Research Article

Differential Long-Term Outcomes for Individuals With Histories of Preschool Speech Sound Disorders

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Purpose: The goal of this study was to determine whether adolescent outcomes for individuals with histories of early speech sound disorders (SSD) could be differentiated by speech and language skills at earlier ages (preschool, 4–6 years, and school age, 7–10 years).

Method: The study used a retrospective longitudinal design. Participants with and without histories of early SSD were classified in adolescence as having no SSD, resolved SSD, low multisyllabic word (MSW; difficulty with MSW repetition but no errors in conversational speech), or persistent speech disorders (errors in both conversational speech and MSW repetition). Analysis of variance was employed to determine whether early speech, language, and literacy skills distinguished these adolescent outcome groups.

Results: Preschool and school-age skills differed for adolescents whose SSD had resolved from those who had persistent speech errors. Adolescents with errors solely in production of MSWs (Low MSW) did not differ in early speech and language skills from adolescents who had difficulty with both MSWs and persistent errors in conversation.

Conclusions: Speech and language assessments earlier in childhood can help establish risks for persistent SSD and other language and literacy difficulties in adolescence. Early identification of these clinically relevant subgroups of SSD may allow for early targeted interventions.

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Children with preschool histories of speech sound disorders (SSD) present with differing longitudinal trajectories and variable long-term outcomes for speech, language, and academic skills. Risks for persisting impairment in these ability domains in individuals with early childhood SSD include comorbid language impairment (LI), persistent speech disorder (PSD), poor phonological awareness skills, lower nonverbal cognitive abilities, motor impairment, and social disadvantage (Larrivee & Catts, 1999; Lewis et al., 2015; Wren, Miller, Peters, Emond, & Roulstone, 2016). However, most studies of PSD have

reported on participants at 8–9 years of age but have not followed these individuals into adolescence. Data on adolescent outcomes on the long-term effects of early SSD are needed to determine the long-term impact on educational achievement, occupational status, and psychosocial skills. Furthermore, the identification of early prognostic predictors of PSD in adolescence may aid in determining which individuals are at greatest risk for poor adult outcomes. The aim of the current study was to identify preschool and school-age factors associated with differing adolescent outcomes of early childhood SSD.

In our previous work, we followed individuals with histories of early SSD into adolescence ($N = 170$). We identified three adolescent outcomes for individuals with histories of preschool SSD (Lewis et al., 2015). The first group consisted of individuals whose early SSD had resolved and who had achieved typical speech sound skills relative to normative data (Resolved SSD group, $n = 105$). This group included individuals with histories of SSD-only and no LI (62%) and individuals with histories of combined SSD and LI (38%). The second group consisted of individuals who no longer demonstrated speech sound errors in conversation, but had difficulty repeating multisyllabic real

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words and nonwords relative to normative data (Low multisyllabic word [MSW], $n = 33$). In our earlier studies, we reported that poor multisyllabic real word and nonword repetition was associated with poorer outcomes at school age (Lewis, Freebairn, & Taylor, 2000) and residual errors in adulthood (Lewis, et al., 2007). The Low MSW group included individuals with histories of SSD-only (15%), individuals with histories of SSD and LI, (76%), and individuals who were not identified as having SSD at preschool but had difficulty MSWs at adolescence (9%). The third group consisted of individuals who continued to present with speech sound errors in conversation at adolescence and also had difficulty with MSW repetition (PSD, $n = 41$). The PSD group included individuals with histories of SSD-only (17%), individuals with histories of combined SSD and LI (68%), and individuals who were not identified at preschool as having SSD (15%). We also included a fourth group of individuals without histories of speech or language difficulties (No SSD group, $n = 137$) as a comparison group.

A battery of tests consisting of standardized and nonstandardized measures were administered that assessed motor speech skills, speech production (MSW repetition), language skills (receptive and expressive oral language skills), literacy (single-word decoding, reading comprehension, and spelling), and nonverbal intelligence. Groups were compared employing analyses of variance (ANOVAs) and correcting for multiple comparisons. Results suggested that the presence of comorbid LI places an individual at risk for poorer outcomes than individuals with SSD-only, but that deficits in other skills may also contribute to persisting deficits. Poorer language and literacy outcomes at adolescence were associated with persistent speech sound problems including difficulty repeating MSWs, lower nonverbal intelligence, and lower socioeconomic status (SES). The PSD group also demonstrated poorer motor speech skills than the other groups.

In the current study, we wished to extend our findings of the adolescent outcome study by examining the early speech, language, and literacy skills for these adolescent outcome groups at preschool (4–6 years) and school age (7–10 years). Identification of early childhood deficits that predict later speech and language outcomes has the potential to guide efforts to target early interventions for children at highest risk for persisting impairments.

Prevalence of PSD

The overall prevalence of SSD of unknown origin is estimated to be 15.6% of 3-year-old children (Campbell et al., 2003) falling to 3.8% of 6-year-old children (Shriberg, Tomblin, & McSweeney, 1999). Other estimates of prevalence are 3.4% at 4 years of age in a population-based study of an Australian cohort (Eadie et al., 2015). SSD is more prevalent in males than females at approximately 2:1 ratio (McKinnon, McLeod, & Reilly, 2007). Some speech sound errors may persist beyond 8–9 years. Rates of PSD vary and may differ depending on the age at which it is assessed; the criteria used to identify persistence; the rate of comorbid

conditions, such as LI in the sample; and whether the sample is clinically based or population based. Wren et al. (2016) estimated the prevalence of PSD at 3.6% in a population-based sample of 8-year-old children with preschool SSD. In a clinical sample of children with early speech and language delay, a higher rate of persistence of continued speech, language, and literacy difficulties (27%) were reported than in the general population (Glogowska, Roulstone, Peters, & Enderby, 2006).

PSD may include a range of speech sound difficulties, such as residual distortion errors of late-8 sounds, for example, /r/, /s/, and /l/ (Flipsen, 2003; Flipsen & Sacks, 2015), difficulty with the production of MSWs (Lewis et al., 2015), and more severe impairments, such as apraxia of speech (Cabbage, Hogan, & Carrell, 2016). Furthermore, individuals with PSD may be variable in terms of etiology (i.e., known and unknown etiologies) and accompanying deficits in motor, language, and literacy skills (Cabbage, et al., 2016; Wren et al., 2016).

Factors Related to Long-Term Outcomes of Early SSD

Children with SSD and comorbid LI are at higher risk for long-term reading and spelling problems than individuals with SSD alone (Bishop, Price, Dale, & Plomin, 2003; Lewis, O'Donnell, Freebairn, & Taylor, 1998). In a study of a community-based sample, Eadie et al. (2015) found comorbid LI in 40.8% of children with SSD compared to 20.8% of children with reading disorders (RD). The rate of comorbid LI for males was almost twice that for females (54% vs. 28%).

Children with histories of early LI have also been examined for persistence. Hayiou-Thomas, Dale, and Plomin (2014) reported that persistent LI was related to psychometric tests at age 4 years but not to parent concerns about their child's language skills. Broader LI in early childhood, including both receptive and expressive disorders, was more likely to persist at 12 years than more limited disorders. Children with early LI had weaker language skills at later ages, even if the disorder had resolved (Hayiou-Thomas et al., 2014).

More recently, studies have examined language skills of older children and adolescents with PSD. Children with PSD demonstrate linguistic, literacy, and social deficits and have higher rates of LI than those children with resolved SSD (Bishop et al., 2003; Lewis et al., 2015, 2016). Children with PSD may have poorer phonological representations than those whose SSD resolves (Nathan, Stackhouse, Goulondris, & Snowling, 2004) and/or motor speech deficits (Lewis et al., 2015; Vick et al., 2014).

In our adolescent outcome study (Lewis et al., 2015), the group whose SSD had resolved reported 38% with a history of LI, whereas 76% in the Low MSW group and 68% in the PSD group had a history of LI. Thus, LI confers additional risk for poor adolescent outcomes of early SSD. In the current study, we examined language skills at preschool and school age to determine if adolescent outcome groups differed in language skills at earlier ages (preschool and school age).

Other studies have examined the type of speech errors that the child makes as an indication of less favorable outcomes. A recent study by Dodd, Reilly, Eecen, and Morgan (2018) examined 94 children with SSD at 4 years of age and followed them again at 7 years of age. At 4 years of age, only 85% made phonological errors, whereas 14% made both phonological and articulatory errors. At 7 years of age, eight of the 13 children with both phonological and articulatory errors at 4 years of age no longer had speech sound errors; however, for the other children, the phonological errors had resolved but articulatory errors persisted with 12% exhibiting distortions of /s/ or /z/. Emergence of articulatory distortions was attributed to refinement of motor speech skills, dentition, and reorganization of phonological representations.

Atypical speech errors (defined as those errors that occur less than 5% in a given age group) are often associated with SSD (Smit, 1993). These atypical phonological errors are highly variable across children and languages (McLeod & Baker, 2017) and occur more frequently on polysyllabic words (James, 2001). Individuals with nondevelopmental phonological process errors and atypical errors are at higher risk for reduced phonological awareness skills and lower literacy scores at school age than children who present with common errors that are often observed in typical children (Preston, Hull, & Edwards, 2013). Investigators have hypothesized that children who make these errors have poor phonological awareness skills and inaccurate phonological representations (Bird, Bishop, & Freeman, 1995; Leitão & Fletcher, 2004; Preston et al., 2013). A study by Larrivee and Catts (1999) followed kindergarten children who demonstrated expressive phonology disorders to first grade. These children demonstrated poorer reading skills, difficulty with repetition of real word and nonword MSWs, and poorer phonological awareness skills and language skills than children without a history of phonology disorders. A recent study found that children with difficulty with repetition of polysyllabic words at preschool are at greater risk for literacy difficulties at early elementary school (Masso, Baker, McLeod, & Wang, 2017). However, it is not clear if atypical early speech sound errors or phonological process use predicts long-term outcome at adolescence. In the current study, we described atypical and typical phonological process use on the Goldman-Fristoe Test of Articulation (GFTA; Goldman & Fristoe, 1986, 2000) at preschool and school age by adolescent outcome group.

Other predictors of PSD include family factors, such as a family history of speech, language, and RD lower maternal education and maternal vocabulary; and low SES. Early childhood factors that are associated with PSD include little or no babbling, unintelligible speech, limited morphology at 38 months, low cognition, neurobiological conditions (e.g., hearing loss, intellectual disability, cerebral palsy), and a history of coordination problems and poor motor skills and male sex (Bishop, 2002; Campbell et al., 2003; Eadie et al., 2015; Lewis et al., 2011; Wren et al., 2016; Wren, Roulstone & Miller, 2012). Conversely, a recent study of children with PSD at 7 years did not find

SES, IQ, family history, language, or gender to be predictive of PSD; rather, children with disordered speech at 4 years were more likely to have PSD at 7 years than children with delayed speech (Morgan et al., 2017).

Studies of PSD frequently include case studies of children with severe forms of SSD, such as childhood apraxia of speech or with genetic syndromes or abnormalities, such as those found in the K. E. family (Vargha-Khadem, Watkins, Alcock, Fletcher, & Passingham, 1995), suggesting a genetic component to PSD. Carrigg, Parry, Baker, Shriberg, and Ballard (2016) examined a large multigenerational family in which six family members presented with PSD and five family members demonstrated resolved SSD. Family members with PSD demonstrated poorer speech accuracy on multisyllabic real words and nonwords and in conversation. Differences in favor of the Resolved SSD group were also observed in verbal IQ, receptive and expressive language, nonword repetition and discrimination and literacy skills, including written expression and single word and nonword decoding, and spelling. The family members with resolved SSD presented only with minimal distortion errors in conversation and difficulty with nonword repetition. Although this study highlights differences of individuals with resolved SSD versus PSD at an older age within a single family, early predictors of resolved versus recovered family members were not examined.

The purpose of this study was to identify speech, language, and literacy skills for individuals with early childhood SSD as assessed at preschool age (4–6 years) and school age (7–10 years) and relate these measures to adolescent outcome groups (Resolved SSD group, Low MSW group, and PSD group). The research question was: Do individuals with histories of SSD, who presented with differing outcomes at adolescence, differ at preschool and school age in their speech, language, and literacy skills? We predict that individuals who presented with PSD would demonstrate more severe deficits at preschool and school age in speech, language, and literacy skills than those individuals in the adolescent Resolved SSD group. Individuals who continue to have deficits in MSW repetition at adolescence would also differ from the Resolved SSD group possibly due to higher rates of early LI (38% in the Resolved SSD group and 76% in the Low MSW group). Finally, we examined whether or not motor speech skill differences between the PSD group and the Low MSW group present at adolescence were also evident at earlier ages.

Method

Participants

The current sample was a subset of a longitudinal family study of speech and language disorders (Lewis et al., 2011). The sample included 110 individuals who completed the preschool assessment (85 with SSD and 25 without SSD) and 133 individuals who completed the school-age assessment (85 with SSD and 48 without SSD). Probands

with SSD were recruited from Northeast Ohio at preschool (4–6 years of age) from the clinical caseloads of speech-language pathologists. Probands were screened to ensure that they met the following criteria: (a) moderate to severe expressive SSD as defined by a score of 1 *SD* or greater below the mean on the GFTA Sound in Words subtest (Goldman & Fristoe, 1986, 2000), with speech sound differences due to dialect being scored as correct; (b) normal hearing acuity as defined by passing a pure-tone audiometric screening test at 25 dB HL ISO for 500, 1000, 2000, and 4000 Hz bilaterally and < 6 episodes of otitis media prior to 3 years as reported by the parent; (c) normal peripheral speech mechanism as documented by the Total Structure Score on the Oral and Speech Motor Control Protocol (OSMCP; Robbins & Klee, 1987) or, for children older than 6 years 11 months, by intact oral structures as measured using the Oral Speech Mechanism Screening Exam—Third Edition (St. Louis & Ruscello, 2000); (d) absence of a history of neurological disorders or developmental delays other than speech and language as reported by the parent; and (e) normal intelligence defined as a Performance IQ ≥ 80 on the Wechsler Preschool and Primary Scale of Intelligence—Revised (Wechsler 1989) or Wechsler Intelligence Scale for Children—Third Edition (Wechsler, 1991). Family SES was determined at the initial assessment based on parent education levels and occupations using the Hollingshead Four Factor Index of Social Class (Hollingshead, 1975).

All available siblings of the probands were also invited to participate in the testing. Siblings were considered as having an SSD if they met the same criteria described above for probands and/or had a history of speech-language therapy for an SSD and were, otherwise, classified as unaffected sibling controls. Siblings were assessed on the age-appropriate test battery. The participants were assessed at preschool age (4–6 years 11 months of age), school age (7–10 years 11 months of age), and adolescence (11–17 years 11 months of age).

Classification of Participants by Adolescent Outcomes

At adolescence, participants were assessed for residual SSD errors and assigned to the following four groups (see Lewis et al., 2015, and the overview of the study in the introduction for details):

1. *No SSD group.* Siblings who never reported or demonstrated an SSD or LI at previous assessments or at the adolescent follow-up.
2. *Resolved SSD group.* Individuals with a history of a preschool SSD who no longer presented with speech sound errors in a conversational speech sample and scored higher than -1.5 *SD* from the mean on the repetition of MSWs at adolescence.
3. *Low MSW group.* Participants with a history of a preschool SSD who scored less than or equal to -1.5 *SD* from the mean on the repetition of MSWs but had no errors in a conversational speech sample at adolescence. See Appendix A for a list and description of the MSWs.
4. *PSD group.* Participants with a history of a preschool SSD who scored below or equal to -1.5 *SD* from the mean on the repetition of MSWs and demonstrated speech sound errors in a conversational speech sample.

Measures

A comprehensive test battery was administered at each assessment including measures of speech sound production, motor speech skills, vocabulary, and language. Literacy skills were also assessed at the school-age follow-up visit. The preschool and school-age measures employed in this study are described below.

Speech and Language Measures (Administered at Preschool and School Age)

Speech sound production was assessed by a standardized articulation test, the GFTA Sounds-in-Word subtest (Goldman & Fristoe, 1986; 2000). The GFTA uses picture plates and target words to elicit consonants in the initial, medial, and final position of words, as well as consonant clusters (blends) in the initial position. Responses were audio-recorded and phonetically transcribed. Errors on the GFTA were also analyzed for phonological process use by the Khan-Lewis Phonological Analysis (Khan & Lewis, 1986, 2002; see Appendix B for process use at preschool and Appendix C for school-age process use).

Motor speech skills were assessed by the Total Function Score of the Robbins and Klee OSMCP (Robbins & Klee, 1987) in children 4–6 years old. Diadochokinetic rates on single, double, and multisyllables were timed and scored. The Fletcher Time-by-Count Test of Diadochokinetic Syllable Rate (Fletcher, 1977) was administered to children at school age. This test also assesses rates of syllable repetition on single, double, and MSWs. *z* scores for both measures were employed in analyses.

Vocabulary was estimated by the Expressive One-Word Picture Vocabulary Test—Third Edition (EOWPVT-3; Gardner, 2000) and the Peabody Picture Vocabulary Test—III (PPVT-III; D. M. Dunn & Dunn, 1997) or the Peabody Picture Vocabulary Test—Fourth Edition (PPVT-IV; L. M. Dunn, 2006). The PPVT measures receptive vocabulary, and the EOWPVT-3 measures expressive vocabulary skills. Standard scores were used in analyses.

Sentence Repetition was assessed by the Sentence Imitation subtest of the Test of Language Development—Primary: Third Edition—(Newcomer & Hammill, 1997) or the Recalling Sentences in Context subtest of the Clinical Evaluation of Language Fundamentals—Preschool (Wiig, Secord, & Semel, 1992) or Clinical Evaluation of Language Fundamentals—Third Edition (Semel, Wiig, & Secord, 1995). The ability to accurately repeat sentences of increasing complexity measures semantic, morphological, and syntactic skills, as well as short-term memory. Sentence repetition skills have

been used to identify language disorders in children. Scaled scores were employed in analyses.

Literacy Measures (Administered at School Age)

Word-level reading was assessed by the Word Identification (WI) and Word Attack (WA) subtests of the Woodcock Reading Mastery Tests–Revised (Woodcock, 1987). The WI subtest consists of real words, and the WA subtest consists of nonwords that follow English phoneme-grapheme correspondence rules. Standard scores were used in analyses.

Reading comprehension was assessed by the Reading Comprehension subtest of the Wechsler Individual Achievement Test (Wechsler, 1992). Participants read passages and answered questions. Standard scores were used in analyses.

Spelling was measured by the Test of Written Spelling–Third Edition (Larsen & Hammill, 1994). The Test of Written Spelling–Third Edition is composed of predictable words that evaluate the child’s ability to spell dictated words that follow English spelling patterns and unpredictable words that are exceptions to common spelling patterns, such as *eight* and *feign*. Standard scores were used in analyses.

Phonological Awareness was assessed by the Elision subtest of the Comprehensive Test of Phonological Processing (Wagner, Torgesen, & Rashotte, 1999). This test requires the child to say how an orally presented word would sound with a given part of the word deleted. Scaled scores were used in data analysis.

Procedure

This study was approved by the Institutional Review Board of University Hospitals Medical Center. Informed consent/assent was obtained prior to testing. Testing was carried out by a master’s-level speech-language pathologist in the speech and language laboratory at Case Western Reserve University. To accommodate families, participants were tested in a quiet room of their home when necessary. Testing required 3.5–4 hr. Tests were administered in counter-balanced order across participants. To avoid fatigue, participants were given frequent breaks and, if necessary, testing was performed over 2 days. Sessions were audio-recorded.

Analyses

Preschool and school-age data were analyzed to determine if adolescent outcome groups were differentiated by earlier preschool and school-age measures. Errors on the GFTA were classified as to phonological process use at preschool (see Appendix B) and school age (see Appendix C) for each outcome group. Either age-adjusted standard scores (for standardized measures) or age-adjusted *z* scores (based on the associations of age to raw scores for the sample) were computed for measures and entered into the analyses. ANOVAs were used to compare the adolescent outcome groups (No SSD, Resolved SSD, Low MSW, and PSD groups) on their preschool and school-age assessments. To correct for multiple testing, we conservatively corrected for 14 ANOVAs using the Bonferroni method;

an experiment-wide α level of .05 corresponded to a nominal *p* value of .0036. Tukey’s post hoc comparisons were computed to determine how significantly the outcome groups differed from one another pairwise.

To assess the sensitivity of our analysis to family structure, we performed a second analysis using generalized estimating equations (GEE), which adjusted for correlations between siblings. Associations of preschool and school-age measures with adolescent outcomes were examined using GEE. The primary independent variable in the analysis was adolescent outcome group with the effect of each group on preschool and school-age measures examined relative to the No SSD group. Dependent variables for both preschool and school-age assessments were the GFTA, PPVT, EOWPVT, motor speech skills, and sentence imitation. Associations of group with reading and spelling were also examined in the analysis of the school-age measures. SES and sex were entered into the models as covariates. In the GEE models, the ANOVA test result is a chi-squared statistics with 3 *df* instead of an *F* statistic. The results of the GEE models were highly similar with those from ANOVA, and where different; the ANOVA results were more conservative; therefore, ANOVA results are presented (see Supplemental Materials S1 and S2 for results of GEE model).

Results

Demographics for the adolescent outcome groups at preschool and school age are presented in Table 1. The number of participants in each group differed at the preschool and school-age assessments as siblings varied in age upon entry into the study, and the age-appropriate test battery (preschool or school age) was administered. At the preschool assessment, adolescent outcome groups differed in SES ($F = 2.63$, $p = .05$) and in the presence of comorbid LI ($p < .001$), with the Low MSW (69%) and PSD (74%) groups demonstrating more diagnoses of LI. At the school-age assessment, adolescent outcome groups differed in gender ($p = .02$), with more males composing the Low MSW (71%) and the PSD (74%) groups compared to the No SSD group (42%). The groups also differed in the report of comorbid RD ($p < .001$), with more reading difficulties reported by the Low MSW (100%) and the PSD (68%) groups relative to the No SSD group (17%).

Comparisons among the adolescent outcome groups on measures at preschool and at school age are presented in Table 2 and Figures 1 and 2. Results revealed a significant overall group effect ($p < .004$) at the preschool assessment for all measures except the EOWPVT, and while the PPVT showed differences, they were no longer significant after the multiple testing corrections. Group differences were significant at the school-age assessment for all measures except the motor speech skills measure (Fletcher Time-by-Count), suggesting that the trend for motor speech skills difficulties observed at preschool may have resolved by school age or that the measure was not sensitive enough to detect subtle differences in motor speech skills.

Table 1. Demographic characteristics of adolescent outcome groups at preschool and school-age assessments.

Adolescent SSD groups							
Characteristic	No SSD	Resolved SSD	Low MSW	PSD	Eta ²	F	p
Preschool assessment							
N (total = 110)	24	50	13	23			
Age, years	5.89 ± 0.88	5.49 ± 0.82	5.94 ± 0.90	5.68 ± 0.68	.051	1.90	.13
Male	13 (54.2%)	34 (68.0%)	9 (69.2%)	16 (69.6%)	—	—	.63
SES	3.93 ± 1.11	4.03 ± 0.98	3.42 ± 1.44	3.90 ± 0.94	.026	2.63	.051*
IQ	110.1 ± 15.6	101.9 ± 14.0	93.6 ± 13.8	93.3 ± 13.7	.041	1.13	.34
Comorbid LI	0 (0.0%)	16 (32.0%)	9 (69.2%)	17 (73.9%)	—	—	< .001***
School-age assessment							
N (total = 133)	48	52	14	19			
Age, years	8.74 ± 1.01	8.69 ± 1.10	8.18 ± 1.03	8.45 ± 1.05	.028	1.26	.29
Male	20 (41.7%)	35 (67.3%)	10 (71.4%)	14 (73.7%)	—	—	.020**
Comorbid RD	8 (17.0%)	13 (25.0%)	14 (100.0%)	13 (68.4%)	—	—	< .001***

Note. Values are mean ± SD or N (%). *p* values are from Fisher's exact test (binary traits and sex) or from analysis of variance *F* statistics (quantitative traits): Em dashes indicate "not applicable." SSD = speech sound disorders; MSW = multisyllabic word; PSD = persistent speech disorder; SES = socioeconomic status; LI = language impairment; RD = reading disorder.

p* < .1. *p* < 0.05. ****p* < .001.

In pairwise group comparisons of scores from the preschool assessment, the PSD group scored more poorly than the Resolved SSD group in motor speech skills (total functional score), receptive vocabulary (PPVT), and expressive language (Sentence Imitation). Articulation skills as measured by the GFTA did not differentiate the Resolved, Low MSW, or PSD groups. This suggests that single-word articulation tests at preschool may not be predictive of long-term outcomes. The Low MSW group did not differ from

the Resolved SSD or PSD groups at preschool for any measure. Thus, the preschool measures generally failed to discriminate the Low MSW group from either the Resolved SSD or PSD groups.

As expected, the No SSD group demonstrated the fewest phonological processes (*M* = 1.6 processes for males and *M* = 3.5 processes for females) and the PSD group employed the most phonological processes (*M* = 8.5 processes for males and *M* = 8.25 processes for females). See

Table 2. Comparisons of adolescent outcome groups on preschool and school-age assessments.

Adolescent SSD groups							
Measure	No SSD	Resolved SSD	Low MSW	PSD	Eta ²	F	p
Preschool assessments							
GFTA ^{a,b,c}	0.73 ± 1.18	−0.33 ± 0.92	−0.80 ± 0.74	−1.01 ± 0.57	.309	13.99	< .001***
PPVT ^{c,e}	110.0 ± 12.0	106.2 ± 15.6	103.2 ± 12.6	93.4 ± 13.6	.145	4.52	.006**
EOWPVT	115.2 ± 14.5	110.0 ± 19.2	104.7 ± 12.2	101.3 ± 20.8	.073	2.09	.11 (NS)
TFS ^{c,e} (Robbins & Klee)	0.43 ± 0.91	−2.82 ± 5.32	−2.63 ± 5.12	−7.11 ± 6.35	.205	7.97	< .001***
Sentence imitation ^{b,c,e}	11.2 ± 3.2	9.6 ± 3.5	7.4 ± 2.5	5.5 ± 3.0	.284	13.61	< .001***
School-age assessment							
GFTA ^{a,b,c,e}	1.66 ± 0.99	0.75 ± 1.36	0.26 ± 1.60	−0.62 ± 1.20	.269	14.01	< .001***
PPVT ^{b,c,d,e}	111.8 ± 11.5	109.3 ± 14.9	95.1 ± 11.5	90.1 ± 17.3	.271	11.92	< .001***
EOWPVT ^{b,c,d,e}	125.3 ± 6.7	120.1 ± 15.5	103.8 ± 12.3	105.5 ± 17.8	.280	12.29	< .001***
Motor speech skills (Fletcher)	−0.20 ± 0.65	−0.11 ± 0.77	0.13 ± 0.87	−0.04 ± 3.52	.004	0.16	.92 (NS)
Sentence Imitation ^{b,c,d,e}	11.0 ± 2.6	10.1 ± 3.3	6.3 ± 3.8	6.3 ± 3.6	.264	14.49	< .001***
Word Identification ^{b,c,d,e}	104.0 ± 15.5	105.7 ± 14.9	80.4 ± 18.5	82.6 ± 20.5	.270	15.05	< .001***
Word Attack ^{b,c,d,e}	103.5 ± 13.6	103.2 ± 14.3	72.6 ± 20.9	80.5 ± 19.8	.346	21.12	< .001***
Reading Comprehension ^{b,c,d,e}	109.2 ± 14.7	103.5 ± 13.5	85.7 ± 12.1	89.5 ± 14.4	.273	11.78	< .001***
Elision ^{b,c,d,e}	0.41 ± 0.67	0.67 ± 0.84	−1.18 ± 0.88	−1.00 ± 0.83	.462	26.58	< .001***
Spelling(TWS) ^{b,c,d,e}	98.1 ± 15.7	93.9 ± 15.9	74.2 ± 12.4	77.5 ± 13.4	.247	12.05	< .001***

Note. Values for outcome groups are mean ± SD. *p* values are from analysis of variance: NS indicates ≥ 0.1. GFTA and Motor Speech are *z* scores. Recalling Sentences are scaled scores. All other scores are standard scores. SSD = speech sound disorders; MSW = multisyllabic word; PSD = persistent speech disorder; GFTA = Goldman-Fristoe Test of Articulation; PPVT = Peabody Picture Vocabulary; EOWPVT = Expressive One-Word Picture Vocabulary Test; TFS = total functional score; TWS = Test of Written Spelling. Post hoc Tukey comparisons are indicated as follows:

^aNo SSD differed from Resolved SSD. ^bNo SSD differed from Low MSW. ^cNo SSD differed from PSD. ^dResolved SSD differed from Low MSW. ^eResolved SSD differed from PSD.

p* < .05. *p* < .001.

Figure 1. Figure 1 shows preschool score means and ranges for the No SSD group and the adolescent outcome groups of Resolved SSD, Low MSW, and PSD on the Sentence Imitation, Peabody Picture Vocabulary Test (PPVT), Oral and Speech Motor Control Protocol (OSMCP), and the Goldman-Fristoe Test of Articulation (GFTA). The dots indicate the scores for each subgroup. The box encompasses the area where 50% of the scores fall (interquartile range), and the horizontal line represents the mean score for each group. As shown in Figure 1, the range of scores within each group is highly variable. Significant differences among the SSD groups were not observed on the GFTA at preschool. SSD = speech sound disorders; MSW = multisyllabic word; PSD = persistent speech disorder.

Appendixes B and C for specific phonological processes employed by participants.

At school age, the GFTA differentiated the Resolved SSD group from the PSD group. The Low MSW group did not differ from either the Resolved SSD or the PSD groups on the GFTA. The Resolved SSD group had better vocabulary scores (PPVT and EOWPVT), phonological awareness (Elision), and expressive language (Sentence Imitation) than either the Low MSW or the PSD group at school age. Group differences in literacy were also evident at school age with the Resolved SSD group performing better on decoding (WI and WA), reading comprehension, and spelling than the Low MSW and PSD groups.

Discussion

The goal of this study was to determine if different adolescent outcomes for individuals with histories early SSD could be differentiated by speech, language, and literacy skills at earlier ages. Such information would be useful in providing more intensive and targeted interventions early for children most at risk for poor outcomes. Overall, our findings demonstrated that the group whose speech and language difficulties had resolved by adolescence (Resolved SSD group) differed from the group with PSD in language and motor speech skills at preschool but not in articulation

skills. At school age, the Resolved SSD group differed from the PSD group on all measures except the motor speech skills measure. The Resolved SSD group also differed from the group with incomplete resolution of the SSD (Low MSW) on measures of language skills (vocabulary, sentence imitation, phonological awareness) and literacy measures at school age, but these groups did not differ in articulation skills at this age or in any of the language measures at preschool age. The Low MSW and PSD groups showed deficits across these measures at preschool and school-age assessments. However, the PSD group was not distinguishable from the Low MSW group at either time point based on these assessments. Below, we discuss these early differences among the adolescent outcome groups.

Speech Measures

As expected, the No SSD group differed from all three SSD groups on the GFTA at preschool. However, significant differences were not observed on the GFTA among the three SSD groups. This suggests that severity of SSD alone as measured by the GFTA at preschool may not be predictive of recovery versus persistence at later ages. There was a wide range of scores within the Resolved SSD group at preschool with some individuals scoring very poorly (-2 SD below the mean) and some with high scores (1 SD or greater above the mean; see Figure 1).

Figure 2. Figure 2 shows school-age score means and ranges for the No SSD group and the adolescent outcome groups of Resolved SSD, Low MSW, and PSD groups on the Goldman-Fristoe Test of Articulation (GFTA), Peabody Picture Vocabulary Test (PPVT), Test of Written Spelling (TWS), Reading Comprehension of the Wechsler Individual Achievement Test (WIAT), Expressive One-Word Picture Vocabulary Test (EOWPVT), and Sentence Imitation. The dots indicate the scores for each subgroup. The box encompasses the area where 50% of the scores fall (interquartile range), and the horizontal line represents the mean score for each group. As shown in Figure 2, the range of scores within each group is highly variable and scores among groups are overlapping. This suggests that no single measure may be predictive of adolescent outcomes rather a constellation of deficits and protective factors such as intervention may impact outcomes. SSD = speech sound disorders; MSW = multisyllabic word; PSD = persistent speech disorder; Elision = phonological awareness.

Another explanation for the lack of differences among SSD groups may be that a single-word articulation test did not capture the type of deficits in speech sound production at preschool that are predictive of later outcomes. At school age, all three SSD groups had lower scores on the GFTA than the No SSD group, suggesting some residual articulation errors. Although the PSD group made more errors at adolescence than the Resolved SSD group, errors at school age did not distinguish the PSD group from the Low MSW group. These findings provide some support for a range of speech sound deficits at school age and underscore the general lack of sensitivity of single-word measures of articulation composed of mono- and di-syllables focused on consonant accuracy as predictors of adolescent outcomes.

Vocabulary Measures

At preschool age, the PSD group scored more poorly than the No SSD and Resolved SSD groups on the PPVT, but not the EOWPVT. The PSD group also had the highest percentage of comorbid LI (74%) at preschool. Poorer vocabulary knowledge may signal the presence of a more general early LI in the PSD group that lead to poorer long-term outcomes. There are several possible explanations for the lack of significant differences on the EOWPVT at the preschool assessment. First, it may be that the test itself is not as discriminating as the PPVT as all groups performed well on the EOWPVT with mean scores ranging from 101 to 115. Second, all participants presented with an SSD at preschool, and the EOWPVT is an expressive naming task. Preschool participants may have had equal difficulty retrieving the underlying phonological representation for a word or articulating the word. Third, vocabulary may not be as sensitive at preschool for predicting adolescent outcomes as it is at older ages. Although adolescents in the Low MSW group had a high rate of comorbid LI at preschool age (69%), they did not differ significantly from the other outcome groups on the PPVT or EOWPVT. The mean score of the Low MSW group on the PPVT was 103, suggesting receptive vocabulary scores within normal limits. At school age, the Low MSW and PSD groups obtained lower scores on both the PPVT and EOWPVT than the No SSD and Resolved SSD groups, suggesting that vocabulary skills at school age may differentiate individuals at risk for poor adolescent outcomes.

Motor Speech Skills

At preschool, the PSD group had poorer motor speech skills as measured by the Total Function Score of the Robbins and Klee OSMCP than the No SSD and Resolved SSD groups, suggesting that weak motor speech skills at preschool age may be predictive of persistent speech sound difficulties in adolescence. The mean score on the motor speech skills measure for the Low MSW group was poorer than the Resolved SSD group's mean but better than the PSD group's mean, suggesting that

the Low MSW group had milder motor speech skills difficulties than the PSD group. At school age, however, the groups did not differ on another motor speech measure, the Fletcher Time-by-Count. It is possible that this measure was not as sensitive to motor speech difficulties or that motor speech difficulties present in early childhood had resolved by school age for many children with SSD.

Sentence Imitation

At preschool age, both the Low MSW and PSD group obtained lower scores than the No SSD group on sentence imitation. Although differences on this measure between the Resolved SSD group and Low MSW group were not significant, the Resolved SSD group had higher scores than the PSD group. Sentence imitation has been widely used clinically and in research to identify children with language processing difficulties (Conti-Ramsden, Botting, & Faragher, 2001; Stothard, Snowling, Bishop, Chipchase, & Kaplan, 1998). Although this task assesses verbal memory, Klem et al. (2015) argue that sentence repetition is a "complex linguistic task" that involves speech perception, lexical knowledge, grammatical skills, and speech production. In the current study, the mean scores on sentence imitation reflected a continuum of language abilities with the No SSD group scoring at the highest level on this task and the PSD group scoring at the lowest level. At school age, the Low MSW and PSD groups also scored more poorly than the Resolved SSD group on sentence imitation, suggesting that language processing difficulties of preschool-age children in the Low MSW and PSD groups persisted to school age.

School-Age Literacy Skills

At school age, the Low MSW and PSD groups obtained lower scores than the No SSD and Resolved SSD groups on all literacy measures including real word and nonword decoding (WI and WA), reading comprehension, phonological awareness (Elision), and spelling. Children whose SSD resolved by adolescence did not differ from children who never had a speech or language disorder on the school-age literacy measures. The Low MSW and PSD groups did not differ significantly on any of the literacy measures with both groups scoring 1 *SD* below the mean on decoding, reading comprehension, spelling, and phonological awareness skill. Individuals with SSD and comorbid LI have been shown to be at higher risk for literacy difficulties than children with SSD alone (Lewis, Freebairn, Hansen, Iyengar & Taylor, 2004). Both the Low MSW and PSD groups had higher rates of LI at preschool age than the Resolved SSD group. Parent report of reading difficulty at the school-age assessment were 17% for the No SSD group (close to the population prevalence estimated at 16%), 25% for the Resolved SSD group, 100% for the Low MSW group, and 68% for the PSD group.

It is interesting to note that the Low MSW group did not differ significantly from the PSD group on most of

the preschool and school-age assessments. The Low MSW group represents partially resolved SSD with continued difficulty on challenging speech production tasks such as the MSW. Repetition of MSW requires many language processes including speech perception, phonological encoding, phonological memory, phonological assembly, and articulation. Although not demonstrating overt motor speech skill difficulty at adolescence as observed in the PSD group, the Low MSW group may continue to have difficulty with phonological assembly (i.e., sequencing the phonemes into a unitary phonological representation). The PSD group, while performing more poorly than the other groups on all measures, had residual motor speech skill difficulties reflected in continued errors in conversational speech at adolescence. These findings suggest a continuum of speech, language, and literacy deficits that may manifest differently at various developmental stages.

Strengths and Limitations

The strengths of this study are the large sample size followed prospectively from preschool into adolescence and the comprehensive assessment of speech, language, and literacy skills at each time point. A limitation of the study is that not all individuals were followed at each time point due to the family study design. Siblings may have been younger or older than proband children upon entry into the study. Another limitation of the study is the lack of control for intervention history. Although all participants with SSD were enrolled in speech-language therapy, we were unable to determine the frequency, duration, or type of therapy that each child received. Other limitations include the failure to distinguish errors that were phonological in nature (linguistic) versus articulatory errors due to motor speech skills limitations. We also did not distinguish errors resulting from poor phonological memory and errors in phonological assembly. Future studies may evaluate the specific types of errors including atypical errors and non-developmental phonological processes and their underlying etiology in prediction of adolescent outcomes as well as the contributions of intervention to adolescent outcomes.

Summary and Conclusions

In summary, the Resolved SSD group showed early deficits in speech that continued to school age but not into adolescence. The children with incomplete resolution of their SSD (Low MSW group) did not differ from the Resolved SSD group on measures administered at preschool age, but did show differences in language and literacy skills (word-level reading, reading comprehension and spelling) at school age. The PSD group was not distinguishable from the Low MSW group at either time point based on these assessments. These findings suggest that there is continuum of deficits in speech and language skills at school age that are related to poorer adolescent outcomes and that these deficits include literacy skills.

Although overall group data suggest better early speech and language skills are related to better adolescent outcomes, children's performance varied widely on these early speech and language skills within each of the adolescent outcome groups (see Figures 1 and 2). This heterogeneity emphasizes the importance of considering other influences on long-term outcomes such as speech-language interventions and other co-morbid conditions such as attention-deficit/hyperactivity disorder. The unique constellation of deficits or protective factors that a child has may contribute to the resolution or persistence of the SSD. The interaction of these multiple deficits may have resulted in poor outcomes for the PSD group. These findings support a multiple cognitive deficit model as proposed by Pennington (2006) and colleagues (McGrath et al., 2011) to explain complex developmental disorders. Shared and unique cognitive skills (i.e., phonological processing, vocabulary, or motor speech skills) among comorbid disorders (i.e., SSD, LI, and RD) may predict long-term outcomes. There is a need to identify clinically relevant subgroups based on these early skills so that targeted intervention for subgroups may be developed. Longitudinal research studies on the polysyllable production of preschoolers and early school-age children may be a way of identifying potential subgroups of children at risk for poorer long-term outcomes. Future studies may examine subgroup differences on types of speech sound errors (i.e., articulatory versus phonological, delay versus disordered speech, atypical errors, and nondevelopmental phonological processes) as well as other linguistic endophenotypes such as phonological memory and assembly.

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Appendix A

Multisyllabic Word List

The multisyllabic word (MSW) repetition task was administered at adolescence. The MSW list consists of 20 real words ranging from three to five syllables in length (10 words were three syllables; seven words were four syllables; three words were five syllables). Ten words had primary stress on the first syllable, eight had primary stress on the second syllable, and two had primary stress on the third syllable. Participants were asked to repeat MSWs. Responses were digitally recorded and, phonetically transcribed, and the percent of phonemes correct were calculated. Age-based normative data were derived from unaffected individuals, and z scores were generated. These words were developed by Catts (1986) to study speech production difficulties in individuals with RD. Performance on the MSW repetition task was used to classify participants into Resolved, Low MSW, or PSD groups at adolescence. We have employed these words in our longitudinal studies and have found them to distinguish individuals with persistent speech sound disorders.

Directions: You are going to hear some words on this audiotape. After you hear each word, I would like you to repeat the word just as you heard it on the tape. Some of the words may be difficult to say, but do the best you can.

1. peculiar
2. aluminum
3. emphasis
4. probably
5. cinnamon
6. susceptible
7. consciousness
8. orchestra
9. vulnerable
10. symphony
11. regularly
12. pneumonia
13. sympathize
14. municipal
15. skeptical
16. fire extinguisher
17. Nicaragua
18. particularly
19. pistachio
20. Episcopal church

Note. PSD = persistent speech disorder; MSW = multisyllabic word; SSD = speech sound disorders.

Appendix B

Phonological Process Use at Preschool for Adolescent Outcome Groups

Error type	Participants ages 3–6 years															
	PSD				Low MSW				Resolved SSD				No SSD			
	Male (n = 16)		Female (n = 8)		Male (n = 7)		Female (n = 4)		Male (n = 36)		Female (n = 17)		Male (n = 12)		Female (n = 11)	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Phonological processes																
Deletion of final consonants	14	88	4	50	6	86	4	100	23	64	13	76	3	25	6	55
Initial voicing	8	50	2	25	1	14	1	25	13	36	4	24	0	0	3	27
Syllable reduction	13	81	5	63	4	57	3	75	21	58	10	59	2	17	4	36
Palatal fronting	12	75	6	75	2	29	1	25	17	47	10	59	2	17	0	0
Deaffrication	8	50	2	25	0	0	2	50	13	36	4	24	0	0	1	9
Velar fronting	9	56	5	63	2	29	1	25	17	47	8	47	2	17	2	18
Consonant harmony	14	88	8	100	4	57	3	75	30	83	11	65	2	17	1	9
Stridency deletion	14	88	7	88	2	29	2	50	26	72	11	65	2	17	4	36
Stopping	13	81	7	88	5	71	3	75	26	72	10	59	2	17	4	36
Cluster simplification	13	81	8	100	6	86	4	100	27	75	11	65	2	17	7	64
Final devoicing	3	19	1	13	3	43	1	25	6	17	3	18	0	0	3	27
Liquid simplification	15	94	8	100	6	86	4	100	24	67	13	75	3	25	4	36
Epenthesis	1	6	0	0	1	14	0	0	6	17	1	6	0	0	1	9
Nondevelopmental phonological processes																
Deletion of initial consonants	5	31	2	25	0	0	0	0	8	22	2	12	0	0	1	9
Glottal replacement	2	13	0	0	1	14	1	25	0	0	0	0	0	0	0	0
Backing to velars	2	13	0	0	1	14	1	25	2	6	0	0	0	0	0	0

Note. PSD = persistent speech disorder; MSW = multisyllabic word; SSD = speech sound disorders.

Appendix C

Phonological Process Use at School Age for Adolescent Outcome Groups

Error type	Participants ages 7–12															
	PSD				Low MSW				Resolved SSD				No SSD			
	Male (n = 16)		Female (n = 6)		Male (n = 17)		Female (n = 7)		Male (n = 50)		Female (n = 21)		Male (n = 29)		Female (n = 44)	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Phonological processes																
Deletion of final consonants	7	44	3	50	4	24	1	14	6	12	3	14	0	0	0	0
Initial voicing	5	31	0	0	1	6	0	0	0	0	0	0	0	0	0	0
Syllable reduction	3	19	0	0	2	12	0	0	3	6	0	0	1	3	0	0
Palatal fronting	5	31	2	33	3	18	0	0	3	6	0	0	1	3	0	0
Deaffrication	1	6	2	33	1	6	0	0	1	2	0	0	0	0	0	0
Velar fronting	2	13	0	0	3	18	1	14	1	2	0	0	0	0	0	0
Consonant harmony	4	25	3	50	2	12	1	14	6	12	1	5	0	0	0	0
Stridency deletion	4	25	0	0	5	29	1	14	3	6	2	10	1	3	0	0
Stopping	7	44	3	50	5	29	1	14	5	10	0	0	1	3	0	0
Cluster simplification	9	56	3	50	6	35	1	14	7	14	1	5	2	7	0	0
Final devoicing	2	13	1	17	2	12	0	0	2	4	0	0	0	0	0	0
Liquid simplification	11	69	5	83	5	29	0	0	14	28	2	10	1	3	0	0
Epenthesis	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0
Nondevelopmental phonological processes																
Deletion of initial consonants	0	0	0	0	1	6	0	0	0	0	0	0	0	0	0	0
Glottal replacement	0	0	0	0	1	6	0	0	0	0	0	0	0	0	0	0
Backing to velars	2	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distortion errors	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
/s/ dentalized	0	0	0	0	0	0	0	0	4	8	2	10	1	3	0	0
/z/ dentalized	0	0	0	0	0	0	0	0	3	6	1	5	0	0	0	0
/r/ derhotacized	3	19	1	17	0	0	0	0	4	8	0	0	0	0	0	0
/ch/ lateralized	1	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
/s/ lateralized	2	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
/z/ lateralized	2	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
/w/ nonlabialized	0	0	1	17	0	0	0	0	1	2	0	0	0	0	0	0

Note. PSD = persistent speech disorder; MSW = multisyllabic word; SSD = speech sound disorders.