JSLHR

Research Article

Rhyme Production Strategies Distinguish Stuttering Recovery and Persistence

Katelyn Gerwin,[a] Françoise Brosseau-Lapré,[a] Barbara Brown,[a] Sharon Christ,[b] and Christine Weber[a]

Purpose: The primary aim of the current study was to examine the developing phonological awareness of 4- to 5-year-old children who stutter (CWS) in relation to eventual recovery (CWS-eRec) or persistance (CWS-ePer) in stuttering, accounting for the presence of typical speech (TS) production or speech sound disorder (SSD).
Method: In the 1st year of a 5-year longitudinal study, 37 children who do not stutter (CWNS) and 48 CWS completed a rhyme discrimination and a rhyme production task from the Phonological Awareness Test–Second Edition (Robertson & Salter, 2007). Using data from their last year of participation, CWS were classified into CWS-ePer and CWS-eRec. Each CWS group was further divided into TS and SSD groups based on speech production abilities at the time of the rhyme tasks. Accuracy on the rhyme tasks was compared. Groups were also compared on strategies used to generate correct and incorrect responses for the rhyme production task (e.g., real-word correct, nonword correct, semantic association, repeated cues).
Results: All groups performed similarly on the rhyme discrimination task. On the rhyme production task, CWS-ePer-SSD and CWS-eRec-SSD performed with less accuracy than CWNS, but CWS-ePer-TS, CWS-eRec-TS, and CWNS achieved similar task accuracy. On correct rhyme production trials, CWS-ePer-TS created more nonword rhymes than real-word rhymes. CWS-ePer-TS used the nonword strategy at 1.88 times the CWNS rate. CWS-eRec-TS fell between CWS-ePer-TS and CWNS in use of the nonword strategy.
Conclusions: Reliance on a nonword strategy for rhyme production in CWS-ePer-TS may reflect differences in underlying phonological representations and ease of phonological access to the lexicon compared to CWNS.

Stuttering is a speech disorder that typically onsets between 2 and 4 years of age (Yairi & Ambrose, 1999). Five percent to 8% of preschool children stutter, and of that group, 80% recover (Yairi & Ambrose, 1999, 2013). Stuttering is characterized by stuttering-like disfluencies (SLDs) in the speech stream, including blocks, part-word repetitions, single-syllable word repetitions, and prolongations of sounds (Ambrose & Yairi, 1999). Although these observable disfluencies characterize the disorder, many theories of stuttering argue that studying the characteristics of SLDs is not sufficient for understanding the development and course of the disorder (e.g., dual diathesis-stressor model, Walden et al., 2012; demands and capacities model, Starkweather & Gottwald, 1990; multifactorial model of stuttering, Smith, 1999; multifactorial dynamic pathways [MDP] theory, Smith & Weber, 2017).

In the MDP theory, Smith and Weber (2017) propose that individual contributing factors be investigated in the context of dynamic neurodevelopmental interactions. Factors are investigated in the onset and trajectory of stuttering persistence or recovery. Within this framework, stuttering is thought to result from unstable speech motor networks, which interact with rapidly developing linguistic and psychosocial systems. The authors suggest that these interacting neural systems may develop to further support or interfere with speech motor stabilization, resulting in either recovery or persistence in children who stutter (CWS; Smith & Weber, 2017). The current study focuses on furthering our understanding of the influence of developing phonology as a factor that may help to predict whether a young child will recover or persist in stuttering. Specifically, we assess emerging phonological awareness skills through rhyme discrimination and rhyme production tasks in 4- to 5-year-old children who are stuttering and grouped according

[a]Department of Speech, Language, and Hearing Sciences, Purdue University, West Lafayette, IN
[b]Department of Human Development and Family Science, Purdue University, West Lafayette, IN
Correspondence to Katelyn L. Gerwin: kgerwin@purdue.edu

Editor-in-Chief: Julie Liss
Editor: J Scott Yaruss
Received July 20, 2018
Revision received February 22, 2019
Accepted June 12, 2019
https://doi.org/10.1044/2019_JSLHR-S-18-0294

Disclosure: The authors have declared that no competing interests existed at the time of publication.

to their speech sound production abilities and eventual persistence or recovery.

Development of Phonological Knowledge and Phonological Awareness

Phonological knowledge has been conceptualized as interacting levels of representation, including acoustic–phonetic, phonological, and articulatory–phonetic representations (Rvachew & Brosseau-Lapré, 2018; Savage, Blair, & Rvachew, 2006). Phonological representations include the encoded phonological characteristics of words such as individual phonemes and the rules by which those phonemes are combined (Preston & Edwards, 2010; Rvachew & Brosseau-Lapré, 2018). Acoustic–phonetic representations are built as the child perceives speech input, whereas articulatory–phonetic representations emerge from a child's experience with speech production (Edwards, Beckman, & Munson, 2004; Rvachew & Brosseau-Lapré, 2012; Savage et al., 2006).

As a child's mental lexicon expands to include an increasing number of words, the phonological representations restructure, identifying frequent sublexical units such as syllables, rimes, onsets, and phonemes (Metsala, 1997; Rvachew, 2006; Rvachew & Grawburg, 2006). The restructuring is thought to allow the child to become aware of smaller sublexical units to efficiently contrast words that sound similar, such as minimal pairs (Metsala, 1997). This restructuring based on speech perception and increasing receptive language is a proposed mechanism for the development of phonological awareness (Rvachew & Grawburg, 2006). In other words, the development of phonological awareness skills or the knowledge that words are composed of sublexical units relies on detailed and well-specified underlying representations (Elbro & Pallesen, 2002).

Edwards et al. (2004) provided evidence that increases in lexicon size contribute to the development of more detailed underlying representations of words that contain phoneme-level information. They assessed the abilities of 104 children with typical development ages 3–8 years to repeat nonwords with phoneme sequences, which were either infrequent (absent and rare) or frequent in a database of child language. The children repeated the nonwords with frequent phoneme sequences more accurately than nonwords with infrequent phoneme sequences. Additional analyses showed that the children's vocabulary size, rather than age, predicted their accuracy in repeating nonwords, especially those containing infrequent phoneme sequences. The authors concluded that children with larger vocabulary sizes were able to extract more robust representations at the phoneme level from the growing number of words in their lexicon. In turn, this allowed them to more accurately combine and repeat these infrequent sequences of phonemes.

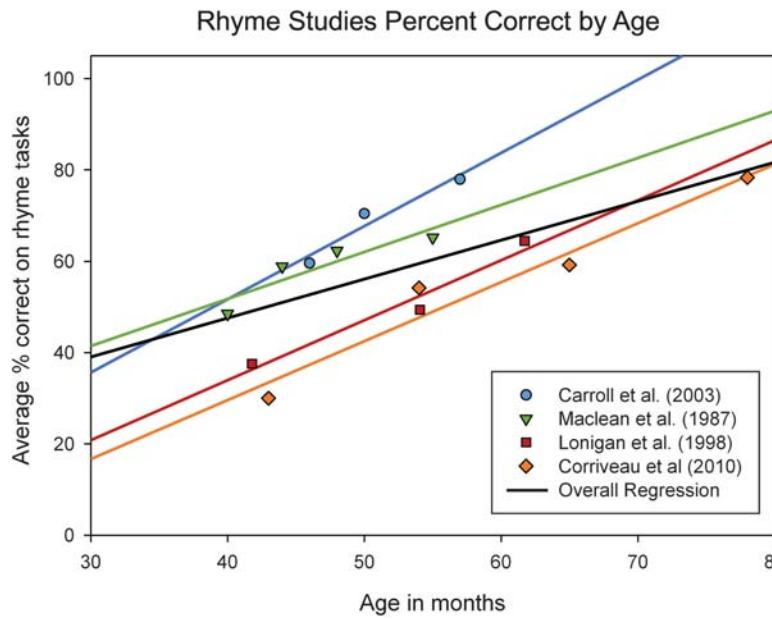
As restructuring occurs, phonological awareness of sublexical units tends to follow a developmental order from larger units, such as words and syllables, to smaller units, such as phonemes (Anthony & Francis, 2005; Anthony et al., 2002; Anthony, Lonigan, Driscoll, Phillips, & Burgess, 2003). Cross-cultural studies reveal that the features of a child's native language influence the order of awareness for sublexical units of similar size. For example, English-speaking children may develop onset–rime awareness (e.g., c-at) before head–coda awareness (e.g., ca-t), whereas Japanese children show the opposite pattern. This occurs because English has a high proportion of words with similar rimes (Anthony & Francis, 2005).

A similar developmental order exists for the type of phonological awareness task used to assess a given sublexical unit. In a study of children ages 2–6 years, Anthony et al. (2003) demonstrated that children tend to be able to complete phonological awareness detection tasks (e.g., hear separated syllables, choose the picture that represents the word that blends the syllables) before they complete production tasks (e.g., hear separated syllables, produce the word that blends the syllables). In addition, children were able to blend phonological units before they could elide units. The authors conclude that assessment of phonological awareness should take into consideration both task and sublexical unit.

The current study focuses on onset–rime awareness or rhyming abilities. These abilities develop rapidly during the same time period as most stuttering onsets. Children begin demonstrating rhyming abilities as early as 2–3 years of age (Lonigan, Burgess, Anthony, & Barker, 1998; Maclean, Bryant, & Bradley, 1987). Maclean et al. (1987) showed that, at age 3 years, 21% of their 66 subjects demonstrated rhyme detection above chance level and 42% could produce at least one rhyming word out of five opportunities. Carroll, Snowling, Stevenson, and Hulme (2003) found that performance on rhyme detection was still variable, but increasing, among children as they aged from 4 to 5 years. Over that year time frame, the percentage of children scoring above chance rose from 23.88% to 65.67%. Figure 1 summarizes children's accuracy on rhyme detection tasks across different age groups as reported in various investigations of phonological development (Carroll et al., 2003; Corriveau, Goswami, & Thomson, 2010; Lonigan et al., 1998; Maclean et al., 1987). Studies included rhyme-matching tasks, in which participants choose a word from two options that rhymes with a stimulus (Carroll et al., 2003; Maclean et al., 1987), and rhyme oddity tasks, in which participants choose a word from three to four options that does not rhyme with the others (Corriveau et al., 2010; Lonigan et al., 1998; Maclean et al., 1987). An overall regression line taking into account data points from each study is included in the figure to approximate rhyme detection development over time.

Rhyme production development has not been studied as thoroughly as rhyme detection. For example, Maclean et al. (1987) assessed rhyme production in only one session of their 15-month longitudinal study, whereas rhyme detection was studied at all four sessions. However, when rhyme production and rhyme detection tasks are both assessed in a study, they tend to follow a pattern consistent with the findings of Anthony et al. (2003) where accuracy on detection tasks is higher than on production tasks (Gernand & Moran, 2007; Savage et al., 2006). Savage et al. (2006) noted

Figure 1. Scatter plot and regressions from studies of phonological awareness representing children's percent accuracy on rhyme tasks across ages (Carroll et al., 2003; Corriveau et al., 2010; Lonigan et al., 1998; Maclean et al., 1987). Studies included rhyme-matching tasks, in which participants choose a word from two options that rhymes with a stimulus (Carroll et al., 2003; Maclean et al., 1987), and rhyme oddity tasks, in which participants choose a word from three to four options that does not rhyme with the others (Corriveau et al., 2010; Lonigan et al., 1998; Maclean et al., 1987). The overall regression line considers data points from each study and is included to approximate rhyme development from 40 to 78 months.



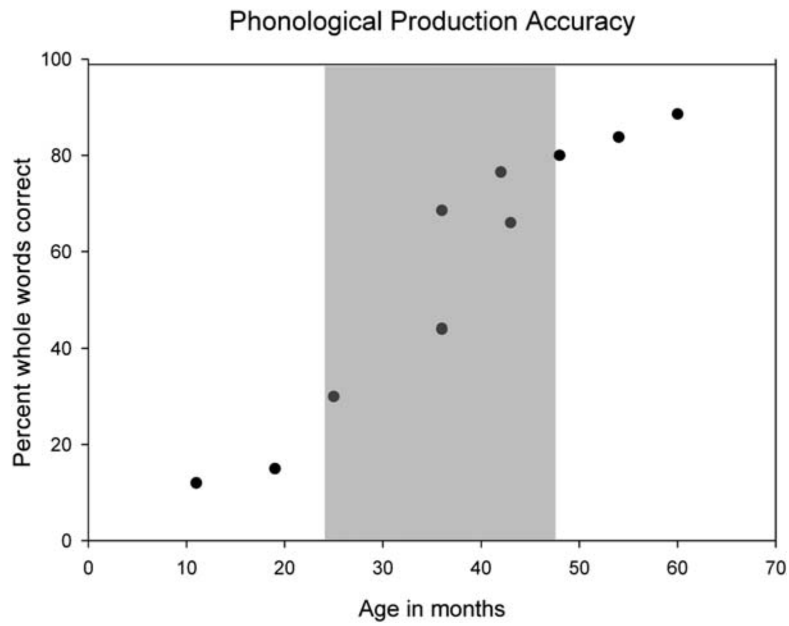
that children ages 3–6 years completed a receptive rhyming discrimination task more accurately than a common unit rhyme production task. In the discrimination task, each child was asked to indicate whether two presented words rhymed or not, whereas for the common unit task, each child was asked to produce the common unit or rime of the two presented words. The current study investigated rhyming skills using both a rhyme discrimination and rhyme production task.

Furthermore, the current study extends investigation of rhyme production from a measurement of task accuracy only to include an analysis of the strategies used to complete the task. Rhyme production tasks do not always limit correct responses to real words. Two studies that included rhyme production tasks accepted real-word and nonword rhymes as correct (Maclean et al., 1987; Schaefer, Stackhouse, & Wells, 2017). However, participants' use of real-word and nonword strategies was not reported. One study that included four typically developing children (ages 5–7 years) reported the proportion of real-word and nonword rhyming responses provided during rhyme production (Marion, Sussman, & Marquardt, 1993). In this study, all of the typically developing children provided more real-word rhymes than nonword rhymes. Incorrect responses were also divided into nonrhymes, no response, and unintelligible. However, none of these three studies investigating rhyme production reported the types of nonrhyming responses, such as whether or not they were real words. Investigating the types of rhyme and nonrhyme production responses may provide a deeper understanding of the processes underlying task accuracy for children with high and low scores. For instance, if a child cannot rhyme but responds to each trial, questions may be asked about what type of response they provided and how they may have arrived at that particular response. Therefore, we extended investigation of rhyme production to include the type of rhyme production strategy used for both correct and incorrect responses.

Stuttering and Phonological Production

During the time period when stuttering onsets are most likely to occur, a child's speech sound production accuracy is increasing dramatically. Figure 2 shows the percent whole words correct a child produces in spontaneous speech, increasing from approximately 30% at age 25 months to approximately 88% at 60 months of age (Rvachew & Brosseau-Lapré, 2018, pp. 164–169; for reviews, see Bunta, Fabiano-Smith, Goldstein, & Ingram, 2009; Ingram, 2002; MacLeod, Laukys, & Rvachew, 2011; Schmitt, Howard, & Schmitt, 1983). This rapid development of accurate speech sound production occurs naturally in most children; however, speech sound disorder (SSD) occurs when a child mispronounces more speech sounds than is typical for their age (American Speech-Language-Hearing Association, 1993). SSD represents the highest proportion of cases seen by speech-language pathologists practicing in pediatric settings (Broomfield & Dodd, 2004; Mullen & Schooling, 2010).

Figure 2. Scatter plot displaying development of phonological production over time in relation to stuttering onset (data from Rvachew & Brosseau-Lapré, 2018, pp. 164–169; for reviews, see Bunta et al., 2009; Ingram, 2002; MacLeod et al., 2011; Schmitt et al., 1983). The gray rectangle represents the onset of stuttering, which usually occurs between 24 and 48 months of age (Yairi & Ambrose, 2013). Phonological production accuracy increases steeply from approximately 30% at 25 months of age to approximately 80% at 48 months of age.



Researchers estimate that 30%–40% of CWS also have a concomitant SSD, and boys who stutter are more likely than girls who stutter to have co-occurring SSD (Blood, Ridenour, Qualls, & Hammer, 2003; Wolk, Conture, & Edwards, 1990). Wolk, Edwards, and Conture (1993) found that a sample of male CWS with SSD produced a greater percentage of sound prolongations and fewer word repetition iterations compared to the CWS without SSD. However, other studies, some with more stringent inclusionary criteria and including female CWS, did not support a relationship between types of disfluencies and SSDs (Gregg & Yairi, 2007, 2012; Yaruss & Conture, 1996).

In a longitudinal study, Paden, Yairi, and Ambrose (1999) investigated the acquisition of phonological skills as it related to persistence or recovery from stuttering. Stuttering status was determined for a cohort of 84 children after following them for at least 2 years post–stuttering onset. Phonology was assessed using data from the first year of participation when the children were between the ages of 2;1 and 4;11 (years;months). Paden et al. concluded that, as a group, children who persisted in stuttering had lower scores on the Assessment of Phonological Processes–Revised (Hodson, 1986) when scores are weighted by age in months, compared to those who would recover. Interestingly, both groups acquired phonological skills in the expected developmental order; however, the children who would persist consistently made more errors in phonological patterns developing in the preschool years than the children who would recover. Similarly, Spencer and Weber-Fox (2014) found that a standardized measure of articulation and performance on a nonword repetition task (Dollaghan & Campbell, 1998) was a predictor of recovery and persistence in preschool CWS. Both Paden et al. and Spencer and Weber-Fox emphasize that their findings are group effects with a wide range of individual differences present. Taken together, these studies suggest that phonological production development may be related to stuttering outcomes in some young children.

Stuttering and Phonological Awareness

In addition to phonological production, phonological awareness has been investigated in CWS. Pelczarski and Yaruss (2014) examined phonological awareness in 10 CWS and 10 children who do not stutter (CWNS) ages 5–6 years using the Phonological Awareness Composite Score of the Comprehensive Test of Phonological Processing (Wagner, Torgesen, & Rashotte, 1999). The three phonological awareness subtests were administered: Sound Matching, Elision, and Blending Words. The Sound Matching subtest is the only one in which the child was presented with a stimulus and provided response options. Pictures were provided on each trial, and the child was asked to point to the picture that starts with the same sound as the target. The Blending Words and Elision subtests required the child to produce a response based on the stimulus provided. For instance, on the Blending Words subtest, the child was asked, "which word do these sounds make" when given constituent parts such as syllables or phonemes (e.g., "can-" /kæn/ and "-dy" /di/—"candy"

/kændi/). On the Elision subtest, the child was asked to remove a sound from a target to create another real word (e.g., say *cup* /kʌp/ without /k/—“up” /ʌp/). All children scored within normal limits for their age on this assessment; however, CWNS scored higher than CWS on the composite score, Blending Words subtest, and Elision subtest, but not the Sound Matching subtest. These findings suggest subtle differences in phonological awareness abilities of CWS, particularly when tasks require the production of a response (Blending Words and Elision subtests) rather than selection of an answer choice (Sound Matching subtest). These findings may reflect less refinement of the underlying phonological representations in CWS (Pelczarski & Yaruss, 2014).

Previous research into the neural underpinnings of phonological processing using event-related potentials (ERPs) and rhyme discrimination tasks reveal differences between people who stutter and age-matched peers at a variety of ages, including adults (Weber-Fox, Spencer, Spruill, & Smith, 2004), children ages 9–13 years (Weber-Fox, Spencer, Cuadrado, & Smith, 2003; Weber-Fox, Spruill, Spencer, & Smith, 2008), and most recently children ages 7–8 years (Mohan & Weber, 2015). This most recent study is significant because the ERPs elicited by rhyming and nonrhyming word pairs distinguished CWS who had recovered at the time of testing from those who were continuing to stutter. One limitation of these ERP studies in children and adults who stutter is that they examine processes mediating rhyme discrimination only, not rhyme production. The current study furthers the investigation of phonological awareness, namely, rhyming, in CWS by including rhyme discrimination and production tasks.

In addition, the current study accounts for how the presence of SSD may impact the relationship between the development of phonological awareness and persistence and recovery in CWS. It has been estimated that up to 30%–40% of CWS may also have an SSD (Wolk et al., 1990). Children with SSD produce more articulation errors than other children of the same age and are particularly at risk of presenting with deficits in phonological awareness (e.g., Raitano, Pennington, Tunick, Boada, & Shriberg, 2004; Rvachew, Ohberg, Grawburg, & Heyding, 2003). There is currently no consensus on the causes of SSD (Munson & Krause, 2017). Nonetheless, Waring and Knight (2013) identified three common subgroups of children in current classification systems of children with SSD based on etiological differences (speech disorders classification system; e.g., Shriberg et al., 2010), psycholinguistic profiles of the children (psycholinguistic framework; Stackhouse & Wells, 1997), and linguistic manifestations of the disorder (differential diagnosis classification system; Dodd, 1995, 2005). The majority of children were classified in the phonological subgroup; smaller groups of children presented with residual speech errors and were in the articulation-based subgroup or presented with motor speech disorders and were in the motor planning/programming subgroup.

As a group, children with SSD have more poorly specified phonological representations than children of the same age with typical speech development and have been found to have more difficulties with phonological processing tasks such as speech perception and phonological awareness skills (Anthony et al., 2011; Rvachew, 2006). It has been proposed that their imprecise underlying phonological representations lead to the production of more omission and substitution errors than children with typical development, as well as difficulties with phonological processing (e.g., Anthony et al., 2010; Rvachew, 2006; Rvachew, Chiang, & Evans, 2007). In the current study, we considered that the presence of SSD may impact developing phonological awareness and prediction of recovery and persistence within the CWS population.

The Current Study

The primary aim of the current study was to examine the developing phonological awareness of 4- to 5-year-old CWS in relation to eventual recovery or persistence in stuttering. We assessed phonological awareness using both rhyme discrimination and rhyme production. Based on earlier findings in older CWS (Mohan & Weber, 2015; Pelczarski & Yaruss, 2014), we predicted that accuracy of rhyme discrimination may not distinguish eventual persistence or recovery from stuttering. However, given the additional demands of retrieval and speech formulation for rhyme production, we predicted that CWS who eventually persisted (CWS-ePer) would display lower accuracy relative to CWNS and CWS who eventually recovered (CWS-eRec). Although slightly lower than CWNS performance, CWS who had recovered and CWS who had persisted at ages 7–8 years demonstrated similar accuracy in rhyme discrimination (Mohan & Weber, 2015). In contrast, earlier findings from phonological awareness tasks, which included speech production, revealed reduced accuracy by CWS relative to CWNS (Pelczarski & Yaruss, 2014). It is important to highlight that the current study investigated children ages 4–5 years who were currently developing rhyming abilities, and therefore, we expected greater variability in performance than in the 5- to 8-year-old children in these previous studies. A CWNS group was included in the current study to interpret differences between CWS-ePer and CWS-eRec. Previous research indicates that CWS-eRec may perform similarly to CWNS or fall between CWNS and CWS-ePer on measures used to predict recovery and persistence (Walsh et al., 2018).

Furthermore, to comprehensively assess the primary aim, we grouped CWS according to their speech sound production abilities in addition to eventual recovery or persistence in stuttering. We know that a significant portion of CWS have a concomitant SSD and that children with SSD have difficulty with phonological awareness skills. Therefore, if rhyme discrimination or production distinguishes eventual stuttering recovery or persistence in children with typical speech production, it is unclear whether this variable would also predict stuttering outcome in CWS with SSD. To investigate this relationship, we compared the performance of CWS-ePer and CWS-eRec with SSD on both of our rhyme tasks.

Finally, the current study was designed to evaluate an additional aspect of rhyme production, specifically the use of rhyme production strategies. Rhyme production has been less extensively researched compared to rhyme discrimination, and few studies reported on the types of correct or incorrect responses generated by participants. The current design allowed us to investigate the types of responses produced by a large sample of 4- to 5-year-old children with a range of phonological awareness skills. This measure provided new depth to the rhyme production task by investigating potential processes underlying task accuracy.

In summary, the current study expanded on previous studies of rhyming in CWS and CWNS in several ways. First, the current study included CWS with a wide range of phonological awareness skills, such as those who exhibit SSD, to be more representative of the CWS population. Second, both rhyme discrimination and rhyme production tasks were included. As mentioned previously, ERP studies in CWS have focused on rhyme discrimination. However, it is recommended that phonological awareness of a particular sublexical unit be assessed with tasks of varying difficulty (Anthony et al., 2003). Finally, in addition to measuring rhyme discrimination and rhyme production task accuracy, we also examined the type of rhyme production strategies used by each child.

Method

Participants

Participants were part of a 5-year longitudinal study as part of the Purdue Stuttering Project conducted at Purdue University and the University of Iowa. Eighty-five children ranging from ages 3;5 to 5;10 at their first visit were included in the current study. Of those children, 37 were CWNS, 19 were CWS-ePer, and 29 were CWS-eRec.

All clinical assessments and diagnoses were completed by a certified speech-language pathologist. The two Purdue Stuttering Project speech-language pathologists at the Purdue University and University of Iowa sites have extensive experience specializing in the diagnosis and treatment of CWS. A participant was diagnosed as stuttering in their first year of participation if they met the following criteria based on Yairi and Ambrose (1999): (a) the child's parent(s) perceived the child as stuttering; (b) the project speech-language pathologist perceived the child as stuttering and rated stuttering severity as a 2 or higher on an 8-point scale where 0–1 was considered typical fluency, 2–3 was considered mild stuttering, 4–5 was considered moderate stuttering, and 6–7 was considered severe stuttering; and (c) the child produced at least three SLDs per 100 syllables in a spontaneous speech sample. In a number of cases (23% of the CWS), the child did not produce three SLDs per 100 syllables, and parents reported that the language samples collected in the laboratory during the parent–child and clinician–child interactions were not representative of the child's disfluencies at home and in other contexts. This description is consistent with reports that stuttering can vary across situations (Yaruss, 1997). In these cases, the project speech-language pathologist assessed the child's fluency throughout additional interactions during the visits to the lab. This included several contexts, for example, first meeting with the child during lab tours and transitions between labs, and during other speech and language assessments. The speech-language pathologist's diagnosis of stuttering in these cases was then based on the observed frequency and characteristics of SLDs, which exceeded that of typical fluency. Characteristics of SLDs included factors such as number of iterations, presence of respiratory irregularities, tension, abnormal intonation patterns, and/or pauses.

Formation of Groups

Five groups were formed to account for stuttering status and SSD. CWS were followed for 12–48 months after their initial visit. Each year of participation, they were evaluated for stuttering based on criteria from Yairi and Ambrose (1999) mentioned previously. CWS were divided into the CWS-ePer and CWS-eRec groups based on the assessment of stuttering in their last year of participation. Children were considered recovered from stuttering if they met the following criteria: (a) the child's parent(s) no longer perceived the child as stuttering; (b) the project speech-language pathologist no longer perceived the child as stuttering and stuttering severity was rated as a 1 or lower on the 8-point scale where 0–1 was considered typical fluency, 2–3 was considered mild stuttering, 4–5 was considered moderate stuttering, and 6–7 was considered severe stuttering; and (c) the child produced less than three SLDs per 100 syllables in a spontaneous speech sample. A CWS participant was considered to be persisting unless he or she met all of the above recovery criteria. Of the 48 CWS, 29 eventually recovered from stuttering (CWS-eRec) and 19 eventually persisted (CWS-ePer). Information about length of participation, age at first and last year of participation, therapy by the first year of participation, and family history of recovery and persistence from stuttering can be found for each CWS participant in Table 1.

Groups were further divided based on the presence or absence of SSD in their first year of participation when the rhyme tasks of interest (described below) were administered. Children assigned to the SSD groups scored below a standard score of 85 on the Consonant Inventory and/or the Phonological Processes Inventory of the Bankson–Bernthal Test of Phonology (BBTOP; Bankson & Bernthal, 1990). All CWS and CWNS, including those assigned to the SSD group, passed an oral–motor screening assessment and therefore did not present with a motor–speech disorder (Robbins & Klee, 1987). CWS-eRec and CWS-ePer groups were subdivided into those with SSD and typical speech (TS). Consistent with estimates from the literature, the overall percentage of CWS in our sample with a concomitant SSD was 44%. Of the CWS-eRec, 11 had SSD (CWS-eRec-SSD) and 18 had TS (CWS-eRec-TS). Of

Table 1. Characteristics of participants who stutter.

CWS	Gender	Family history of stuttering	Age first year	Speech production abilities first year	Therapy received by first year	Years in study	Age final year	Stuttering status final year	Speech production abilities final year
CWS 1	M	N	4;0	WNL	N	5	8;3	Persisting	n/a
CWS 2	M	N	4;10	WNL	N	3	6;11	Persisting	n/a
CWS 3	M	Adopted	4;2	WNL	L	2	5;2	Persisting	n/a
CWS 4	M	Per	4;2	WNL	N	2	5;4	Persisting	n/a
CWS 5	F	Rec	4;4	WNL	N	4	7;5	Persisting	n/a
CWS 6	M	Y–Unspecified	5;8	WNL	S, A	4	8;11	Persisting	n/a
CWS 7	M	Per	4;0	WNL	S	3	6;7	Persisting	n/a
CWS 8	F	Y–Unspecified	4;11	WNL	S, A	4	8;0	Persisting	n/a
CWS 9	M	Adopted	5;8	WNL	S	4	8;9	Persisting	n/a
CWS 10	M	N	5;6	WNL	S	4	8;7	Recovered	n/a
CWS 11	F	Per	4;1	WNL	S, A	5	8;4	Recovered	n/a
CWS 12	M	N	4;7	WNL	N	3	6;8	Recovered	n/a
CWS 13	M	N	5;1	WNL	N	5	9;5	Recovered	n/a
CWS 14	M	N	3;9	WNL	S	3	6;2	Recovered	n/a
CWS 15	M	N	4;7	WNL	N	5	8;8	Recovered	n/a
CWS 16	M	N	4;9	WNL	N	5	8;10	Recovered	n/a
CWS 17	F	N	4;2	WNL	N	5	8;3	Recovered	n/a
CWS 18	M	Adopted	4;0	WNL	N	4	7;4	Recovered	n/a
CWS 19	M	N	5;9	WNL	N	4	8;9	Recovered	n/a
CWS 20	M	N	4;8	WNL	N	5	8;10	Recovered	n/a
CWS 21	F	Adopted	4;11	WNL	N	3	7;0	Recovered	n/a
CWS 22	F	N	3;11	WNL	N	4	6;10	Recovered	n/a
CWS 23	F	N	4;10	WNL	N	4	7;11	Recovered	n/a
CWS 24	F	Per	4;10	WNL	N	4	7;10	Recovered	n/a
CWS 25	M	Y–Unspecified	4;7	WNL	S	3	6;10	Recovered	n/a
CWS 26	M	N	4;0	WNL	N	2	5;1	Recovered	n/a
CWS 27	M	Rec	3;11	WNL	N	4	7;1	Recovered	n/a
CWS 28	M	Per	5;7	SSD	S	5	9;7	Persisting	Normalized
CWS 29	M	Per	4;1	SSD	N	5	8;4	Persisting	SSD
CWS 30	F	Y–Unspecified	4;1	SSD	N	5	8;1	Persisting	Normalized
CWS 31	M	N	5;1	SSD	S, A, L	4	8;2	Persisting	Normalized
CWS 32	M	Per	5;0	SSD	S, A	3	7;1	Persisting	SSD
CWS 33	M	Y–Unspecified	5;5	SSD	A	2	6;6	Persisting	SSD
CWS 34	M	N	4;0	SSD	S, A	5	8;2	Persisting	SSD
CWS 35	M	N	5;3	SSD	A	3	7;4	Persisting	SSD
CWS 36	F	Y–Unspecified	4;10	SSD	Y–Unspecified	3	6;7	Persisting	SSD
CWS 37	M	u/a	4;8	SSD	N	3	6;10	Persisting	SSD
CWS 38	M	Rec	4;0	SSD	S, A	3	6;1	Recovered	SSD
CWS 39	M	N	3;10	SSD	A	5	8;7	Recovered	SSD
CWS 40	M	Y–Unspecified	3;6	SSD	N	5	8;4	Recovered	Normalized
CWS 41	F	No	4;1	SSD	S, A	5	8;3	Recovered	Normalized
CWS 42	M	Per	4;5	SSD	A	4	7;7	Recovered	Normalized
CWS 43	F	N	4;6	SSD	N	4	7;7	Recovered	Normalized
CWS 44	M	N	4;6	SSD	A	4	7;8	Recovered	SSD
CWS 45	M	N	4;7	SSD	S, A	3	6;8	Recovered	SSD
CWS 46	M	N	4;9	SSD	S, A	5	8;11	Recovered	SSD
CWS 47	M	N	3;5	SSD	L	2	4;6	Recovered	SSD
CWS 48	M	N	5;1	SSD	N	4	8;2	Recovered	SSD

Note. M = male; F = female; Per = persistence; Rec = recovery; Y–Unspecified = positive report of treatment services or family history of stuttering but no additional details provided to describe type of services or stuttering outcome; Adopted = history of stuttering not known for biological family; N = none; u/a = unavailable; WNL = within normal limits; SSD = speech sound disorder; S = stuttering therapy; L = language therapy, A = articulation therapy; n/a = not applicable; Normalized = normalized speech production abilities by final year of participation.

the CWS-ePer, 10 had SSD (CWS-ePer-SSD) and nine had TS (CWS-eRec-TS). Information about whether each CWS participant with SSD normalized their speech production abilities by the final year of participation is in Table 1. CWNS were required to demonstrate articulation abilities within normal limits on both inventories. Mean scores on the BBTOP inventories for the five groups are reported in Table 2.

The five groups (CWNS, CWS-eRec-TS, CWS-eRec-SSD, CWS-ePer-TS, and CWS-ePer-SSD) were matched for age, $F(4, 80) = 2.18$, $p = .08$, mother's level of education, $F(4, 80) = 2.23$, $p = .07$, and nonverbal intelligence, $F(4, 80) =$

Table 2. Age, socioeconomic status, nonverbal intelligence, language, and speech production abilities of participants at initial year of participation.

Group	*n* (female)	Age in months *M* (*SE*)	MLE *M* (*SE*)	CMMS *M* (*SE*)	TACL-3 *M* (*SE*)	BBTOP-CI *M* (*SE*)	BBTOP-PPI *M* (*SE*)
CWNS	37 (12)	57.24 (1.07)	6.08 (0.18)	113.05 (1.58)	119.38 (2.43)	103.08 (1.38)	103.78 (1.69)
CWS-eRec-TS	18 (6)	54.61 (1.59)	6.33 (0.18)	108.78 (2.29)	113.94 (3.04)	103.39 (1.71)	102.11 (2.26)
CWS-eRec-SSD	11 (2)	50.91 (1.89)	5.55 (0.34)	110.36 (2.67)	115.30 (4.41)[a]	79.00 (1.91)	81.09 (2.77)
CWS-ePer-TS	9 (2)	55.67 (2.68)	5.44 (0.29)	113.22 (1.82)	112.11 (4.57)	97.78 (2.23)	98.11 (2.03)
CWS-ePer-SSD	10 (2)	57.60 (2.19)	5.50 (0.34)	104.50 (2.76)	108.20 (5.47)	79.10 (3.11)	74.30 (2.59)

Note. MLE = mother's level of education as measured by the Hollingshead Education Scale (Hollingshead, 1975); CMMS = Columbia Mental Maturity Scale (Burgemeister et al., 1972); TACL-3 = Test for Auditory Comprehension of Language–Third Edition Quotient score (Carrow-Woolfolk, 1999); BBTOP-CI/PPI = Consonant Inventory and Phonological Processes Inventory of the Bankson–Bernthal Test of Phonology (Bankson & Bernthal, 1990); CWNS = children who do not stutter; CWS-eRec-TS = children who stutter and eventually recovered with typical speech; CWS-eRec-SSD = children who stutter and eventually recovered with speech sound disorder; CWS-ePer-TS = children who stutter and eventually persisted with typical speech; CWS-ePer-SSD = children who stutter and eventually persisted with speech sound disorder.

[a] *n* = 10 because one participant did not complete all subtests to calculate the TACL-3 Quotient score.

2.15, $p = .08$. Nonverbal intelligence was measured using the Columbia Mental Maturity Scale (Burgemeister, Blum, & Lorge, 1972). Socioeconomic status (SES) was estimated from the mother's level of education using the Hollingshead Education Scale (Hollingshead, 1975). This scale provides a score starting at 1, which represents "less than seventh grade," through 7, which represents "graduate professional training (graduate degree)" (Hollingshead, 1975). Matching for SES was particularly important as differences in rhyming abilities have been noted in 3- to 5-year-old children when divided into groups based on SES (Lonigan et al., 1998).

Finally, receptive language was assessed using the Test for Auditory Comprehension of Language–Third Edition (TACL-3; Carrow-Woolfolk, 1999). The TACL-3 is made up of three subtests (Vocabulary, Grammatical Morphemes, and Elaborated Phrases and Sentences), which combine to provide an overall quotient measure. One participant in the CWS-ePer-SSD group did not complete the Elaborated Phrases and Sentences subtest and therefore does not have a quotient score. Groups were matched on the TACL-3 overall quotient score, $F(4, 79) = 1.47$, $p = .22$, as well as the scaled scores for the Vocabulary subtest, $F(4, 80) = 0.29$, $p = .88$; the Grammatical Morphemes subtest, $F(4, 80) = 1.54$, $p = .20$; and the Elaborated Phrases and Sentences subtest, $F(4, 79) = 1.75$, $p = .15$. Group means for age, SES, Columbia Mental Maturity Scale standard score, and TACL-3 quotient score are reported in Table 2.

Rhyme Tasks

Tasks for the current study were taken from the Phonological Awareness Test–Second Edition, which is designed to assess a variety of phonological awareness skills related to literacy (Robertson & Salter, 2007). Specifically, we used the Rhyming Subtest of the Phonological Awareness Test–Second Edition, which assesses rhyme discrimination and rhyme production abilities. Both tasks were administered in accordance with the test manual. During the rhyme discrimination task, the child listened to two words and decided whether the words rhymed by answering "yes" or "no." During the rhyme production task, the child listened to a stimulus word and provided a word that rhymes with the stimulus. Both the discrimination and production tasks included one practice item with feedback followed by 10 test items. Correct trials out of 10 were recorded for each subtest. On the production task, children were instructed that they could provide a real word or nonword that rhymed with the stimulus word. For instance, if the stimulus word was "cat" /kæt/, children received credit for producing a real word such as "bat" /bæt/ or a nonword such as "blat" /blæt/. Furthermore, the rhyme production task was compared to the results of the BBTOP, and participants were given credit for answers that would rhyme but contained identified phonological processes or errors. For instance, a child with documented stopping of fricatives would receive credit for "mother" pronounced /mʌdɚ/ in response to the stimulus brother /bɹʌðɚ/. BBTOPs were consulted for five participants (one CWNS, two CWS-eRec-TS, and two CWS-ePer-TS), and documented errors allowed additional credit in three cases (one CWS-eRec-TS and two CWS-ePer-TS).

The words produced by the children during the rhyme production task were documented in writing for all participants except two CWNS where only a score was provided. The responses given by the children were categorized based on the strategy by which the child arrived at their response. Children demonstrated a wide variety of correct and incorrect responses to the 10 rhyme production prompts. Correct responses could be obtained by creating a real English word (real-word correct strategy) or a nonword (nonword correct strategy) that rhymed with the prompt. Incorrect responses were more variable containing strategies such as attempts at rhyming real words (e.g., "pan"–"hand"), attempts at rhyming nonwords (e.g., "shower"–"crowber"), semantic associations (e.g., "bark"–"dog"), cue repetition (e.g., "kite"–"kite"), and a variety of nonresponses (e.g., "I don't know"). There were also trials in which no clear strategy could be identified (e.g., "brother"–"bubble," "shower"–"kitten," "kite"–"rat").

The current analyses focused on the following top four identifiable strategies, which captured 73% of the overall responses: real-word correct, nonword correct, semantic association, and cue repetition strategies. The remaining 27% of responses were trials with no clear strategy (18%), nonresponses (4%), and the remaining incorrect strategies (5%).

Data Analysis

Task Accuracy

The rhyme discrimination and rhyme production scores were not normally distributed and showed skewed or bimodal distributions. These distributions suggested that, at this age, participants who could rhyme performed with high accuracy whereas those who were still developing rhyming abilities performed with low accuracy. As a result, there were few scores in the midrange. Given these distributions, nonparametric statistical assessments were utilized. To determine whether the five groups differed in rhyme production or rhyme discrimination accuracy, a separate Kruskal–Wallis test was completed for each task. Significance values were set at $p < .05$. When significant group differences were detected, pairwise comparisons were completed to determine differences between specific groups. To determine the relationship between task accuracy and stuttering outcome, comparisons were made between groups that eventually recovered and those that eventually persisted (CWS-ePer-TS to CWS-eRec-TS, CWS-ePer-SSD to CWS-eRec-SSD). In addition, to understand how task accuracy may differ between CWNS and CWS, each CWS group was compared to the CWNS group (CWNS to CWS-ePer-TS, CWS-eRec-TS, CWS-ePer-SSD, CWS-eRec-SSD). A total of six pairwise comparisons were made for each task using Mann–Whitney *U* tests. The Bonferroni corrected *p* value for the post hoc comparisons was $p = .008$. IBM SPSS Statistics (Version 24) was used for these analyses.

Rhyme Production Strategies

Interrater reliability of rhyme production strategy categorization was performed on 17 participants (21% of the sample). Agreement between a trained second rater and the first author was 94%. Negative binomial regression was used to evaluate the rhyme production strategies of each group where the count of each of the four primary strategies is the outcome in four separate regression models (Long, 1997). Models were also estimated separately for participants with and without SSD, resulting in eight separate negative binomial regressions. The count outcomes were not normally distributed and followed a Poisson distribution. Tests showed that there was overdispersion for the counts of each of the four strategies, and therefore, negative binomial regression was used as a correction (Long, 1997). Age, mother's level of education, and nonverbal intelligence were controlled for in all models. Effects were interpreted as incidence rate ratios, which are obtained by exponentiating the raw coefficients (expected log counts). Incident rate ratios, which reflect effect size, give the rate of use of a specific strategy for one group versus another group over the trials. Therefore, the negative binomial regression allowed us to test rhyme production strategies used as a function of stuttering outcome (eventually recovered, eventually persisted, typically fluent). Stata (Version 15) was used for these analyses (StataCorp, 2017).

In addition, the proportion of responses made using each strategy was calculated for each group to provide a group-specific description of strategy use. Individual patterns of strategy use on correct trials were also explored to ensure that the group-specific description of strategy use was not driven by a few high-performing participants. For example, because correct trials must be either real words or nonwords, a highly accurate participant who uses only one strategy (e.g., 10 correct trials all achieved by the real-word correct strategy) could influence the group patterns more readily than a less accurate participant who uses both the real-word and nonword correct strategies (e.g., two correct trials with one achieved by each strategy). Individual patterns were investigated by calculating the number of individuals in each group using the real-word and nonword strategy equally (RW = NW), the real-word strategy more than the nonword strategy (RW > NW), or the nonword strategy more than the real-word strategy (NW > RW) on correct trials. Reported percentages are rounded to the nearest whole number.

Results

Average scores and standard deviations of the rhyme discrimination and rhyme production task for each group are presented in Table 3. One CWNS completed the rhyme discrimination task but did not complete the rhyme production task. Kruskal–Wallis tests revealed differences between the groups on the rhyme discrimination task, $\chi^2(4) = 9.93$, $p = .04$, and the rhyme production task, $\chi^2(4) = 15.22$, $p < .01$. Mann–Whitney *U* pairwise comparisons with a Bonferroni-corrected *p* value ($p = .008$) were used to

Table 3. Performance on the rhyme tasks by group.

	Rhyme Discrimination			Rhyme Production		
Group	*n*	*M* (*SE*)	Range	*n*	*M* (*SE*)	Range
CWNS	37	7.89 (0.35)	3–10	36	6.19 (0.65)	0–10
CWS-eRec-TS	18	7.56 (0.49)	3–10	18	5.72 (0.95)	0–10
CWS-eRec-SSD	11	6.64 (0.62)	4–10	11	1.91 (0.94)	0–9
CWS-ePer-TS	9	8.56 (0.53)	6–10	9	6.00 (1.45)	0–10
CWS-ePer-SSD	10	6.20 (0.55)	4–9	10	2.10 (0.97)	0–8

Note. Rhyme Discrimination and Rhyme Production subtests of the Phonological Awareness Test–Second Edition (Robertson & Salter, 2007). CWNS = children who do not stutter; CWS-eRec-TS = children who stutter and eventually recovered with typical speech; CWS-eRec-SSD = children who stutter and eventually recovered with speech sound disorder; CWS-ePer-TS = children who stutter and eventually persisted with typical speech; CWS-ePer-SSD = children who stutter and eventually persisted with speech sound disorder.

further investigate the differences between specific groups on each task. Results of the six comparisons made for each task are displayed in Figure 3 and described below.

Rhyme Discrimination

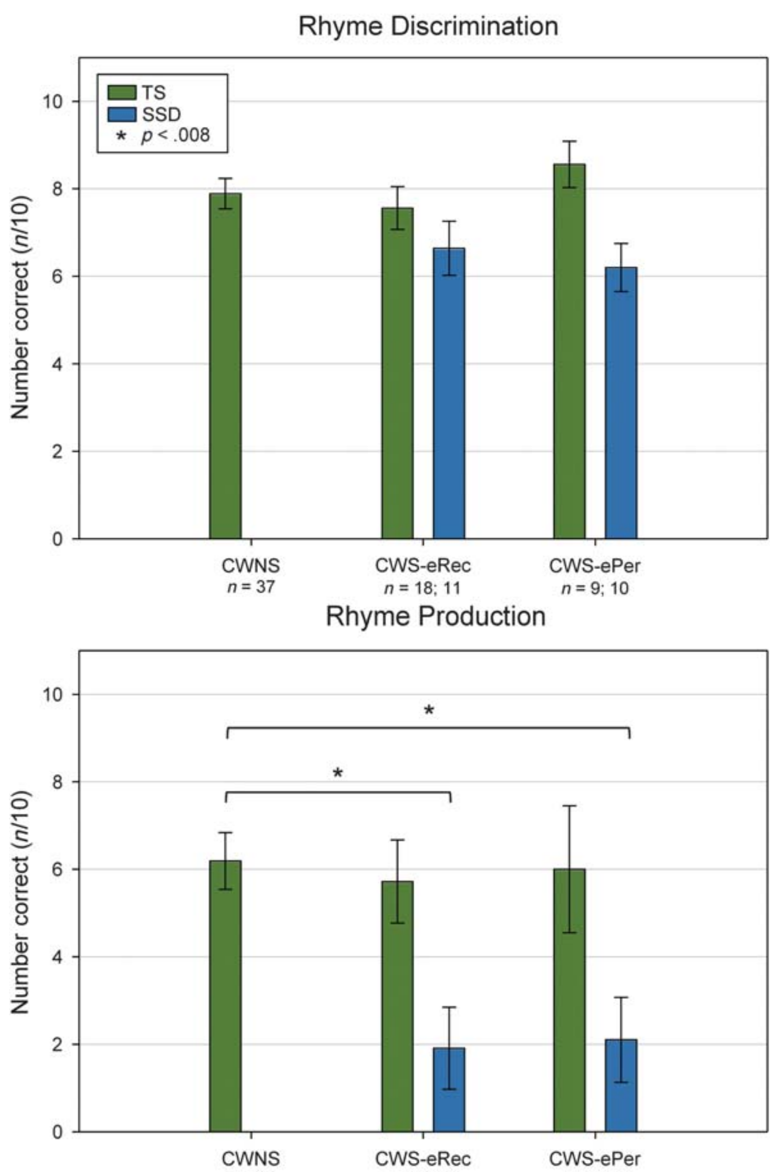
CWS who eventually persisted performed similarly to those who eventually recovered on the rhyme discrimination task, CWS-ePer-TS and CWS-eRec-TS ($U = 58.50$, $z = -1.19$, $p = .25$) and CWS-ePer-SSD and CWS-eRec-SSD ($U = 48.50$, $z = -0.46$, $p = .65$). In addition, all CWS groups performed similarly to CWNS, CWNS and CWS-ePer-TS ($U = 145.50$, $z = -0.60$, $p = .57$), CWNS and CWS-eRec-TS ($U = 290.00$, $z = -0.79$, $p = .43$), CWNS and CWS-ePer-SSD ($U = 98.00$, $z = -2.31$, $p = .02$), and CWNS and CWS-eRec-SSD ($U = 132.50$, $z = -1.78$, $p = .08$).

Rhyme Production

Accuracy

CWS who eventually persisted performed similarly to those who eventually recovered on the rhyme production

Figure 3. Differences between groups on the rhyme discrimination and rhyme production tasks. Our six post hoc pairwise comparisons with conservative Bonferroni-corrected *p* value ($p = .008$) revealed that groups performed similarly on the rhyme discrimination task. On the rhyme production task, groups with typical speech (TS) performed with similar accuracy; however, the groups of CWS (children who stutter) with speech sound disorder (SSD) performed significantly lower than children who do not stutter (CWNS). CWS-eRec = children who stutter and eventually recovered; CWS-ePer = children who stutter and eventually persisted.



task, CWS-ePer-TS and CWS-eRec-TS (U = 76.00, z = −0.26, p = .82) and CWS-ePer-SSD and CWS-eRec-SSD (U = 51.50, z = −0.27, p = .81). CWS groups with TS scored similarly to CWNS on the rhyme production task, CWNS and CWS-ePer-TS (U = 157.00, z = −0.14, p = .90) and CWNS and CWS-eRec-TS (U = 296.50, z = −0.51, p = .61). However, CWNS scored higher than the two CWS groups with SSD on the rhyme production task, CWNS and CWS-ePer-SSD (U = 71.00, z = −2.95, $p < .008$) and CWNS and CWS-eRec-SSD (U = 86.00, z = −2.85, $p < .008$).

Strategies

We examined the incidence rate ratio to test differences across groups in the rate of rhyme production responses made using the following strategies: real-word correct, nonword correct, semantic association, and repeated cues. Table 4 contains the results of all eight negative binomial regressions comparing groups on the use of rhyme production strategies. Negative binomial regression interpreted as incident rate ratios revealed that, as a group, CWS-ePer-TS were more likely to use nonword correct strategy compared to the CWNS. Their rate of using this strategy was 1.88 times the rate for CWNS (p = .02). The comparisons of strategy use between CWS-eRec-TS and CWNS and between CWS-eRec-TS and CWS-ePer-TS were not significant for any rhyme production strategies, including the nonword correct strategy. This indicates that strategy use was similar for CWNS and CWS-eRec-TS and for CWS-eRec-TS and CWS-ePer-TS. For further description and to understand how CWS-eRec-TS compared to the other groups, proportion of strategy use for each group was calculated and is illustrated in Figure 4. CWS-ePer-TS used the nonword correct strategy on 44% of trials, whereas CWNS used it on 32% of trials. CWNS used the real-word correct strategy on 33% of trials, whereas CWS-ePer-TS used it on 16% of the trials. Although CWS-ePer-TS performed with the same accuracy as CWNS on the rhyme production task, they relied more heavily on the nonword correct strategy than CWNS. CWS-eRec-TS used the nonword correct strategy on 32% of trials, which was the same percentage as CWNS; however, they fell between CWNS and CWS-ePer-TS on use of the real-word correct strategy at 26% of trials. CWS-eRec-SSD and CWS-ePer-SSD relied on the repeated cues strategy at 35% and 34% of trials, respectively. By comparison, CWNS used repeated cues on only 4% of trials. All groups were similar in their use of the semantic association strategy, ranging from 7% to 15% in each group.

For correct trials, individual patterns of strategy use were also explored. Figure 5 shows the percentage of individuals within each group using the real-word and nonword strategy equally (RW = NW), the real-word strategy more often than the nonword strategy (RW > NW), and the nonword strategy more than the real-word strategy (RW < NW). Also illustrated is the percentage of individuals in each group that did not obtain any correct trials. CWNS and CWS-eRec-TS showed mixed patterns of strategy use on correct trials, with a majority of the individuals using RW > NW; however, each of the participants in the CWS-ePer-TS group with correct trials used the nonword correct strategy more often than the real-word correct strategy (RW < NW). Similarly, all CWS-ePer-SSD with correct trials used the nonword correct strategy equally

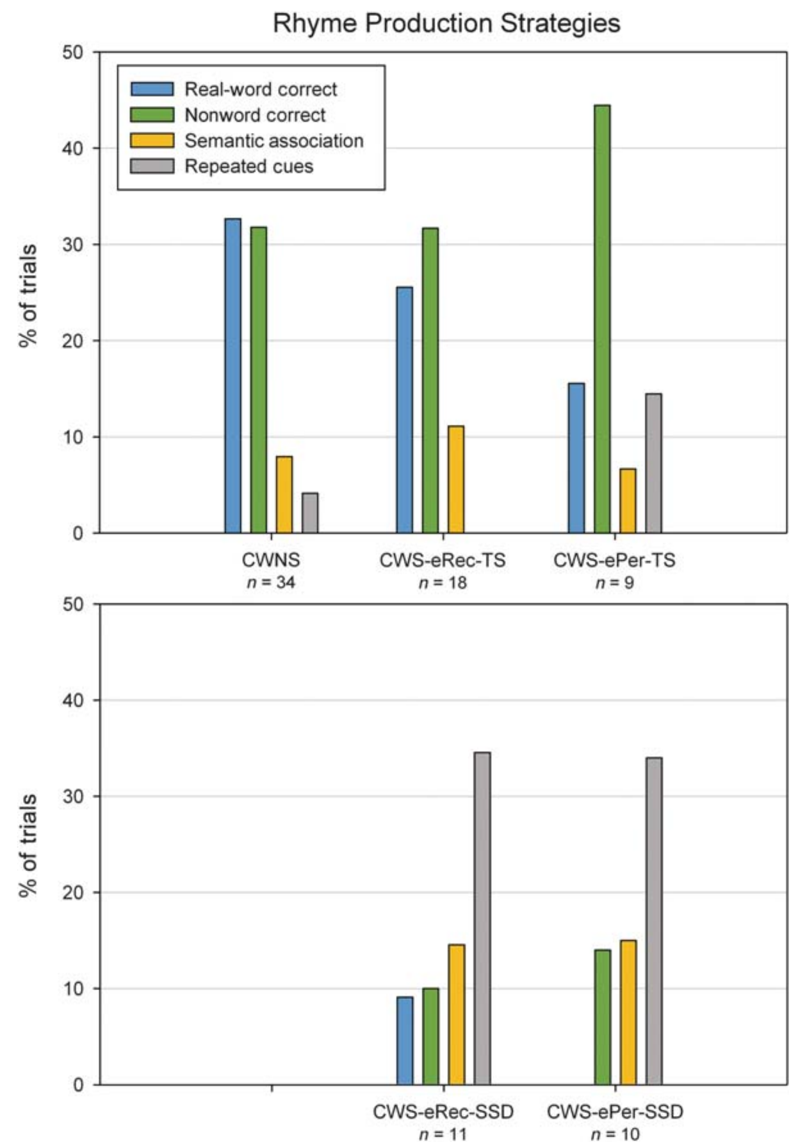
Table 4. Results of the negative binomial regression for rhyme production strategies.

Group comparisons	Groups with typical speech[a] IRR	Groups with typical speech[a] p	Groups with speech sound disorder[b] IRR	Groups with speech sound disorder[b] p
Real-word correct strategy				
CWS-ePer vs. CWNS	0.60	.14	n/a	n/a
CWS-eRec vs. CWNS	0.92	.73	n/a	n/a
CWS-eRec vs. CWS-ePer	1.54	.25	1.69	.46
Nonword correct strategy				
CWS-ePer vs. CWNS	1.88	.02*	n/a	n/a
CWS-eRec vs. CWNS	1.12	.62	n/a	n/a
CWS-eRec vs. CWS-ePer	0.60	.09	0.89	.94
Semantic association strategy				
CWS-ePer vs. CWNS	0.38	.33	n/a	n/a
CWS-eRec vs. CWNS	0.62	.55	n/a	n/a
CWS-eRec vs. CWS-ePer	1.64	.65	1.32	.68
Repeated cues strategy				
CWS-ePer vs. CWNS	3.63	.32	n/a	n/a
CWS-eRec vs. CWNS	0.00	.99	n/a	n/a
CWS-eRec vs. CWS-ePer	0.00	.99	0.38	.40

Note. IRR = incident rate ratio; CWS-ePer = children who stutter and eventually persisted; CWNS = children who do not stutter; n/a = not applicable; CWS-eRec = children who stutter and eventually recovered.

[a]n = 61 for the four models including groups with typical speech. [b]n = 21 for the four models including groups with speech sound disorder. *$p < .05$.

Figure 4. Percentage of responses from each group that used the following rhyme production strategies: real-word correct, nonword correct, semantic association, and repeated cues. The upper graph shows groups with typical speech (TS), and the lower graph shows groups with speech sound disorder (SSD). Although the CWNS (children who do not stutter) and CWS-ePer-TS (children who stutter and eventually persisted with typical speech) performed similarly on the rhyme production task, a greater proportion of correct responses from CWS-ePer-TS were achieved through nonword correct trials than real-word correct trials. CWS-eRec-TS = children who stutter and eventually recovered with typical speech; CWS-eRec-SSD = children who stutter and eventually recovered with speech sound disorder; CWS-ePer-SSD = children who stutter and eventually persisted with speech sound disorder.

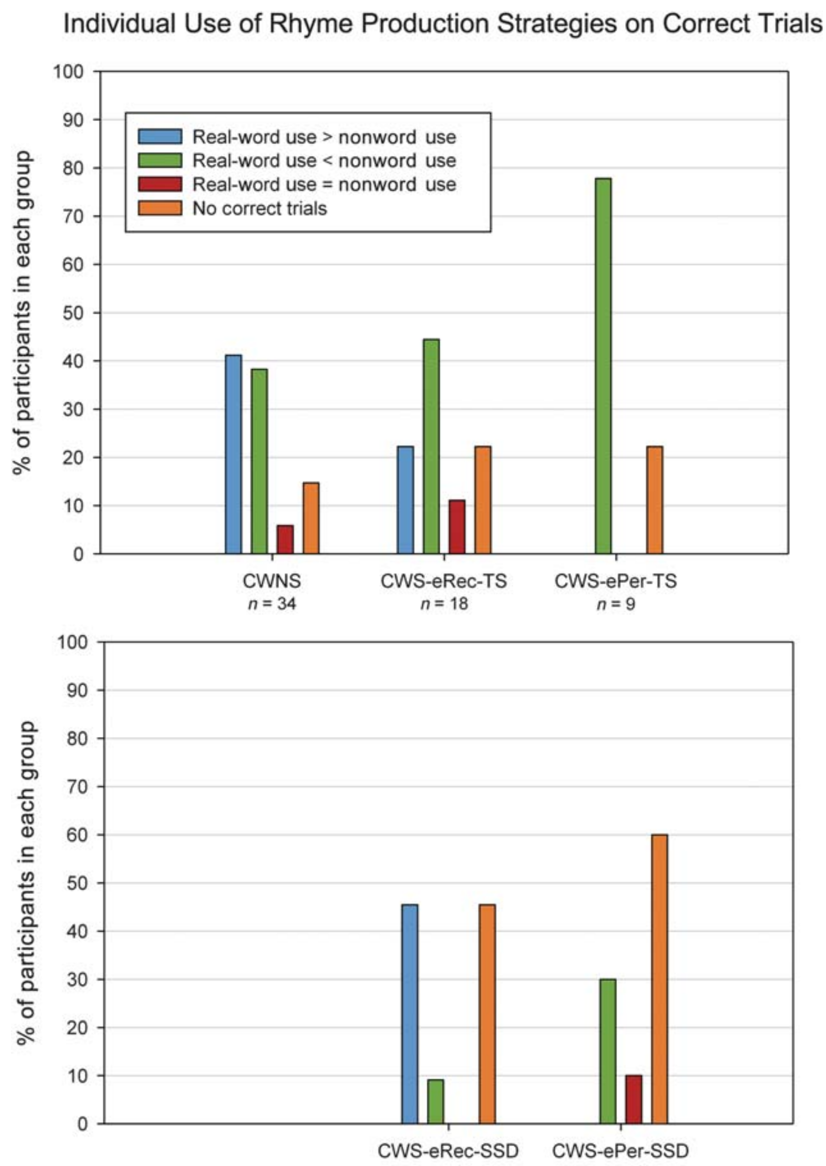


(RW = NW) or more often than the real-word correct strategy (RW < NW).

Discussion

The primary aim of the current study was to examine the developing phonological awareness of 4- to 5-year-old CWS in relation to eventual recovery or persistence in stuttering. The current study evaluated whether proficiency in rhyme discrimination and rhyme production, as well as rhyme production strategy use, may help predict recovery or persistence in young CWS. Consistent with previous estimates, 44% of the current CWS sample demonstrated a concomitant SSD (Wolk et al., 1990). Therefore, to account for the influence of SSD on phonological awareness skills, five groups determined by stuttering outcome and speech sound development were assessed. Analyses focused on comparing groups who eventually recovered to

Figure 5. Participant patterns of rhyme production strategy use on correct trials. The upper plot shows groups with typical speech, and the lower plot shows groups with speech sound disorder (SSD). Although the groups with typical speech demonstrated similar performance on the rhyme production task, individual CWNS (children who do not stutter) and CWS-eRec-TS (children who stutter and eventually recovered with typical speech) demonstrated mixed patterns of strategy use compared to individual CWS-ePer-TS (children who stutter and eventually persisted with typical speech). None of the individual CWS-ePer-TS or CWS-ePer-SSD (children who stutter and eventually persisted with speech sound disorder) used the real-word correct strategy more than the nonword correct strategy. CWS-eRec-SSD = children who stutter and eventually recovered with speech sound disorder.



those who eventually persisted and comparing CWS groups to the CWNS group. No group differences were found for the rhyme discrimination task. Similarly, no differences were found for rhyme production accuracy between the groups of CWS who eventually recovered and the groups of CWS who eventually persisted. However, CWS who also displayed SSD (CWS-eRec-SSD, CWS-ePer-SSD) performed less accurately on the rhyme production task compared to typically fluent controls (CWNS). While the score on the rhyme production task did not differentiate the CWS who eventually recovered from those who eventually persisted, the strategies they used to create rhymes (real word vs. nonword) distinguished the groups. The CWS who eventually persisted with typical speech sound development utilized a nonword rhyme production strategy to a greater extent than the typically fluent control children.

Rhyme Discrimination

Differences between groups of interest did not reach significance on the rhyme discrimination task. All group means were above chance, and 69 of the children (81% of the sample) scored above chance on the task. The high accuracy of the large majority of the sample suggests that most participants at this age had phonological representations that were refined at least to the level of onset and rime resulting in accurate rhyme judgments. However, 16 children (19% of the sample) scored at or below chance. This finding suggests that the rhyme discrimination skill was still developing at this age in some of the participants, both CWNS and CWS.

The results of the rhyme discrimination task utilized in the current study indicate that the majority of participants, both CWNS and CWS, had developed basic detection abilities. The rhyme discrimination task required analysis and judgment of two stimulus words and a simple "yes" or "no" response. It is possible that other rhyme awareness tasks that require additional phonological analyses may have revealed group differences. Previous studies of children with typical development investigated rhyme awareness between 2 and 5 years of age with tasks such as rhyme oddity and rhyme matching, which required analysis and comparison of up to four stimulus words (Carroll et al., 2003; Corriveau et al., 2010; Lonigan et al., 1998; Maclean et al., 1987). These studies suggest that many children within our 4- to 5-year age range could complete rhyme judgment tasks with greater complexity. Also, the current rhyme discrimination task tested phonological representations at the level of onset and rime. Testing a further refined representation, such as individual phonemes, would be more challenging for children at this age and therefore may result in greater variability in task accuracy. Specifically, a more challenging task may result in more scores toward the midrange, which we did not see in the skewed and bimodal distributions. It is also possible that a more graded measure of rhyme processing, such as ERPs, could detect group differences. The behavioral measures used in the current study focus only on response accuracy, whereas ERPs can index subtle differences in underlying neural activity and have resulted in differences related to recovery and persistence in stuttering (Mohan & Weber, 2015).

Rhyme Production

Accuracy

No differences in rhyme production accuracy were found when comparing groups with similar speech sound development. The three groups with typical speech scored similarly to one another as did the two groups with SSD. However, both CWS groups with SSD scored lower than CWNS. Lower performance by children with SSD compared to CWNS on phonological awareness tasks is consistent with previous findings that indicated this population may have poorly specified phonological representations, which lead to difficulty in phonological awareness (Anthony et al., 2011; Rvachew, 2006).

Strategy

Strategies used to formulate and produce rhymes differentiated groups with typical speech sound development. While the CWS-ePer-TS group performed with the same rhyme production accuracy compared to the CWNS group, they relied more heavily on the nonword correct strategy. As a group, CWS-ePer-TS used the nonword correct strategy at approximately twice the rate of CWNS. No differences were noted in the use of rhyme production strategies between CWS-eRec-TS and CWNS.

The difference in use of the real-word and nonword strategies may be due to factors such as the activation and organization of phonological networks within the lexicon. The rhyme production task required the participant to listen to the stimulus, analyze the acoustic–phonetic representation of the stimulus, identify the rime, generate that rime in a new form, access the articulatory–phonetic representation for that form, and finally produce a response. The lexical restructuring hypothesis predicts that, upon hearing the stimulus word, a child may activate a network of phonological representations in the mental lexicon, which sound similar to the stimulus (same initial phoneme, onset, rime, etc.; Metsala, 1997). If a child's phonological representations are organized around common sublexical units, an efficient approach to the rhyme production task would be to search the activated network for a word that rhymes. This approach would result in the real-word correct strategy. However, none of the 82 children completed the rhyme production task using the real-word strategy exclusively. In fact, individuals in each group showed different patterns of real-word correct and nonword correct strategy use. Forty-one percent of CWNS and 22% of CWS-eRec-TS used real-word correct strategy more often than the nonword correct strategy. However, each of the CWS-ePer-TS with correct responses used the nonword correct strategy more often than the real-word correct strategy. The difference in patterns of strategy use suggests that, as a group, CWS-ePer-TS have phonological representations that may be underspecified compared to their CWNS peers. Specifically, refinement and flexibility of phonological representations may play a role in the differences in rhyme production strategy between groups. This idea is supported by other studies in which CWS were challenged by processing and manipulating phonological representations. Byrd, Conture, and Ohde (2007) used priming to suggest that CWS are delayed in their transition from processing words holistically to processing words as a combination of phonemes (incrementally). Three- and 5-year-old CWS demonstrated a faster speech onset for primes, which provided a majority of the word (holistic), as compared to primes, which provided only the first phoneme (incremental). Three-year-old CWNS were primed more by the holistic prime, but five-year-old CWNS showed a preference for the incremental prime (Byrd et al., 2007). The delay in transition from holistic to incremental processing in CWS may indicate less refinement and flexibility in their phonological representations. In addition, Spencer and Weber-Fox (2014) demonstrated that nonword repetition and performance on the BBTOP were predictors of recovery and persistence. CWS-ePer scored lower than their peers who would recover on the nonword repetition measure and the test of articulation accuracy. As mentioned in the introduction, higher accuracy on nonword repetition may indicate robust phonological representations, which are more accurately combined and repeated (Edwards et al., 2004). The lower performance by CWS-ePer on nonword repetition supports the idea that their phonological representations may not be as well specified. If CWS-ePer-TS do not have flexible, refined phonological representations, they may have difficulty separating and manipulating the onset and rime in order to produce a real-word rhyme.

A second factor, which may contribute to the differences in rhyming strategy used by CWS-ePer-TS, is ease of phonological access. Neural activity underlying rhyme discrimination, as measured by ERPs, differentiated 7- and 8-year-old children who had recovered from stuttering and children who were persisting (Mohan & Weber, 2015). Specifically, children who were persisting did not demonstrate the anterior onset rhyme effect to the second word of the stimulus pair (target word). The anterior onset rhyme effect was hypothesized to facilitate phonological access to the representation of the target word in rhyming pairs as compared to nonrhyming pairs. In other words, the first word of the pair (prime word) is thought to activate a network of similar sounding words, which could include the rhyming target word. When the target word rhymes with the prime, this activation is reflected in an early increase in mean amplitude over frontal parietal sites, the early onset rhyme effect. The authors indicate that the absence of the early onset rhyme effect in CWS who were persisting may reflect less saliency of the phonological representation of the prime. If the prime is not salient or maintained in memory, it may not activate the phonological network containing the target allowing for efficient access to the phonological representation of the target. These findings suggest that CWS-ePer-TS in the current study may not as easily activate a network of phonologically related words in response to the stimulus word. It is reasonable to hypothesize that a lack of efficient phonological access to the lexicon led these children to produce real-word responses less frequently than CWNS.

Related to the idea of access to the lexicon, it is possible that semantic processing may also play a role in the increased use of a nonword correct strategy in the CWS-ePer-TS group given the overlap and interactions of phonological and lexical networks (Edwards, Munson, & Beckman, 2011). However, we speculate that the group differences in the current study were more likely related to phonological processing for several reasons. First, our rhyming tasks are known to reflect phonological awareness abilities (e.g., Anthony et al., 2003; Mohan & Weber, 2015). In addition, the groups were matched on vocabulary. This matching was important due to the relationship between vocabulary growth and development of phonological awareness (Metsala, 1997); therefore, the groups in this study have similarly sized lexicons from which to produce real words that rhyme. Second, previous work in 5-year-old CWS and CWNS indicated that CWS-eRec showed a more mature pattern of processing related to semantic anomalies while CWS-ePer showed similar processing to CWNS (Kreidler, Wray, Usler, & Weber, 2017). Given the similar semantic processing of CWS-ePer and CWNS in that study, it does not seem likely that semantic processing alone would account for the group differences found in the use of the nonword correct strategy. Finally, none of the group comparisons revealed differences in the use of the semantic association strategy. Use of the semantic association strategy implies the ability to provide words that are related based on their meaning (e.g., “water” as a response to the prompt “shower”). If a semantic deficit influenced performance of CWS-ePer-TS, we might expect them to show decreased use of the semantic association strategy compared to the other groups. For these reasons, we speculate that the group differences in the current study are related primarily to differences in phonological processing.

Conclusions

The current study sought to further our understanding of developing phonology as a factor that may help to predict whether a young child will recover or persist in stuttering. Speech sound production abilities were taken into account given the relationship between SSD and phonological awareness. We found that CWS with typical speech sound development complete rhyme discrimination and rhyme production tasks with the same accuracy as their typically fluent peers. However, CWS-ePer-TS achieved accuracy on the rhyme production task by creating nonwords that rhyme as opposed to real words to a much larger extent. This reliance on a nonword strategy may reflect differences in underlying phonological representations and differences in ease of phonological access to the lexicon.

How do these findings relate to the MDP theory of stuttering and eventual recovery or persistence? Developing phonology is one of the linguistic factors considered in the MDP, which may develop to either support or interfere with speech motor stabilization in CWS (Smith & Weber, 2017). The current study demonstrates that rhyme production strategy at 4 and 5 years of age may help differentiate children who will recover from stuttering from those who will persist. Our findings, in combination with past research, suggest that CWS-ePer-TS may have less refined phonological representations and less efficient phonological access to the lexicon. These differences in phonological processing in CWS-ePer-TS may be one of the additional taxes on the overall speech motor system that interfere with speech motor stabilization and the establishment of fluent speech (Smith & Weber, 2017).

Limitations and Future Directions

Findings from the current study added to our understanding of the relationship between phonological awareness and stuttering outcome. Future research should continue to investigate not only performance scores on phonological tasks but also underlying task strategies or neural processes. Research is underway to investigate the underlying neural activity mediating phonological processing in CWS at ages 4 and 5 years. In addition, future studies may investigate more complex phonological awareness tasks in CWS within this age range by altering phonological unit and task. For example, studies may investigate further refinement of phonological representations using detection and production tasks at the level of the phoneme. As suggested by Byrd et al. (2007), CWS may be delayed in refined, incremental processing of phonological representations that could impact speech production.

Findings from the current study also added to our understanding of the relationship between the presence of SSD and development of phonological awareness in the CWS population. Future research may continue to explore the smaller subpopulation of CWS who have a concomitant SSD. Specifically, research may compare CWS with SSD to CWNS with SSD. The current study did not include CWNS with SSD, and therefore, we cannot indicate whether decreased rhyme production accuracy in CWS groups with SSD was related solely to SSD or to both disorders. However, future studies including CWS with SSD, CWNS with SSD, and CWNS without SSD could provide insight into the development and processing of phonological representations in distinct speech production disorders. Future studies of phonological development in these populations may also include a measure of speech perception. The current study included a measure of vocabulary; however, speech perception has also been shown to influence the development of phonological awareness (Rvachew & Grawburg, 2006).

Finally, future studies may include an even larger sample size, particularly when looking at the subpopulations of CWS with concomitant SSD. Our study was designed to collect a large, representative sample of CWS. This sample clearly represents the heterogeneous features of the CWS population; however, a larger sample size with increased power for group comparisons may have revealed additional group differences that did not reach significance after conservative corrections for multiple comparisons.

Acknowledgments

This research was funded by National Institute on Deafness and Other Communication Disorders Grants DC000559 (Smith and Weber, co-PIs) and 4T32DC000030-25 (Laurence Leonard, PI). We would like to acknowledge Patricia Zebrowski and her research team at the University of Iowa for their help with data collection. We would also like to thank members of the Neural Systems for Language Processing lab Gina Catania, Carlie Lepore, and Samantha Hayes for their assistance in data scoring.

References

Ambrose, N. G., & Yairi, E. (1999). Normative disfluency data for early childhood stuttering. *Journal of Speech, Language, and Hearing Research, 42*(4), 895–909. https://doi.org/10.1044/jslhr.4204.895

American Speech-Language-Hearing Association. (1993). *Definitions of communication disorders and variations* [Relevant paper]. Retrieved from https://www.asha.org/policy

Anthony, J. L., Aghara, R. G., Dunkelberger, M. J., Anthony, T. I., Williams, J. M., & Zhang, Z. (2011). What factors place children with speech sound disorders at risk for reading problems? *American Journal of Speech-Language Pathology, 20*(2), 146–160. https://doi.org/10.1044/1058-0360(2011/10-0053)

Anthony, J. L., & Francis, D. J. (2005). Development of phonological awareness. *Current Directions in Psychological Science, 14*(5), 255–259. https://doi.org/10.1111/j.0963-7214.2005.00376.x

Anthony, J. L., Lonigan, C. J., Burgess, S. R., Driscoll, K., Phillips, B. M., & Cantor, B. G. (2002). Structure of preschool phonological sensitivity: Overlapping sensitivity to rhyme, words, syllables, and phonemes. *Journal of Experimental Child Psychology, 82*(1), 65–92. https://doi.org/10.1006/jecp.2002.2677

Anthony, J. L., Lonigan, C. J., Driscoll, K., Phillips, B. M., & Burgess, S. R. (2003). Phonological sensitivity: A quasi-parallel progression of word structure units and cognitive operations. *Reading Research Quarterly, 38*(4), 470–487.

Anthony, J. L., Williams, J. M., Aghara, R. G., Dunkelberger, M., Novak, B., & Mukherjee, A. D. (2010). Assessment of individual differences in phonological representation. *Reading and Writing, 23*(8), 969–994. https://doi.org/10.1007/s11145-009-9185-7

Bankson, N., & Bernthal, J. (1990). *Bankson–Bernthal Test of Phonology*. Austin, TX: Pro-Ed.

Blood, G. W., Ridenour, V. J., Jr., Qualls, C. D., & Hammer, C. S. (2003). Co-occurring disorders in children who stutter. *Journal of Communication Disorders, 36*(6), 427–448. https://doi.org/10.1016/S0021-9924(03)00023-6

Broomfield, J., & Dodd, B. (2004). Children with speech and language disability: Caseload characteristics. *International Journal of Language & Communication Disorders, 39*(3), 303–324. https://doi.org/10.1080/13682820310001625589

Bunta, F., Fabiano-Smith, L., Goldstein, B., & Ingram, D. (2009). Phonological whole-word measures in 3-year-old bilingual children and their age-matched monolingual peers. *Clinical Linguistics & Phonetics, 23*(2), 156–175. https://doi.org/10.1080/02699200802603058

Burgemeister, B., Blum, L., & Lorge, I. (1972). *Columbia Mental Maturity Scale*. New York, NY: Harcourt Brace Jovanovich.

Byrd, C. T., Conture, E. G., & Ohde, R. N. (2007). Phonological priming in young children who stutter: Holistic versus incremental processing. *American Journal of Speech-Language Pathology, 16*(1), 43–53. https://doi.org/10.1044/1058-0360(2007/006)

Carroll, J. M., Snowling, M. J., Stevenson, J., & Hulme, C. (2003). The development of phonological awareness in preschool children. *Developmental Psychology, 39*(5), 913–923. https://doi.org/10.1037/0012-1649.39.5.913

Carrow-Woolfolk, E. (1999). *Test for Auditory Comprehension of Language–Third Edition*. Austin, TX: Pro-Ed.

Corriveau, K. H., Goswami, U., & Thomson, J. M. (2010). Auditory processing and early literacy skills in a preschool and kindergarten population. *Journal of Learning Disabilities, 43*(4), 369–382. https://doi.org/10.1177/0022219410369071

Dodd, B. (1995). *Differential diagnosis and treatment of young children with speech sound disorder*. London, United Kingdom: Whurr.

Dodd, B. (2005). *Differential diagnosis and treatment of children with speech disorder* (2nd ed.). London, United Kingdom: Whurr.

Dollaghan, C., & Campbell, T. (1998). Nonword repetition and child language impairment. *Journal of Speech, Language, and Hearing Research, 41*(5), 1136–1146. https://doi.org/10.1044/jslhr.4105.1136
Edwards, J., Beckman, M. E., & Munson, B. (2004). The interaction between vocabulary size and phonotactic probability effects on children's production accuracy and fluency in nonword repetition. *Journal of Speech, Language, and Hearing Research, 47*(2), 421–436. https://doi.org/10.1044/1092-4388(2004/034)
Edwards, J., Munson, B., & Beckman, M. E. (2011). Lexicon-phonology relationships and dynamics of early language development—A commentary on Stoel-Gammon's relationships between lexical and phonological development in young children. *Journal of Child Language, 38*(1), 35–40. https://doi.org/10.1017/S0305000910000450
Elbro, C., & Pallesen, B. R. (2002). The quality of phonological representations and phonological awareness: A causal link? In L. Verhoeven, C. Elbro, & P. Reitsma (Eds.), *Precursors of functional literacy* (pp. 17–32). Philadelphia, PA: John Benjamins.
Gernand, K. L., & Moran, M. J. (2007). Phonological awareness abilities of 6-year-old children with mild to moderate phonological impairments. *Communication Disorders Quarterly, 28*(4), 206–215. https://doi.org/10.1177/1525740107311819
Gregg, B. A., & Yairi, E. (2007). Phonological skills and disfluency levels in preschool children who stutter. *Journal of Communication Disorders, 40*(2), 97–115. https://doi.org/10.1016/j.jcomdis.2006.04.003
Gregg, B. A., & Yairi, E. (2012). Disfluency patterns and phonological skills near stuttering onset. *Journal of Communication Disorders, 45*(6), 426–438. https://doi.org/10.1016/j.jcomdis.2012.08.001
Hodson, B. W. (1986). *The Assessment of Phonological Processes–Revised*. Austin, TX: Pro-Ed.
Hollingshead, A. B. (1975). *Four factor index of social status*. Unpublished manuscript, Department of Sociology, Yale University, New Haven, CT.
Ingram, D. (2002). The measurement of whole-word productions. *Journal of Child Language, 29*(4), 713–733. https://doi.org/10.1017/S0305000902005275
Kreidler, K., Wray, A. H., Usler, E., & Weber, C. (2017). Neural indices of semantic processing in early childhood distinguish eventual stuttering persistence and recovery. *Journal of Speech, Language, and Hearing Research, 60*(11), 3118–3114. https://doi.org/10.1044/2017_JSLHR-S-17-0081
Long, J. S. (1997). *Regression models for categorical and limited dependent variables*. Thousand Oaks, CA: Sage.
Lonigan, C. J., Burgess, S. R., Anthony, J. L., & Barker, T. A. (1998). Development of phonological sensitivity in 2- to 5-year-old children. *Journal of Educational Psychology, 90*(2), 294–311. https://doi.org/10.1037/0022-0663.90.2.294
Maclean, M., Bryant, P., & Bradley, L. (1987). Rhymes, nursery rhymes, and reading in early childhood. *Merrill-Palmer Quarterly, 33*(3), 255–281. https://www.jstor.org/stable/23086536
MacLeod, A., Laukys, K., & Rvachew, S. (2011). The impact of bilingual language learning on whole-word complexity and segmental accuracy among children aged 18 and 36 months. *International Journal of Speech-Language Pathology, 13*(6), 490–499. https://doi.org/10.3109/17549507.2011.578658
Marion, M. J., Sussman, H. M., & Marquardt, T. P. (1993). The perception and production of rhyme in normal and developmentally apraxic children. *Journal of Communication Disorders, 26*(3), 129–160. https://doi.org/10.1016/0021-9924(93)90005-U
Metsala, J. (1997). An examination of word frequency and neighborhood density in the development of spoken-word recognition. *Memory & Cognition, 25*(1), 47–56. https://doi.org/10.3758/BF03197284
Mohan, R., & Weber, C. (2015). Neural systems mediating processing of sound units of language distinguish recovery versus persistence in stuttering. *Journal of Neurodevelopmental Disorders, 7,* 28. https://doi.org/10.1186/s11689-015-9124-7
Mullen, R., & Schooling, T. (2010). The National Outcomes Measurement System for pediatric speech-language pathology. *Language, Speech, and Hearing Services in Schools, 41*(1), 44–60. https://doi.org/10.1044/0161-1461(2009/08-0051)
Munson, B., & Krause, M. O. P. (2017). Phonological encoding in speech-sound disorder: Evidence from a cross-modal priming experiment. *International Journal of Language & Communication Disorders, 52*(3), 285–300. https://doi.org/10.1111/1460-6984.12271
Paden, E. P., Yairi, E., & Ambrose, N. G. (1999). Early childhood stuttering II: Initial status of phonological abilities. *Journal of Speech, Language, and Hearing Research, 42*(5), 1113–1124. https://doi.org/10.1044/jslhr.4205.1113
Pelczarski, K. M., & Yaruss, J. S. (2014). Phonological encoding of young children who stutter. *Journal of Fluency Disorders, 39,* 12–14. https://doi.org/10.1016/j.jfludis.2013.10.003
Preston, J., & Edwards, M. L. (2010). Phonological awareness and types of sound errors in preschoolers with speech sound disorders. *Journal of Speech, Language, and Hearing Research, 53*(1), 44–60. https://doi.org/10.1044/1092-4388(2009/09-0021)
Raitano, N. A., Pennington, B. F., Tunick, R. A., Boada, R., & Shriberg, L. D. (2004). Pre-literacy skills of subgroups of children with speech sound disorders. *The Journal of Child Psychology and Psychiatry, 45*(4), 821–835. https://doi.org/10.1111/j.1469-7610.2004.00275.x
Robbins, J., & Klee, T. (1987). Clinical assessment of oropharyngeal motor development in young children. *Journal of Speech and Hearing Disorders, 52*(3), 271–277. https://doi.org/10.1044/jshd.5203.271
Robertson, C., & Salter, W. (2007). *Phonological Awareness Test–Second Edition*. East Moline, IL: LinguiSystems.
Rvachew, S. (2006). Longitudinal predictors of implicit phonological awareness skills. *American Journal of Speech-Language Pathology, 15*(2), 165–176. https://doi.org/10.1044/1058-0360(2006/016)
Rvachew, S., & Brosseau-Lapré, F. (2012). An input-focused intervention for children with developmental phonological disorders. *Perspectives on Language Learning and Education, 19*(1), 31–35. https://doi.org/10.1044/lle19.1.31
Rvachew, S., & Brosseau-Lapré, F. (2018). *Developmental phonological disorders: Foundations of clinical practice* (2nd ed.). San Diego, CA: Plural.
Rvachew, S., Chiang, P.-Y., & Evans, N. (2007). Characteristics of speech errors produced by children with and without delayed phonological awareness skills. *Language, Speech, and Hearing Services in Schools, 38*(1), 60–71. https://doi.org/10.1044/0161-1461(2007/006)
Rvachew, S., & Grawburg, M. (2006). Correlates of phonological awareness in preschoolers with speech sound disorders. *Journal of Speech, Language, and Hearing Research, 49*(1), 74–87. https://doi.org/10.1044/1092-4388(2006/006)
Rvachew, S., Ohberg, A., Grawburg, M., & Heyding, J. (2003). Phonological awareness and phonemic perception in 4-year-old children with delayed expressive phonology skills. *American Journal of Speech-Language Pathology, 12*(4), 463–471. https://doi.org/10.1044/1058-0360(2003/092)
Savage, R., Blair, R., & Rvachew, S. (2006). Rimes are not necessarily favored by prereaders: Evidence from meta- and

epilinguistic phonological tasks. *Journal of Experimental Child Psychology, 94*(3), 183–205. https://doi.org/10.1016/j.jecp.2006.03.005

Schaefer, B., Stackhouse, J., & Wells, B. (2017). Phonological awareness development in children with and without spoken language difficulties: A 12-month longitudinal study of German-speaking pre-school children. *International Journal of Speech-Language Pathology, 19*(5), 465–475. https://doi.org/10.1080/17549507.2016.1221449

Schmitt, L. S., Howard, B. H., & Schmitt, J. F. (1983). Conversational speech sampling in the assessment of articulation proficiency. *Language, Speech, and Hearing Services in Schools, 14*(4), 210–214. https://doi.org/10.1044/0161-1461.1404.210

Shriberg, L. D., Fourakis, M., Hall, S. D., Karlsson, H. B., Lohmeier, H. L., McSweeny, J. L., . . . Wilson, D. L. (2010). Extensions to the speech disorders classification system (SDCS). *Clinical Linguistics & Phonetics, 24*(10), 795–824. https://doi.org/10.3109/02699206.2010.503006

Smith, A. (1999). Stuttering: A unified approach to a multifactorial, dynamic disorder. In N. Bernstein Ratner & E. C. Healey (Eds.), *Stuttering research and practice: Bridging the gap* (pp. 27–44). New York, NY: Psychology Press.

Smith, A., & Weber, C. (2017). How stuttering develops: The multifactorial dynamic pathways theory. *Journal of Speech, Language, and Hearing Research, 60*(9), 2483–2505. http://doi.org/10.1044/2017_JSLHR-S-16-0343

Spencer, C., & Weber-Fox, C. (2014). Preschool speech articulation and nonword repetition abilities may help predict eventual recovery or persistence of stuttering. *Journal of Fluency Disorders, 41,* 32–46. https://doi.org/10.1016/j.jfludis.2014.06.001

Stackhouse, J., & Wells, B. (1997). *Children's speech and literacy difficulties: A psycholinguistic framework*. London, United Kingdom: Whurr.

Starkweather, C. W., & Gottwald, S. R. (1990). The demands and capacities model II: Clinical applications. *Journal of Fluency Disorders, 15*(3), 143–157. https://doi.org/10.1016/0094-730X(90)90015-K

StataCorp. (2017). Stata Statistical Software: Release 15 [Computer software]. College Station, TX: StataCorp LLC.

Wagner, R. K., Torgesen, J. K., & Rashotte, C. A. (1999). *Comprehensive Test of Phonological Processing*. Austin, TX: Pro-Ed.

Walden, T. A., Frankel, C. B., Buhr, A. P., Johnson, K. N., Conture, E. G., & Karrass, J. M. (2012). Dual diathesis-stressor model of emotional and linguistic contributions to developmental stuttering. *Journal of Abnormal Child Psychology, 40*(4), 633–644. https://doi.org/10.1007/s10802-011-9581-8

Walsh, B., Usler, E., Bostian, A., Mohan, R., Gerwin, K. L., Brown, B., . . . Smith, A. (2018). What are predictors for persistence in childhood stuttering? *Seminars in Speech and Language, 39*(4), 299–312. https://doi.org/10.1055/s-0038-1667159

Waring, R., & Knight, R. (2013). How should children with speech sound disorders be classified? A review and critical evaluation of current classification systems. *International Journal of Language & Communication Disorders, 48*(1), 25–40. https://doi.org/10.1111/j.1460-6984.2012.00195.x

Weber-Fox, C., Spencer, R. M. C., Cuadrado, E., & Smith, A. (2003). Development of neural processes mediating rhyme judgments: Phonological and orthographic interactions. *Developmental Psychobiology, 43*(2), 128–145. https://doi.org/10.1002/dev.10128

Weber-Fox, C., Spencer, R. M. C., Spruill, J. E., & Smith, A. (2004). Phonologic processing in adults who stutter: Electrophysiological and behavioral evidence. *Journal of Speech, Language, and Hearing Research, 47*(6), 1244–1258. https://doi.org/10.1044/1092-4388(2004/094)

Weber-Fox, C., Spruill, J. E., III, Spencer, R. M. C., & Smith, A. (2008). Atypical neural functions underlying phonological processing and silent rehearsal in children who stutter. *Developmental Science, 11*(2), 321–337. https://doi.org/10.1111/j.1467-7687.2008.00678.x

Wolk, L., Conture, E. G., & Edwards, M. L. (1990). Comorbidity of stuttering and disordered phonology in young children. *The South African Journal of Communication Disorders, 37,* 15–20. https://www.ncbi.nlm.nih.gov/pubmed/2097729

Wolk, L., Edwards, M. L., & Conture, E. G. (1993). Coexistence of stuttering and disordered phonology in young children. *Journal of Speech and Hearing Research, 36*(5), 906–917. https://doi.org/10.1044/jshr.3605.906

Yairi, E., & Ambrose, N. G. (1999). Early childhood stuttering I: Persistency and recovery rates. *Journal of Speech, Language, and Hearing Research, 42*(5), 1097–1112. https://doi.org/10.1044/jslhr.4205.1097

Yairi, E., & Ambrose, N. G. (2013). Epidemiology of stuttering: 21st century advances. *Journal of Fluency Disorders, 38*(2), 66–87. https://doi.org/10.1016/j.jfludis.2012.11.002

Yaruss, J. S. (1997). Clinical implications of situational variability in preschool children who stutter. *Journal of Fluency Disorders, 22*(3), 187–203. https://doi.org/10.1016/S0094-730X(97)00009-0

Yaruss, J. S., & Conture, E. G. (1996). Stuttering and phonological disorders in children: Examination of the covert repair hypothesis. *Journal of Speech and Hearing Research, 39*(2), 349–364. https://doi.org/10.1044/jshr.3902.349