, p < .001, and the LTR factor, t (135) = 3.13, p < .01, such that children with SSD had poorer phonological awareness and less letter knowledge than control participants. Raw score means, standard deviations, and ranges for letter name and sound knowledge skills for the SSD and Control groups were as follows: SSD Letter Names M = 20.26, SD = 7.29, *Range* = 0–26, Letter Sounds M = 12.98, SD = 8.61, *Range* = 0–26; Control Letter Names M = 24.46, SD = 4.14, *Range* = 5–26, Letter Sounds M = 18.20, SD = 6.81, *Range* = 0–26. Results of analyses completed with raw scores for letter knowledge were largely consistent with the results completed with factor scores reported above. In contrast to the PA and LTR findings, significant between-group differences were not obtained for the RSN factor (t < 2, p > .2). Because children with a history of SSD were found to have lower nonverbal IQ scores than controls on average, the PA and LTR analyses were re-run with nonverbal IQ as a covariate. The findings replicated, such that children with a history of SSD performed less well on the PA (F (1, 133) = 23.19, p < .001) and LTR (F (1, 133) = 4.79, p < .05) factors, and they did not differ on the rapid naming factor (F < .2, p > .7). Lastly, the possible influence of socioeconomic differences on between-group findings was addressed by redoing the analysis using the Hollingshead Four Factor Index score as a covariate. Findings remained significant, with children with SSD performing less well on the PA (F (1,126) = 19.38, p < .001) and LTR (F (1,126) = 3.95, p < .05) factors after removal of variance associated with both nonverbal IQ and Hollingshead scores. These findings indicated that the children with SSD identified for this study were impaired relative to the control participants on two of the three pre-literacy

Table 4 Means (standard deviations) on pre-literacy factors (reported as *z*-scores) for Control and SSD groups

	Control vs. Whole SSD		Within SSD Group[1]			
	Control	Whole SSD	SSD Normalized No LI	SSD Persistent No LI	SSD Normalized LI	SSD Persistent LI	2 × 2 ANCOVA Results (with age covaried)[1]
Phonological Awareness Factor	.60 (.89)***	−.33 (.88)	−.04 (.74)	−.26 (.75)	−.87 (.77)	−1.42 (.74)	Main effects Persistence & LI
Rapid Serial Naming Factor	.11 (.61)	−.09 (1.13)	.11 (1.04)	.09 (1.05)	−1.28 (1.08)	−.22 (1.04)	Interaction of Persistence & LI *a* > *c*
Letter Knowledge Factor	.38 (.69)***	−.18 (1.05)	.11 (.85)	−.26 (.86)	−.76 (.88)	−.69 (.85)	Main effect LI only

*** Control vs. SSD Whole Group differences, $p < .001$.
[1]: SSD group means are reported as Estimated Marginal Means with age covaried.

measures, even when group differences in nonverbal IQ and socioeconomic status were controlled statistically.

Relations among SSD persistence, LI status, and pre-literacy factors. A 2 × 2 MANCOVA with age covaried was completed to test for possible differences on the pre-literacy scores associated with children's SSD persistence and LI status. The results of the omnibus MANCOVA with age covaried were significant for both SSD persistence ($F(3, 89) = 3.17$, $p < .05$) and LI status ($F(3,89) = 12.25$, $p < .001$), but there was not a significant interaction ($F(3,89) = 1.76$, $p > .1$). The omnibus MANCOVA results remained significant for persistence and LI status after NIQ was covaried in addition to age.

Follow-up univariate tests with age covaried revealed the most robust effects for the PA factor. Specifically, main effects of PA were found for both SSD persistence ($F(1,91) = 4.07$, $p < .05$) and LI status ($F(1, 91) = 27.31$, $p < .001$), such that persistent SSD and comorbid LI were associated with poorer performance. The contributions of SSD persistence and LI appeared to be additive, as the interaction term was not significant ($F(1,91) = .74$, $p > .3$). In addition, the main effects of SSD persistence and LI status remained after nonverbal IQ was covaried ($F(1,89) = 4.14$, $p < .05$, $F(1,89) = 18.7$, $p < .001$, for SSD persistence and LI status, respectively). The effect sizes for SSD persistence and LI status on the phonological awareness factor after age and nonverbal IQ were covaried were .41 and 1.14, respectively. The estimated marginal means (controlling for age and nonverbal IQ) were as follows: SSD persistent $M = -.83$, $SD = .87$ and Normalized $M = -.44$, $SD = 1.01$, LI $M = -1.09$, $SD = .81$ and NonLI $M = -.18$, $SD = .78$.

Letter knowledge results (LTR) were less robust than those obtained for the PA factor. A main effect of LI status on LTR was obtained ($F(1,91) = 8.96$, $p < .01$), with children with comorbid LI having lower average scores than those without LI. However, there was no significant main effect for SSD persistence ($F(1,91) = .44$, $p > .5$), nor was there a significant interaction between persistence and LI status on LTR ($F(1,91) = 1.04$, $p > .3$). With nonverbal IQ covaried, the main effect of LI status on LTR was no longer significant, suggesting a possible relation between nonverbal IQ and the measures comprising the LTR factor.

Lastly, contributions of SSD persistence and LI status to rapid serial naming (RSN) were analyzed. The univariate analyses with age covaried revealed a main effect of LI status on the RSN factor ($F(1,91) = 10.22$, $p < .01$), such that children with SSD and LI were slower to name colors and objects than those SSD participants without LI. A trend for a main effect for SSD persistence was also obtained ($F(1,91) = 3.67$, $p < .06$), but findings were not in the expected direction. Specifically, children with persistent SSD

named colors and objects *more* quickly than those with normalized speech. However, both main effects were qualified by a significant interaction between these two variables (F (1, 91) = 4.22, $p < .05$). This interaction occurred because children in the Normalized, LI group had the lowest scores on the RSN factor, whereas RSN scores for participants in the other three groups did not differ significantly from one another. Tests of simple effects indicated that RSN scores for children in the Normalized, no LI group were better than those for children in the Normalized, LI group ($p < .05$, Tukey adjustment). A trend was also evidenced, such that the RSN scores for children with persistent SSD, no LI tended to be better than those for the children in the Normalized, LI group ($p = .052$, Tukey adjustment). However, this interaction (as well as main effects of SSD persistence and LI) no longer reached statistical significance when the contributions of nonverbal IQ were covaried, suggesting a relation between nonverbal IQ and rapid serial naming speed.

SSD Normalized versus Control group comparisons. To investigate whether the presence of SSD without either additional risk factor (SSD persistence or LI) relates to pre-literacy skills, a series of *t*-tests was completed comparing factor scores for these variables for children in this subgroup to scores from control group participants. Results revealed that children with normalized SSD (without LI) performed less well than control participants on the PA factor score (t (86) = 3.30, $p < .01$). This result was maintained when nonverbal IQ was covaried (F (1,84) = 8.96, $p < .01$), providing additional evidence that children with a history of SSD but normalized speech have deficits on tasks of phonological awareness relative to control participants. Statistically significant differences were not obtained on analyses comparing RSN or LTR factor scores of children in the SSD normalized group (without LI) with scores from children in the control group (t (86) = .12, $p > .9$; t (86) = 1.40, $p = .16$, respectively). These results suggest that a history of SSD alone is related to deficits on some but not all tasks assessing pre-literacy skills.

Discussion and conclusion

The current study examined how two dimensions of SSD heterogeneity, namely the persistence of speech production errors and the presence of a comorbid language impairment, relate to pre-literacy skills in a sample of 5- to 6-year-old children with a history of SSD. Three interrelated questions were posed by this study: (1) Do children with SSD as a group perform worse than control participants on pre-literacy tasks, including tasks of phonological awareness, rapid serial naming, and letter knowledge? (2) Do the presence of a language impairment and the persistence of SSD each make unique contributions to the severity of pre-literacy deficits in children with SSD, and do they interact? (3) Do children with histories of SSD but without either persistent speech production errors or a comorbid language impairment demonstrate deficits on pre-literacy tasks compared to age-matched control participants?

With regard to the first question, results revealed that the entire group of children with SSD performed less well than control participants on tasks assessing phonological awareness and letter knowledge skills (even after the effects of nonverbal IQ and socioeconomic status were controlled), but did not differ from Controls on tasks assessing rapid serial naming abilities. These findings are consistent with previous findings that children with SSD are at heightened risk for literacy difficulties (e.g., Leitao et al., 1997; Bishop & Adams, 1990; Catts, 1993; Bird et al., 1995; Webster, Plante, & Couvillion, 1997).

Methodological differences may explain the present study's rapid serial naming findings, which are inconsistent with findings from previous studies of children with SSD (Leitao et al., 1997) and children at familial risk for RD (Pennington & Lefly, 2001). We hypothesized that this may be because the current study utilized tasks that assess the rapid naming of objects and colors, rather than alphanumeric symbols, which have been used in prior studies of children at familial risk for RD (e.g., Pennington & Lefly, 2001). In the Leitao et al. (1997) study examining rapid serial naming of children with speech and language disorders, participants with speech and language disorders scored lower than controls on both alphanumeric and color/object naming tasks, but the alphanumeric naming task more clearly discriminated children in the two groups. Consistent with the results of the current study, Young et al. (2002) recently reported negative findings for rapid serial naming (of digits) for adults with a history of isolated speech difficulties, but significant group differences for adults with a history of language difficulties. Thus, it is difficult to draw conclusions about the rapid naming abilities of children with SSD, particularly with regard to the rapid naming of non-alphanumeric items.

With regard to question 2, analyses yielded robust main effects of SSD persistence and LI status on phonological awareness skill that appear to be additive in nature. These results were maintained after nonverbal IQ was covaried. Effects of SSD persistence and LI status on letter knowledge and rapid serial naming abilities were less strong. While no main effect for SSD persistence on letter knowledge was obtained, a main effect for LI indicated that LI status was significantly associated with lower scores on the letter knowledge tasks. This result was not maintained, however, when nonverbal IQ was covaried. Lastly, rapid serial naming findings were complex and also influenced by nonverbal IQ scores. A trend for a main effect of

SSD persistence on rapid serial naming was obtained, as was a main effect of LI status. However, a significant interaction indicated that children with *normalized* SSD and comorbid LI had the lowest scores of the four groups on the RSN factor, but these findings were not maintained when nonverbal IQ was entered as a covariate.

Finally, our examination of children with SSD but without either risk factor (i.e., normalized SSD without current LI) revealed a significant group difference on the PA factor, such that children with normalized SSD performed less well on phonological awareness tasks than control participants without a history of speech disorder (even with nonverbal IQ statistically controlled). In contrast, no differences between the SSD and control groups were obtained on the letter knowledge or rapid serial naming tasks. These findings suggest that children with normalized SSD (without LI) are at somewhat heightened risk for literacy difficulties relative to matched control participants, despite the fact that their speech production errors have resolved.

Taken together, the results of this study suggest that a history of SSD, whether or not it is persistent or accompanied by LI, is a risk factor for deficits on pre-literacy tasks that have been found to be highly predictive of later reading difficulties (Scarborough, 1998). Findings also indicate that persistent SSD and a comorbid language impairment are additive risk factors for deficits in phonological awareness, with implications for the prediction of literacy outcome. The finding that LI status is associated with deficits on all pre-literacy tasks (prior to nonverbal IQ being covaried) is highly consistent with previous findings indicating that children with SSD and comorbid LI tend to have poorer literacy outcomes and phonological processing abilities compared to those with isolated speech disorders (Catts, 1993; Bishop & Adams, 1990).

Limitations and implications for future research

Before discussing the implications of this research, it is appropriate to review several of the limitations of the current study. First, because the majority of children included in this study were not yet reading, we were unable to assess directly associations among SSD persistence, LI status, and literacy skill at this time. This clearly limited our ability to thoroughly examine the phenotypic relationship between SSD and RD. Efforts to examine this relationship more directly are currently under way in our laboratory as we begin phase two of this longitudinal study. Second, the construct of speech sound disorder persistence is confounded to some degree by several factors, including the initial severity of a child's speech difficulties as well as the quantity and quality of speech therapy services received. We are currently gathering initial speech evaluations and information about the quantity of speech therapy services each participant has received in an effort to explore this relationship more directly.

Notwithstanding these methodological limitations, the findings of this study have implications for understanding the phenotypic relation between SSDand RD, two disorders that have been found to be cofamilial (Lewis et al., 1989; Lewis, 1990, 1992) and coheritable (Tunick & Pennington, 2002), but that manifest at different ages in development. Our examination of the pre-literacy skills of 5- to 6-year-old children with SSD allowed a direct comparison of our findings to those reported in the literature for children of the same age at familial risk for RD (e.g., Pennington & Lefly, 2001; Elbro, Borstom, & Petersen, 1998). This study's results provide support that children with SSD (with or without LI) share similar deficits on phonological awareness tasks to children at familial risk for RD. Such tasks have been found to be highly predictive of reading difficulties in children at familial risk for RD (Pennington & Lefly, 2001; Elbro et al., 1998), and suggest a possible shared core deficit in phonological processing abilities between children with SSD and children with RD. In addition, children with SSD who did not meet criteria for a diagnosis of concurrent LI in this sample demonstrated deficits on measures of general oral language skill relative to matched controls; such deficits were also observed within our subsample of children with normalized SSD and no LI (even after the effects of nonverbal IQ were covaried). Such subclinical deficits in language domains are consistent with studies of children who are at familial risk for RD (Scarborough, 1990; Pennington & Lefly, 2001; Snowling et al., 2000) and suggest another shared deficit between SSD and RD. Thus, these results suggest that children with SSD and RD share a similar linguistic phenotype at ages 5 to 6, consistent with the hypothesis that at least a subtype of SSD and RD are the same disorder, which manifests at different points in development.

Our finding that LI status was associated with poorer performance on both phonological awareness and letter knowledge tasks also provides strong support for the proposed phenotypic relation between RD and LI at the linguistic level. It should also be highlighted that the only phenotypic variable associated with poorer performance on letter knowledge measures in our sample was LI, although this relationship was influenced by the lower nonverbal IQ in this group. This finding is of particular import for understanding phenotypic commonalties between LI and RD, as several studies have suggested that letter knowledge is one of the best predictors of literacy skills in children (Scarborough, 1998). Consistent with the findings for children with SSD (regardless of LI status), these results provide strong support for prior findings that LI and RD overlap at the phenotypic level. Currently, investigations are under way in our

laboratory to determine if an overlap exists for SSD, LI, and RD at the genotypic level as well.

This study's results also may augment knowledge about subtypes of SSD and their relation to later literacy problems. Specifically, our finding that both SSD persistence and LI status made additive contributions to performance on tasks of phonological awareness suggests the contributions of two somewhat independent influences on the development of phonological awareness, consistent with connectionist theories of development of phonological representations (Plaut & Kello, 1999). Specifically, our persistence findings suggest a link between the developmental mapping of the acoustic signal onto phonological representations through the precision of articulatory gestures, while our LI findings suggest a link between semantic representations and the honing of phonological representations, consistent with lexical restructuring hypothesis (Metsala & Walley, 1989).

Taken together, these findings are highly consistent with the multiple deficit, interactive view of reading proposed by Bishop (1997), Snowling (1998), and Plaut and colleagues (Plaut, McClelland, Seidenberg, & Patterson, 1996), in which the quality of both phonological and semantic representations contributes to reading abilities. Thus, according to this view and connectionist accounts of phonological development, children with different subtypes of SSD are likely to have differing literacy outcomes. Specifically, according to this account, it is likely that children with SSD with normalized speech and no LI will likely have the best literacy outcome, as the quality of their phonological representations may be the most intact of the four SSD subtypes examined in this research. In contrast, children with persistent SSD + LI will likely have the worst literacy outcome, with both word decoding and reading comprehension difficulties, due to weaknesses in both their phonological and semantic representations. Children with persistent SSD without LI will likely perform like individuals with phonological dyslexia on reading tasks, with word decoding deficits, but intact reading comprehension skills. Lastly, children with normalized speech but concomitant LI will likely have a reading profile that is characterized by poor reading comprehension skills. These predictions will be explored in phase two of this longitudinal study when these subgroups of children with SSD return to our laboratory to complete an extensive reading battery.

Acknowledgements

The present study was supported by a National Institute of Mental Health grant, the Linguistic Phenotype of Familial Dyslexia (MH 38820). The authors wish to extend their gratitude to the children and families who participated in this research and to our collaborators on this project.

Correspondence to

Nancy A. Raitano, Department of Psychology, University of Denver, 2155 S. Race Street, Denver, CO 80208, USA; Email: nraitano@du.edu

References

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders: DSM-IV-TR*. Washington, DC: Author.

American Speech-Language Hearing Association. (1990). Guidelines for screening for hearing impairment and middle-ear disorders. *Asha*, *32* (Suppl. 2), 17–24.

Austin, D., & Shriberg, L. D. (1996). *Lifespan reference data for ten measures of articulation competence using the Speech Disorders Classification System (SDCS)* (Tech. Rep. No. 3). Phonology Project, Waisman Center, University of Wisconsin–Madison.

Beitchman, J.H., Hood, J., & Inglis, A. (1992). Familial transmission of speech and language impairment: A preliminary investigation. *Canadian Journal of Psychiatry*, *37*, 151–156.

Bird, J., & Bishop, D. (1992). Perception and awareness of phonemes in phonologically impaired children. *European Journal of Disorders of Communication*, *27*, 289–311.

Bird, J., Bishop, D.V.M., & Freeman, N.H. (1995). Phonological awareness and literacy development in children with phonological impairments. *Journal of Speech and Hearing Research*, *38*, 446–462.

Bishop, D.V.M. (1997). *Uncommon understanding: Development and disorders of language comprehension in children*. Hove, England: Psychology Press.

Bishop, D.V.M., & Adams, C. (1990). A prospective study of the relationship between specific language impairment, phonological disorders, and reading retardation. *Journal of Child Psychology and Psychiatry*, *31*, 1027–1050.

Bishop, D.V.M., & Edmundson, A. (1987). Language impaired 4-year-olds: Distinguishing transient from persistent impairment. *Journal of Speech and Hearing Disorders*, *52*, 156–173.

Campbell, T.F., Dollaghan, C.A., Rockette, H.E., Paradise, J.L., Feldman, H.M., Shriberg, L.D., Sabo, D.L., & Kurs-Lasky, M. (2003). Risk factors for speech delay of unknown origin in 3-year-old children. *Child Development*, *74*, 346–357.

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

Elbro, C., Borstom, I., & Petersen, D.K. (1998). Predicting dyslexia from kindergarten: The importance of distinctness of phonological representations of lexical items. *Reading Research Quarterly*, *33*, 36–60.

Elliott, C.D. (1990). *The Differential Ability Scales*. San Antonio, TX: The Psychological Corporation.

Fowler, A. (1991). How early phonological development might set the stage for phoneme awareness. In S.A. Brady & D.P. Shankweiler, (Eds.), *Phonological processes in literacy: A tribute to Isabelle U. Liberman* (pp. 97–117). Hillsdale, New Jersey: Lawrence Erlbaum and Associates.

Gallagher, A., Frith, U., & Snowling, M.J. (2000). Precursor to literacy delay among children at genetic risk of dyslexia. *Journal of Child Psychology and Psychiatry*, *41*, 202–213.

Goldman, R., & Fristoe, M. (1986). *The Goldman Fristoe Test of Articulation*. American Guidance Service.

Hall, P.K., & Tomblin, J.B. (1978). A follow-up study of children with articulation and language disorders. *Journal of Speech and Hearing Disorders*, *43*, 227–241.

Hollingshead, A.B. (1975). *Four factor index of social status*. Unpublished manuscript.

Johnston, J. (1994). Cognitive abilities of children with language impairment. In R.V. Watkins & M.L. Rice (Eds), *Specific language impairments in children: Communication and language intervention series, Vol. 4* (pp. 107–121). Baltimore, MD: Paul M. Brooks Publishing Company.

Jorm, A.F. (1979). The cognitive and neurological basis of developmental dyslexia: A theoretical framework and review. *Cognition*, *7*, 19–33.

Larrivee, L.S., & Catts, H.W. (1999). Early reading achievement in children with expressive phonological disorders. *American Journal of Speech-Language Pathology*, *8*, 118–128.

Leitao, S., Hogben, J., & Fletcher, J. (1997). Phonological processing skills in speech and language impaired children. *European Journal of Disorders of Communication*, *32*, 91–111.

Levi, G., Capozzi, F., Fabrizi, A., & Sechi, E. (1982). Language disorders and prognosis for reading disabilities in developmental age. *Perceptual and Motor Skills*, *54*, 1119–1122.

Lewis, B.A. (1990). Familial phonological disorders: Four pedigrees. *Journal of Speech and Hearing Disorders*, *55*, 160–170.

Lewis, B.A. (1992). Pedigree analyses of children with phonology disorders. *Journal of Learning Disabilities*, *24*, 586–597.

Lewis, B.A. (1996, November). *The comorbidity of phonology and reading disorders*. Paper presented at the American Speech and Hearing Association, Atlanta, GA.

Lewis, B., Ekelman, B., & Aram, D. (1989). A family study of severe phonological disorders. *Journal of Speech and Hearing Research*, *32*, 713–724.

Liberman, I.Y. (1973). Segmentation of the spoken word and reading acquisition. *Bulletin of the Orton Society*, *23*, 65–77.

Liberman, I.Y., Shankweiler, D., Fischer, F.W., & Carter, B. (1974). Explicit syllable and phoneme segmentation in the young child. *Journal of Experimental Child Psychology*, *18*, 201–212.

Metsala, J.L., & Walley, A.C. (1998). Spoken vocabulary growth and segmental restructuring of lexical representation: Precursors to phoneme awareness and early reading ability. In J.L. Metsala & L.C. Ehri (Eds), *Word recognition in beginning literacy* (pp. 89–120). Mahwah, NJ: Erlbaum.

Neils, J., & Aram, D.M. (1986). Family history of children with developmental language disorders. *Perceptual and Motor Skills*, *63*, 655–658.

Newcomer, P.L., & Hammill, D.D. (1997). *Test of Language Development, Primary: Third Edition*. Austin, TX: ProEd.

Pennington, B.F., & Lefly, D.L. (2001). Early reading development in children at family risk for dyslexia. *Child Development*, *72*, 816–833.

Plaut, D.C., & Kello, C.T. (1999). The emergence of phonology from the interplay of speech comprehension and production: A distributed connectionist approach. In B. MacWhinney (Ed.), *The emergence of language* (pp. 391–415). Mahwah, NJ: Lawrence Erlbaum Associates.

Plaut, D., McClelland, J.L., Seidenberg, M.S., & Patterson, K.E. (1996). Understanding normal and impaired reading: Computational principles in quasi-irregular domains. *Psychological Review*, *103*, 56–115.

Scarborough, H.S. (1990). Very early language deficits in dyslexic children. *Child Development*, *61*, 1728–1743.

Scarborough, H.S. (1998). Early identification of children at risk for reading disabilities: Phonological awareness and some other promising predictors. In A.C. Accardo & B. Shapiro (Eds.), *Specific reading disability: A view of the spectrum* (pp. 75–119). Timonium, MD: York.

Share, D.L. (1995). Phonological recoding and self-teaching: Sine qua non of reading acquisition. *Cognition*, *55*, 618–629.

Shriberg, L.D. (1993). Four new speech and prosody-voice measures for genetics research and other studies in developmental phonological disorders. *Journal of Speech and Hearing Research*, *36*, 105–140.

Shriberg, L.D. (1994). Five subtypes of developmental phonological disorders. *Clinics in Communication Disorders*, *4*, 38–53.

Shriberg, L.D. (2002, November). *Classification and misclassification of child speech sound disorders*. Seminar presented at the Annual Convention of the American Speech-Language-Hearing Association, Atlanta, GA.

Shriberg, L.D., Allen, C.T., McSweeny, J.L., & Wilson, D.L. (2001). PEPPER: Programs to examine phonetic and phonologic evaluation records [Computer software]. Madison, WI: Waisman Center Research Computing Facility, University of Wisconsin-Madison.

Shriberg, L.D., & Austin, D. (1998). Comorbidity of speech-language disorder: Implications for a phenotype marker for speech delay. In R. Paul (Ed.), *The speech-language connection* (pp. 73–117). Baltimore, MD: Paul H. Brookes.

Shriberg, L.D., Austin, D., Lewis, B.A., McSweeny, J.L., & Wilson, D.L. (1997a). The Speech Disorders Classification System (SDCS): Extensions and lifespan reference data. *Journal of Speech, Language, and Hearing Research*, *40*, 723–740.

Shriberg, L.D., Austin, D., Lewis, B.A., McSweeny, J.L., & Wilson, D.L. (1997b). The percentage of consonants correct (PCC) metric: Extensions and reliability data. *Journal of Speech and Hearing Research*, *40*, 708–722.

Shriberg, L.D., & Kent, R.D. (2003). *Clinical phonetics* (3rd edn). Boston: Allyn & Bacon.

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

Smith, F. (1973). *Psycholinguistics and reading*. New York: Holt, Rinehart, & Winston.

Snowling, M.J. (1998). Reading difficulties. *Educational and Child Psychology*, *15*, 44–58.

Snowling, M., Bishop, D.V.M., & Stothard, S.E. (2000). Is preschool language impairment a risk factor for dyslexia in adolescence? *Journal of Child Psychology and Psychiatry*, *41*, 587–600.

Snowling, M.L., & Hulme, C. (1994). The development of phonological skills. *Philosophical Transactions of the Royal Society London, B*, *346*, 21–27.

Stanovich, K.E. (1988). Explaining the differences between the dyslexic and the garden-variety poor reader: The phonological-core variable-difference model. *Journal of Learning Disabilities*, *21*, 590–604.

Swan, D., & Goswami, U. (1997). Phonological awareness deficits in developmental dyslexia and the phonological representations hypothesis. *Journal of Experimental Child Psychology*, *66*, 18–41.

Tomblin, J.B., Records, N.L., & Zhang, X. (1996). A system for the diagnosis of specific language impairment in kindergarten children. *Journal of Speech and Hearing Research*, *39*, 1284–1294.

Treiman, R., Tincoff, R., Rodriguez, K., Mouzaki, A., & Francis, D.J. (1998). The foundations of literacy: Learning the sounds of letters. *Child Development*, *69*, 1524–1540.

Tunick, R.A., & Pennington, B.F. (2002). The etiological relationship between reading disability and phonological disorder. *Annals of Dyslexia*, *52*, 75–95.

Wagner, R.K., Torgesen, J.K., & Rashotte, C.A. (1999). *Comprehensive Test of Phonological Processing: Administration Manual*. Austin, TX: ProEd.

Webster, P.E., Plante, A., & Couvillion, L.M. (1997). Phonological impairment and prereading: Update on a longitudinal study. *Journal of Learning Disabilities*, *30*, 365–375.

Wechsler, D. (1991). *Manual for the Wechsler Intelligence Scale for Children – Third Edition*. San Antonio, TX: The Psychological Corporation.

Young, A.R., Beitchman, J.H., Johnson, C., Douglas, L., Atkinson, L, Escobar, M., & Wilson, B. (2002). Young adult academic outcomes in a longitudinal sample of early identified language impaired and control children. *Journal of Child Psychology and Psychiatry*, *43*, 635–645.

Manuscript accepted 14 July 2003