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A preliminary investigation of segmentation and rhyme abilities of children who stutter

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ABSTRACT

The present study investigated segmentation and rhyme abilities, skills critical for phonological encoding, of children who stutter (CWS) and those who do not (CNS). Participants were 9 CWS (8 males and 1 female, mean age = 11.1, SD = 2.31) in the age range of 7 and 13 years and 9 age and sex matched CNS (mean age = 11.2, SD = 2.19). Participants performed two verbal monitoring tasks, phoneme and rhyme monitoring, in silent naming. Performances in the verbal monitoring tasks were compared to a neutral, nonverbal tone monitoring task. Additionally, the complexity of the phoneme monitoring task was varied such that participants had to monitor for singletons vs. consonant clusters. Repeated measures analysis of the response time data did not reveal significant differences between the groups in the three monitoring tasks. Analysis of the complexity data revealed a trend for slower monitoring of the consonant clusters in the CWS group compared to the CNS. Present findings do not support a deficit in segmentation and rhyme abilities in CWS, although there was some preliminary evidence of segmentation difficulties with increasing phonological complexity of the stimuli.

Educational objectives: At the end of this activity the reader will be able to: (a) discuss the literature on phonological encoding skills in children who stutter, (b) describe skills underlying the phonological encoding process, (c) summarize whether or not children who stutter differ from those who do not in segmentation and rhyme abilities, (d) suggest future areas of research in the investigation of segmentation and rhyme monitoring abilities in children who stutter.

1. Introduction

Several psycholinguistic theories have implicated phonological encoding as a causal mechanism in stuttering (e.g. Howell, 2004; Perkins, Kent, & Curlee, 1991; Postma & Kolk, 1993; Wingate, 1988). The development of phonological encoding skills in typically fluent children begins with early acquisition of higher-level phonological units, that is, syllables and rhymes, which are considered to be holistic units that are easier to process (Bonte & Blomert, 2004; Jusczyk, 1993). This ability is followed by the acquisition of segmentation, the ability to parse individual phonemes in speech as a consequence of progressive restructuring of the phonological lexicon into smaller, phoneme-sized units (Goswami, 2002; Metsala & Walley, 1998). This knowledge determines competence in both production and perception. Furthermore, the transition from larger (holistic or rhyme) to smaller, segmental (phonemic) level processing is crucial for the production of fluent speech (e.g., Brooks &

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MacWhinney, 2000). In Levelt's speech production model (1989), incremental encoding of segments within word frames is considered integral to speech production. Furthermore, according to the *Lexical Restructuring Model* (Walley, Metsala, & Garlock, 2003) at around age two (near typical onset of childhood stuttering) children experience a significant increase in vocabulary growth and they begin to encode words incrementally as individual sound segments rather than as global syllable shapes. Brooks and MacWhinney (2000) contend that this apparent growth in ability for segmental processing allows children to speak more fluently. Therefore, deficits in the timely acquisition and transition of whole-word to segmentation skills can impair the process of phonological encoding and be a possible mechanism of fluency disruption in persons who stutter. Thus, the study of phonological encoding skills in children who stutter (CWS) necessitates the study of the development of rhyme and segmentation abilities.

1.1. Skills underlying phonological encoding: theoretical considerations

Phonological encoding involves the generation of sounds, syllable, and metric information and their eventual integration during speech production. In addition, theoretical approaches in fluent speakers also consider verbal monitoring, an end process in phonological encoding, as a critical component of speech production. According to Levelt's speech production model, self-monitoring of inner or silent speech occurs at the output of phonological encoding. Levelt and colleagues (Levelt, 1989; Levelt, Roeloffs, & Meyer, 1999) argued that speakers monitor their speech output for errors in the speech plan before sending the code for articulatory planning and execution. Thus, self-monitoring requires access to sublexical units, rhymes and phonemes, during speech production and has been identified as a prerequisite for a just-in-time, incremental approach to fluent speech planning and production (Blackmer & Mitton, 1991; Levelt, 1989). Therefore, we hypothesize that silent monitoring of speech engages the self-monitoring loop and can be used as a viable task for studying rhyme and segmentation abilities, skills that are considered to be essential subcomponents underlying phonological encoding (for further explanation, see Sasisekaran & Weber-Fox, 2012).

According to Levelt and colleagues (Bock & Levelt, 1994; Levelt, 1989; Levelt et al., 1999), potential links between changes in the ability to monitor rhyme and segment-level units with progressive refinement of sub-lexical, phonemic level representations seem plausible. This hypothesis can be accommodated presently within some theoretical frameworks of language development in children. For instance, Metsala and colleagues (Metsala, 1997, 1999; Metsala & Walley, 1998) proposed the *progressive restructuring framework* that young children start with word-like holistic lexical representations and progress to adult-like segmental/phonemic representations of lexical items. Metsala and Walley (1998) suggested that access to sublexical units, including rhymes, phonemes, and syllable onsets, can be attributed to the restructuring of the phonemic lexicon. Thus, superior verbal monitoring skills are likely an epiphenomenon of well-refined sublexical representations to adult-like segmental units. During typical development this restructuring is achieved in several stages but minimally requires the ability to process rhymes and segments in speech. Therefore, it is hypothesized that a deficit in phonological encoding during development could be reflective of a deficit in the processing and representation of holistic and/or segmental units in speech production.

Several theories in the developmental stuttering literature postulate a role for phonological encoding. Of specific interest to the present study is the *Covert Repair Hypothesis* (CRH) of stuttering. Postma and Kolk (1993) postulated that persons who stutter exhibit a higher rate of errors in the speech plan due to deficient phonological encoding. In the *CRH* they argued that stuttering is the result of overt compensations, namely repetitions, blocks, and prolongations, reflective of the covert mechanisms involved in correcting errors in the speech plan. Speakers have access to the output of phonological encoding, the *phonological speech code*, and monitor this code for syllable- and segment-level errors. Thus, syllable- and segment-level processes have been implicated as causal variables in stuttering and this has resulted in several attempts to investigate such skills in CWS.

1.2. Studies of rhyme and segmentation skills in CWS

Attempts have been made to investigate the architecture of the phonological lexicon and the acquisition of rhyme and segmentation skills in children who stutter (CWS) using a multitude of tasks including priming, nonword repetition, and rhyme judgment (Arnold, Conture, & Ohde, 2005; Byrd, Conture, & Ohde, 2007; Hakim & Ratner, 2004; Melnick, Conture, & Ohde, 2003; Weber-Fox, Spruill, Spencer, & Smith, 2008). For instance, Melnick et al. (2003) investigated segmental encoding in 18, 3–5-year-old CWS and an equal number of age-matched children who do not stutter (CNS). They used a priming paradigm with speech reaction times measured from three presentation conditions: no prime, phonologically related prime (initial consonant vowel [CV] or CCV of picture name), and phonologically unrelated prime (different initial CV or CCV). The extent of phonological priming in the related prime condition was comparable for both CWS and CNS. However, the two groups differed in the amount of variability seen in the naming reaction times with the CWS exhibiting higher variability in the task. Higher variability in picture naming was interpreted by the authors to suggest that CWS have somewhat less well-developed articulatory systems than preschool CNS. However, findings from phonological priming did not reveal differences between the CWS and CNS groups indicating that the underlying segmental architecture of the phonological lexicon is comparable between the groups.

In a study directly relevant to the present investigation, Byrd et al. (2007) investigated both holistic and segmental processing in a picture naming auditory priming paradigm in 26 CWS and 26 CNS. There were 13 three-year-olds and 13 five-year-olds in each talker group. Participants were presented with neutral (tone), holistic, or segmental primes before the onset of target pictures and response time to picture naming was measured from picture onset to the time of initiation of naming. The results revealed that the three-year-old CWS and CNS were faster in the holistic priming condition and slower in the incremental priming conditions. However, there were differences in the patterns exhibited in the groups of five-year-olds. The five-year-old CNS were fastest in the incremental condition, but the five-year-old CWS were fastest in the holistic condition. The authors attributed the findings to developmental differences in phonological encoding between the groups. That is, at age 3 CWS demonstrate age appropriate holistic encoding skills but by age 5 they appear to demonstrate a delay in segmental encoding abilities as compared to their typically fluent peers.

Hakim and Bernstein Ratner's (2004) preliminary study compared eight CWS (4; 3–8; 4 years; months) to age-matched CNS using the Children's Test of Nonword Repetition (CNrep; Gathercole, Willis, Baddeley, & Emslie, 1994). CWS had fewer correct productions and more phonemic errors than CNS for one-, two-, and three-syllable nonwords, but significant group differences were observed only at the three-syllable level. A higher percent of phoneme errors was observed in both groups for the longer, four- and five-syllable nonwords. Anderson, Wagovich, and Hall (2006) compared performance of 12 CWS and age-matched controls between 3 and 5 years of age on the CNrep (Gathercole et al., 1994). CWS exhibited significantly fewer correct productions of two- and three-syllable nonwords and a higher percent of phonemic errors in the three-syllable nonwords compared to the CNS. The authors concluded that CWS have weaker phonological working memory skills compared to typically developing children. Although the findings from the above two studies of nonword repetition were not directly interpreted to support a phonological encoding deficit, the fact that more phonemic errors were observed in the CWS group in this task suggests that segmentation skills may have been challenged in this group of children. To the contrary, Bakhtiar, Ali, and Sadegh (2007) studied nonword repetition performance in 12 Iranian CWS between 5 and 7 years of age and 12 CNS. The authors reported that the mean phonemic errors were not significantly different between the groups. They also compared reaction times between the two groups and found no difference, thus finding no support for slowed and/or erroneous phonological encoding.

Arnold et al. (2005) studied the storage and retrieval of segmental units in CWS and CNS by testing response times to words varying in phonological neighborhoods (words that differ by one phoneme substitution, omission, or addition from a target word are considered to be the phonological neighbors). The authors reported comparable performances of nine, 3–5-year-old CWS and age- and gender-matched CNS in the naming of target pictures with sparse (defined as words that have few phonological neighbors) and dense (defined as words that have many phonological neighbors) phonological neighborhoods. Initial analyses indicated that both CWS and CNS were significantly faster (i.e. exhibited shorter speech reaction times) and more accurate on phonologically sparse than phonologically dense words. They interpreted the findings to indicate that phonological processes contribute minimally to the difficulties experienced by CWS in producing fluent speech.

Rhyme paradigms have been used to investigate phonological encoding abilities in both children and adults who stutter. Such paradigms typically require participants to make rhyme judgments on word pairs (e.g. participant hears the word "hair" and then is shown a picture of a bear and has to indicate whether or not the auditory prime rhymes with the picture presented). Several processes are thought to be involved in rhyming judgment, including retrieving the phonological representation of each word in the word pair, holding it in working memory via the articulatory loop, and segmenting it into the corresponding onset and rhyme elements (Besner, 1987). Rhyme judgment is then produced by a comparison of the rhyme of the two words in the pair. For instance, using a visual rhyming paradigm in ten school-age CWS between 9 years 4 months and 13 years 9 months and ten CNS, Weber-Fox et al. (2008) reported reduced behavioral accuracy in rhyme judgment in CWS. However, rather than interpret the findings as support for a phonological encoding deficit, based on the differences in the N400 and contingent negative variation (CNV) waveforms in evoked response potentials, the authors interpreted the reduced behavioral accuracy in CWS to be reflective of less stable neural representation of the prime in the prime target pair during rhyme judgment. In summary, several studies have investigated rhyme and segmentation skills in CWS. The findings from such studies have, however, failed to identify a specific deficit in phonological encoding in this group.

1.3. Purposes of the present study

Lack of concrete evidence for the idea that there is a phonological encoding deficit in CWS is attributable to several factors, which necessitate further systematic investigation of such skills. First, studies have investigated phonological encoding using both rhyme (e.g. Weber-Fox et al., 2008) and segment (e.g. Melnick et al., 2003) encoding tasks in varying paradigms. These tasks vary in the nature and extent of segmentation and the units involved, with rhyme encoding involving encoding of larger units consisting of several segments (syllable nucleus + coda) as compared to segment encoding. Such reports allude to a need to investigate both rhyme and segmentation skills using a single paradigm that is comparable in all aspects except for the skills under study to investigate whether CWS differ in processing both these units of speech. Second, a majority of the studies reported above have investigated rhyme and/or segmentation abilities in children between 3 and 5 years of age and the findings have been mixed. Perhaps such findings may be due to differences in performance among CWS who recover and those who do not. Thus, it is of potential interest to study rhyme and segmentation skills in older CWS as there is a possibility that these children, who are more than likely demonstrating persistent stuttering, are different from typically fluent children in phonological encoding abilities. Therefore, in the present study we investigated both rhyme and segmentation abilities of older children who stutter between 7 and 13 years of age in a silent monitoring paradigm. Sasisekaran and Weber-Fox (2012) demonstrated the viability of using this task to investigate such skills in children as young as 7 years. The authors reported an increase in speed of phoneme monitoring with age indicating the emergence of cognitive processes that are critical to performing phoneme monitoring. If CWS are indeed delayed in the acquisition of encoding skills as suggested by the CRH and in the transition from whole-word to segment encoding as predicted from some reports of rhyme and phoneme encoding difficulties (e.g. Byrd et al., 2007; Weber-Fox et al., 2008), then this will be evident in performing tasks such as phoneme and rhyme monitoring. In addition, we compared the performance in the phoneme and rhyme monitoring tasks to a neutral nonverbal, tone monitoring task that was similar in design to the two tasks in order to investigate whether the hypothesized differences are restricted to the verbal monitoring tasks.

We also investigated the effect of complexity manipulation on monitoring performance by varying the phonemic complexity of the target segments being monitored (singletons vs. consonant clusters) in the phoneme monitoring task. Monitoring of phonemes within consonant clusters requires segmentation of the cluster to its constituent phonemes and is therefore likely to be more challenging than monitoring singletons. Sasisekaran and Weber-Fox (2012) confirmed this assumption and reported a developmental progression in the monitoring of consonant clusters compared to singletons in children between 7 and 13 years. Reports of increasing stuttering with increasing phonemic complexity are frequent in the stuttering literature (e.g. Howell, Au-Yeung, & Sackin, 2000; Wolk, Blomgren, & Smith, 2000). Furthermore, studies of the use of phonological processes have reported more errors within consonant clusters than singletons in CWS (e.g. Louko, Edwards, & Conture, 1990; Paden, Yairi, & Ambrose, 1999). Therefore, in this preliminary study we aimed to investigate if such effects are extendable to difficulties experienced by the CWS in monitoring consonant clusters.

To this end, the purposes of the present preliminary investigation were to study: (a) whether older CWS between 7 and 13-years of age differ from CNS in tasks that tap into rhyme and segmentation skills (rhyme and phoneme monitoring) in a silent picture naming/monitoring task? (b) whether the groups differ in the speed of monitoring singletons vs. consonant clusters (phonemic complexity manipulation) in the phoneme monitoring task? (c) whether the groups differ in both verbal and non-verbal monitoring (tone-sequence monitoring) tasks that are similar in design; and (d) whether the CWS and CNS groups differ in the percent of errors in phoneme, rhyme, and tone-sequence monitoring?

2. Methods

2.1. Participants

Participants were 9 CWS (7 males and 2 females, mean age = 11.1, SD = 2.31) in the age range of 7 and 13 years and 9 age and sex matched CNS (mean age = 11.2, SD = 2.19, $t(16) = -0.106$, $p = 0.45$). We chose children as young as 7 years based on evidence these children can make rhyme and phoneme decisions (e.g. Coch, Grossi, Coffey-Corina, Holcomb, & Neville, 2002; Sasisekaran & Weber-Fox, 2012). Data collection was carried out at two sites, the University of Minnesota and the University of Texas at Austin. Participants were recruited through the stuttering camp and clinic at both sites. All participants spoke North American English as the primary language. At both locations, the test protocol was administered by a trained research assistant under the supervision of the first and the second authors. All procedures were approved by the Institutional Review Board at both sites and participants received reimbursement for participation.

Based on initial screening all participants had a negative history of: (a) neurological deficits, (b) language, speech, reading, and hearing difficulties except stuttering in the CWS group, and (c) current usage of medications likely to affect the outcome of the experiment (e.g. for ADHD and anti-anxiety). All participants passed a hearing screening performed at 0.5, 1, 2, 4, and 8 kHz (20 dB) in both ears. The parents of all participants reported age and grade-appropriate reading skills. One CWS from the initial subject pool did not qualify for participation due to a co-occurring articulation disorder. Similarly, one child from the CNS group did not qualify due to difficulties in reading at grade level.

2.2. Inclusion criteria for children who stutter

Participants were classified as CWS if all of the following three criteria were met:

1) Had received a diagnosis of stuttering by a certified/licensed speech-language pathologist,
2) Were rated by the parent as being 2 or more on a 7-point rating scale of stuttering severity at onset, and
3) Were receiving treatment or had received treatment previously.

In the present study inclusion criteria (either as percent stuttered syllables or percent stuttered words) were not set for the CWS to be eligible to participate. However, speech data from a reading sample and spontaneous speech from the clinician–child interaction were collected from all children in the stuttering group and analyzed for disfluencies. The reading samples from the 7 and 8-year-olds were elicited using the 'Arthur the Rat' passage while samples from the older children were obtained using 'The Rainbow Passage'. Stuttered disfluencies including sound and syllable repetitions, word repetitions (considered as stuttering when the number of iterations were equal to or greater than 3; Yaruss, 1998), prolongations, and blocks were coded from the reading and conversation samples. Inter- and intrajudge reliability of the coding was established at the word level. A trained research assistant coded the stuttered disfluencies in the CWS group, which reached a minimum reliability of 90% intra-judge reliability and 80% inter-judge reliability between the trained RA and the first author for 1/3 of all samples. On average the CWS group exhibited 7.7% (SD = 5.7) syllables stuttered in reading and 8.5% (SD = 6.6) in conversation with a range between 1 and 15% in reading and 0 and 17% in conversation. Only one participant (also the oldest in the CWS group), who had 4% syllables stuttered in reading and 0% in conversation, did not meet the standard criteria of 3% stuttered syllables in both reading and conversation.

2.3. Vocabulary, short-term memory, and phonemic awareness skills

A series of tests were administered to determine if the groups differed in skills which may impact performance on the experimental tasks. Receptive vocabulary was tested using the *Peabody Picture Vocabulary test – Edition IV* (PPVT; Dunn & Dunn, 1997). Short term memory span was determined using the forward and backward digit span tests (*Weschler's Memory scale*; Wechsler, 1997). Rhyme, segmentation, and syllable counting components of phonemic awareness skills were tested for all participants. Rhyme awareness was assessed using an informal test in which participants were required to identify rhymes in word ($N = 10$) and nonword pairs ($N = 5$) in a perception and a production task. In the production task participants heard a word or a nonword and were asked to produce a word or nonword that rhymed with the target. In the perception task participants heard word and nonword pairs and were asked whether the pairs rhymed or not. Segmentation and syllable counting skills were tested using the *Lindamood Auditory Conceptualization Test* – 3 (LAC – 3; Lindamood & Lindamood, 1979). The LAC is used to test the cognitive ability to perceive, conceptualize, and manipulate speech sounds, skills that are indicative of reading readiness and phonemic awareness. Subtest 1 measures participants' familiarity with isolated phoneme and phoneme sequences patterns. For this subtest participants were asked to arrange colored blocks in a sequence depending on how many sounds they heard and the order in which the sounds were repeated within a sequence. Subtest 2 measures phoneme discrimination skills in monosyllables. Participants were asked to re-arrange and add new cubes to a pre-established sequence based on changes to a nonsense syllable sequence. Subtest 3 measures participants' ability to count syllables and make changes to the syllables in multisyllabic nonwords. Participants were asked to show color cubes corresponding to the number of syllables and to change the cubes as the syllables changed. Subtest 4 measures participants' ability to count syllables while tracking phonemes within nonwords.

2.4. Tasks and stimuli

The experiment consisted of four tasks: (1) picture naming, (2) phoneme monitoring, (3) rhyme monitoring, and (4) tone-sequence monitoring. The picture naming task was designed to familiarize participants with the target stimuli. The phoneme monitoring task involved hearing a target speech sound, then seeing a picture of a target word and responding as quickly as possible (via manual button press) as to whether or not the sound was present in the picture's name. The rhyme monitoring task involved hearing a nonword, then seeing a picture of a target word and responding as quickly as possible (via a manual button press) as to whether or not the two items rhymed. The tone monitoring task involved hearing two tone sequences and responding as quickly as possible (via a manual button press) as to whether or not the two sequences matched.

The word and nonword stimuli used for the study were taken from Sasisekaran and Weber-Fox (2012). Twenty-eight monosyllabic high frequency nouns were the target items for the phoneme monitoring task (see Appendix A). The words carried 7 target consonants, each occurring twice as a singleton and twice in a consonant cluster. The target phonemes were balanced in distribution across word-initial and coda positions. Black and white line-drawings representing the target words were selected from Snodgrass and Vandervart (1980) and used as stimuli for eliciting silent picture naming responses. Appendix A shows the age of acquisition, word familiarity (5-point rating scale with 1 – least, 5 – most; mean = 3.3, SD = 1.03), and image agreement (mean = 3.5, SD = 1.02) for the target words as reported by Snodgrass and Vandervart (1980).

Twenty-eight monosyllabic nonwords developed from the target words formed the stimuli for the rhyme monitoring task. The target phonemes and nonwords spoken by a native English speaker were recorded and digitized using PRAAT software. The pre-recorded stimuli were then used in the phoneme and rhyme monitoring tasks. For the tone monitoring task the original stimuli were 14 tone sequences generated using MATLAB consisting of three pure tones in each sequence (e.g. 0.5, 1, 2 kHz; 4, 8, 1 kHz). The 14 sequences were paired such that half of the pairs ($N = 14$) were identical (e.g. 0.5, 1, 2 kHz; 0.5, 1, 2 kHz) and required a 'yes' response and the other half were mismatched (e.g. 0.5, 1, 2 kHz; 4, 8, 1 kHz) and required a 'no' response. The overall length of each tone sequence was matched to the average duration of the target words spoken by a native English speaker and measured acoustically using PRAAT. The average duration of the target words was 568.26 ms (SD = 92.7), therefore the overall length of each tone sequence was 500 ms with an interval of 100 ms between the tones.

2.5. Procedures and tasks

The experiment-proper consisted of four tasks: (1) picture naming, (2) phoneme monitoring, (3) rhyme monitoring, and (4) tone-sequence monitoring. The picture naming task was always presented prior to the phoneme or rhyme monitoring tasks. The phoneme and rhyme monitoring tasks followed each other, but were counterbalanced in order of occurrence across participants. The tone monitoring task was presented either before or after the verbal (phoneme, rhyme) monitoring tasks and the order of presentation of this task was also counterbalanced across participants (e.g. *Subject a*, *Task order*: Tone monitoring, Picture naming, Rhyme monitoring, Phoneme monitoring; *Subject b*, *Task order*: Picture naming, Phoneme

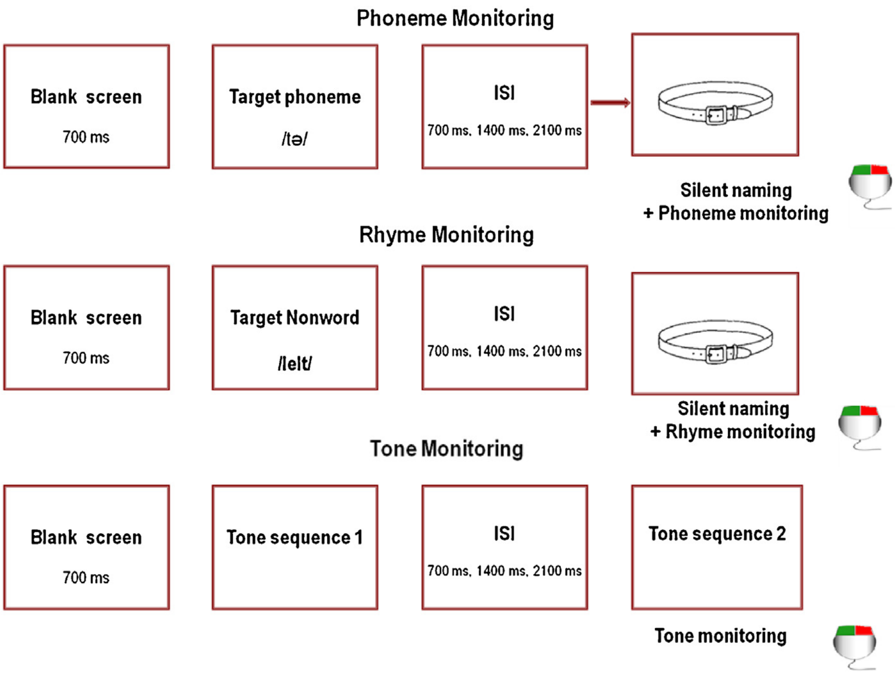

Fig. 1. Illustration of the events in each trial of the phoneme, rhyme, and tone monitoring tasks.

monitoring, Rhyme monitoring, Tone monitoring). Fig. 1 illustrates the event sequence within a single trial of each task. In the following subsections, each of these tasks is described in detail.

2.5.1. Picture naming

The primary purpose of this task was to familiarize participants with the names associated with the target pictures in the monitoring tasks. During the task the 28 target pictures were presented individually on a computer screen and participants were asked to name each picture. Participants were corrected for errors in picture naming at the end of the naming task. Since age-appropriate pictures were used, a majority of participants were able to name all of the pictures. However, naming errors, if any, were corrected before proceeding to the phoneme and rhyme monitoring tasks.

2.5.2. Phoneme monitoring

The purpose of this task was to investigate the response times to phoneme monitoring during silent picture naming. Participants were presented with two blocks of 28 stimuli each with the target words occurring once per block. The phonemes to be monitored (/t/, /k/, /d/, /n/, /f/, /l/, /r/) occurred in either word initial[1] or final (coda) positions[2], C^1VC^2 (e.g. the sound /k/ in "*c*^{1}*at*" and "*duck*^{2}" (singleton), "*c*^{1}*lown*" and "*fork*^{2}" (consonant cluster). Half of the target words in a block carried a target phoneme and required a 'yes' response and the other half required a 'no' response. The order of presentation of the target words was randomized within each block and each target phoneme occurred twice, once as singleton and once within a consonant cluster distributed evenly across word-initial and coda positions (e.g. target phoneme /k/; Block I: "*c*^{1}*at*", "*fork*^{2}"; Block II: "*duck*^{2}", "*c*^{1}*lown*"). The order of the blocks was counterbalanced across participants.

Participants were seated comfortably in front of a 15 in. computer screen. Prior to the task participants were given the following instructions: "*In this task, you will hear a sound, for example, /tə/, /pə/, or /fə/, and this will be followed by one of the pictures that you named earlier. You are required to silently name the picture while looking for the presence or absence of the sound in the picture's name. The sound could be present either at the beginning, middle, or end of the picture's name. Press the green button on this box as soon as you identify the target sound in the name and the 'red' button if the sound is absent. You will see the same picture another time after you press the button and this time you have to name the picture aloud. Wait after you name the picture aloud for the next sound and picture.*" Following instructions, three to five practice trials were used to familiarize participants with each task.

Participants were instructed to monitor the target phoneme irrespective of the sound preceding or following it. A trial in each block consisted of the following series of events: (a) an orienting screen for 700 ms followed by auditory presentation of a pre-recorded target phoneme (each target phoneme was always presented along with a schwa vowel although participants were asked to monitor the target phoneme irrespective of the sound preceding or following it); (b) inter-stimulus interval (ISI) of 700, 1400 or 2100 ms between hearing the target phoneme and seeing the target picture (ISIs were varied to reduce anticipatory button press responses from participants); (c) target picture presented on the screen for 3 s; and (d) participants pressing the green ('yes') or the red ('no') button using the index and middle fingers of the dominant hand to indicate the presence/absence of a phoneme in the target; (e) manual response initiating the presentation of the same picture with participants naming the picture aloud. This was done to determine if a child was thinking of the target word, as opposed to another word, when responding to the monitoring task. Presentation of the next trial in the sequence was initiated by the experimenter after participants' response or automatically after 3 s in case of no response.

2.5.3. Rhyme monitoring

The purpose of this task was to investigate the response times to rhyme monitoring in nonword – word pairs during silent picture naming. The task design was similar to phoneme monitoring except that the order of stimuli presentation in the two blocks was different. Prior to the task participants were given the following instructions: "*In this task, you will hear a made-up word, for example, lat, and this will be followed by one of the pictures that you named earlier. You are required to silently name the picture while looking for the presence or absence of a rhyme match between the made-up word and the picture's name. Press the green button on this box as soon as you identify a rhyme match and the 'red' button if not. You will see the same picture another time after you press the button and this time you have to name the picture aloud. Wait after you name the picture aloud for the next sound and picture.*" A trial in each block consisted of the following series of events: (a) an orienting screen for 700 ms followed by auditory presentation of a pre-recorded target nonword; (b) inter-stimulus interval (ISI) of 700, 1400 or 2100 ms between hearing the target nonword and seeing the target picture; (c) target picture presented on the screen for 3 s; (d) participants pressing the green ('yes') or the red ('no') button using the index and middle fingers of the dominant hand to indicate the presence/absence of a rhyme match; (e) manual response initiating the presentation of the same picture with participants naming the picture aloud. As indicated in Fig. 1 and as described above, the trials in this task were similar to the phoneme monitoring task with the exception that the child monitored for a rhyme match.

2.5.4. Tone-sequence monitoring

The purpose of this task was to investigate the response times to the presence or absence of a tone-sequence match. Tone-sequence monitoring was designed to enable comparison between monitoring of larger-units in the verbal (rhymes) vs. nonverbal (tone sequences) domains. Target tone sequences were paired and presented in two blocks of 28 stimuli each. Prior to the task participants were familiarized with three tone sequence pairs to ensure that they were able to perform the task. Participants were given the following instructions: "*In this task, you will hear a three tone sequence, for example, beep-beep-beep, and this will be followed by another three-tone sequence. You are required to identify if the two tone sequences in the series match each other or not. Press the green button on this box as soon as you identify a sequence match and the 'red' button if not. Wait after you press the button for the next tone sequence pair.*" A trial in each block consisted of the following series of events: (a) an orienting screen for 700 ms followed by auditory presentation of a pre-recorded target tone sequence; (b) inter-stimulus interval (ISI) of 700, 1400 or 2100 ms between hearing the first tone sequence and the second tone sequence in the series; (c) presentation of the second tone sequence in the series; (d) participants pressing the green ('yes') or the red ('no') button using the index and middle fingers of the dominant hand to indicate the presence/absence of a tone-sequence match. Unlike the phoneme and rhyme monitoring tasks, this task did not have a naming component at the end of each trial. Manual response initiated the presentation of the next tone sequence pair. As indicated in Fig. 1, the trials in this task were similar to the verbal monitoring tasks with the exception that the participant monitored for a tone-sequence match.

2.6. Instrumentation

The experimental stimuli were programmed and presented using Super Lab v 4.0 software. A laptop was used to present the stimuli for the three tasks. Manual responses from the monitoring tasks were recorded using the Cedrus response box. Spoken responses from the overt picture naming trials were recorded using a Sony Digital Voice Recorder. Reaction time, the time (in ms) between presentation of the stimuli and subject response across the monitoring tasks, was automatically recorded by Super Lab and stored on the laptop's hard drive.

2.7. Data scoring

Trials in each task were categorized as correct, error, and outlier responses. Correct responses included trials where participants identified correctly the presence or absence of a phoneme, rhyme, or tone match. Outlier responses included trials where the response time was 2 SD above or below the individual's mean response time for each task. Error responses included both incorrect and absent responses, with incorrect responses including trials where participants responded with a *false positive* or a *false negative* response to the presence or absence of a phoneme, rhyme, or tone match. Table 1 provides a summary of the percent outliers and errors that were excluded from each group for the three tasks. The error responses were analyzed separately.

2.8. Statistical analysis

Response time, the primary dependent variable, was analyzed to study differences between the stuttering and nonstuttering groups in the three tasks – phoneme, rhyme, and tone monitoring. Only correct responses, that is, both 'yes' and

Table 1
Percent outliers and error responses for the phoneme, rhyme, and tone monitoring tasks.

Group		Outlier phoneme monitoring	Outlier rhyme monitoring	Outlier tone monitoring	Error phoneme monitoring	Error rhyme monitoring	Error tone monitoring
CWS	Mean	4.6	5.0	3.4	9.7	3.6	9.3
	SD	1.5	2.6	1.4	6.6	2.2	5.1
CNS	Mean	5.4	5.6	4.4	6.7	1.8	9.7
	SD	6.2	2.7	1.5	7.6	2.1	6.2

'no', were included in the response time analysis. For this repeated measures analysis, Group (CWS, CNS) was the between-subjects variable while Task (phoneme, rhyme, tone) was the within-subjects variable. A second repeated measures analysis was run on the phoneme monitoring time data to investigate differences, if any, between the groups in monitoring singletons vs. consonant clusters. For this analysis, Group (CWS, CNS) was the between-subjects variable, while Complexity (singleton, consonant cluster) and Position (onset, offset) were the within-subjects variables. Finally, another repeated measures analysis was run on the error data to investigate differences between the groups in the percent errors in monitoring across the three tasks. For this analysis, Group (CWS, CNS) was the between-subjects variable while Task (phoneme, rhyme, tone) was the within-subjects variable.

3. Results

3.1. Formal and informal test scores

Table 2 shows the mean (SD) scores for the two groups in the formal (standardized) and informal test measures. Independent samples t-tests revealed the group differences to be non-significant for all of the tests (Forward digit span, $t(16) = -0.31$, $p = 0.37$; Backward digit span, $t(16) = -0.27$, $p = 0.36$; PPVT standard score, $t(16) = 0.78$, $p = 0.22$; LAC standard score, $t(16) = -0.38$, $p = 0.35$, rhyme perception, $t(16) = -0.82$, $p = 0.21$; rhyme production, $t(16) = 0.28$, $p = 0.38$). Informal analysis also revealed that the participant in the CWS group who had less than 3% stuttered syllables (the average from reading and conversation was less than 3% syllables stuttered) was not an outlier in any of the tasks.

3.2. Response time data

This analysis was done to study differences between the CWS and CNS groups in the three tasks – phoneme, rhyme, and tone monitoring. Group was the between-subjects variable while Task (Phoneme, Rhyme, Tone) was the within-subjects variable. *Huynh–Feldt p* values are reported for conditions where sphericity was violated. This analysis revealed a non-significant effect of Group, although descriptively the CWS group was slower (mean = 1697 ms, SD = 330) than the CNS group (mean = 1584 ms, SD = 330), $F(1,16) = 0.52$, $p = 0.48$, *partial eta-squared* = 0.03. A significant effect of Task, (*Huynh–Feldt*) $F(2,32) = 18.05$, $p = 0.0001$, *partial eta-squared* = 0.53, was obtained. Post hoc comparisons (*Fischer's LSD*) revealed that in both groups participants were faster in rhyme monitoring (mean = 1372 ms, SD = 357) than tone monitoring (mean = 1647 ms, SD = 117, $p = 0.003$), and in tone monitoring than phoneme monitoring (mean = 1901 ms, SD = 303, $p = 0.006$). A non-significant Group × Task effect was observed, $F(2,32) = 0.01$, $p = 0.99$, *partial eta-squared* = 0.0006.

3.2.1. Complexity effects

This analysis was run to investigate differences, if any, between the groups in monitoring targets varying in phonemic complexity, that is, singletons vs. consonant clusters, during the phoneme monitoring task. For this analysis, Group (CWS, CNS) was the between-subjects variable, while Complexity (singleton, consonant cluster) and Position (onset, offset) were the within-subjects variables. A significant main effect of Complexity was observed such that monitoring of the consonant clusters (mean = 1981 ms, SD = 318) took longer than monitoring of the singletons (mean = 1814 ms, SD = 293), $F(1,16) = 35.9$, $p = 0.0001$, *partial eta-squared* = 0.60. A significant main effect of Position was observed such that monitoring the phonemes in the offset position took longer (mean = 2076 ms, SD = 366) than monitoring those at syllable onset positions (mean = 1719 ms, SD = 267), $F(1,16) = 24.9$, $p = 0.0001$, *partial eta-squared* = 0.69. A nonsignificant Group main effect

Table 2
Formal and informal test scores for the CWS and CNS groups.

Group		Forward digit span	Backward digit span	PPVT[a]	LAC[a]	Rhyme perception	Rhyme production
CWS	Mean	9.8	5.6	121.9	112.1	93.2	96.3
	SD	1.9	1.7	19.3	18.4	12.9	11.5
CNS	Mean	10.1	5.8	115.3	114.6	97.0	94.8
	SD	2.4	1.7	15.7	5.7	5.6	10.5

[a] Both PPVT and LAC standard scores are based on a mean of 100 and SD of 15.

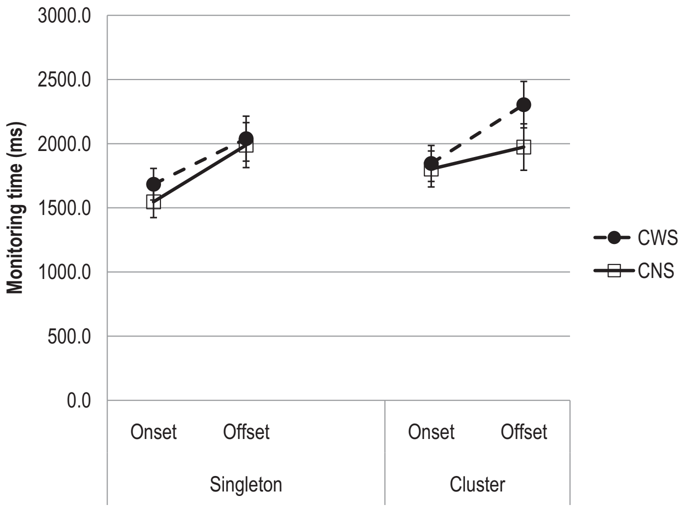

Fig. 2. Average phoneme monitoring times (and SE) for singletons and consonant clusters in syllable onset and offset positions.

was observed in this analysis, $F(1,16) = 0.48$, $p = 0.49$, *partial eta-squared* = 0.029. This analysis revealed a trend for significant Group × Complexity × Position effect, $F(1,16) = 3.69$, $p = 0.073$, *partial eta-squared* = 0.18. This trend revealed that the CWS group took longer to monitor consonant clusters compared to singletons; particularly those in the word/syllable offset position compared to the onset position (see Fig. 2). All other interaction effects were non-significant; Group × Complexity, $F(1,16) = 0.49$, $p = 0.49$, *partial eta-squared* = 0.02, Group × Position, $F(1,16) = 2.7$, $p = 0.11$, *partial eta-squared* = 0.14, Complexity × Position, $F(1,16) = 0.74$, $p = 0.41$, *partial eta-squared* = 0.04.

3.3. Error analysis

A repeated measures analysis was run to investigate differences between the groups in the percent errors in monitoring across the three tasks. For this analysis, Group (CWS, CNS) was the between-subjects variable while Task (phoneme, rhyme, tone) was the within-subjects variable. This analysis revealed a main effect of Task, $F(2,32) = 12.3$, $p = 0.0001$, *partial eta-squared* = 0.43, with the rhyme monitoring task having the least errors (mean = 2.7, SD = 1.5) and the tone monitoring task having the most errors (mean = 9.5, SD = 5.1), closely followed by the phoneme monitoring task (mean = 8.2, SD = 5.0). No other main or interaction effects were significant; Group, $F(1,16) = 0.55$, $p = 0.46$, *partial eta-squared* = 0.03, Task × Group, $F(2,32) = 0.68$, $p = 0.51$, *partial eta-squared* = 0.04.

4. Discussion

The aim of the present study was to investigate skills, namely, rhyme and segmentation, which are considered to underlie phonological encoding abilities in CWS. Earlier studies investigating such skills in younger CWS have reported mixed results (e.g. Arnold et al., 2005; Byrd et al., 2007; Melnick et al., 2003; Weber-Fox et al., 2008) and a majority have used overt production and involved methodologies that have not tested both rhyme and segmentation skills in a single paradigm, with the exception of Byrd et al. (2007). In the present study, we investigated both these skills in a group of 7–13-year-old CWS using a covert picture naming task where all aspects of the design were similar except for the underlying skills being tested. In addition, we investigated the effect of phonemic complexity on monitoring by studying differences in monitoring time for singleton vs. consonant clusters in the phoneme monitoring task. Performances in the verbal monitoring tasks were compared to a nonverbal tone monitoring task to investigate if certain cognitive processes shared across the three tasks may be implicated in CWS. Finally, the groups were compared in the percent errors in monitoring across the three tasks.

4.1. Response time

Present findings of lack of differences between the CWS and CNS in phoneme and rhyme monitoring response times indicate that CWS in the age range of 7 and 13 years do not experience unique difficulties in segmentation and rhyme abilities as measured by a silent monitoring task. Based on the assumption that rhyme and segmentation skills are the building blocks of phonemic competence (Bonte & Blomert, 2004; Goswami, 2002; Jusczyk, 1993; Metsala & Walley, 1998), and are critical for performing tasks such as phonological encoding (e.g. Sasisekaran & Weber-Fox, 2012), the findings of comparable phoneme and rhyme monitoring in CWS and CNS suggest at the outset that the CWS exhibit intact phonological encoding abilities. One possible explanation for the lack of group differences is that the older CWS may have been performing at ceiling in the experimental tasks thereby resulting in less divergence between the groups. Descriptive examination of the response time data did reveal that the three older CWS between 12 and 13 years of age were comparable to the age-matched CNS in all three monitoring tasks, while the younger CWS between 7 and 11 years of age were slower than the CNS in all three tasks (at least by 200 ms).

The present finding seems contradictory to the CRH, which postulated a deficit in phonological encoding as a causal factor in stuttering. Defective phonological encoding would be evident as poor functioning in the rhyme and phoneme monitoring tasks, which in turn could be reflective of a deficit in the processing and/or representation of holistic and segmental units in speech production (e.g. Metsala & Walley, 1998). However, present findings suggest that the processing and/or representation of holistic and segmental units in speech production are intact in CWS. Yet another interpretation of the present findings is that the CWS do not significantly differ from CNS on the verbal monitoring tasks because their monitoring skills are in overdrive (e.g. Bernstein Ratner, 1997), potentially making up for primary phonological processing difficulty or latency. Further testing comparing monitoring performances in both production and perception is required to conclusively interpret that the lack of group differences in the verbal monitoring tasks used in this study are not due to an over-active monitoring system that obscures any observable differences in phonological processing.

The findings also revealed that the groups were comparable in the percent of errors in phoneme and rhyme monitoring. Again, if as suggested by the CRH, the speech plan of individuals who stutter exhibit a higher number of errors then this should result in a higher percent of errors in the phoneme and rhyme tasks. However, the comparable number of errors in these tasks between CWS and CNS did not support such an assumption.

Byrd et al. (2007) investigated holistic and segmental encoding skills in CWS and reported that 5-year-old CWS are delayed in segmental encoding abilities. Their findings suggested that the phonological system in CWS may be less well developed or efficient. Contrary to such findings, the results from the present study do not support a delay in the encoding of either rhyme or segmental information. However, caution is warranted in interpreting the findings from the present study as being contradictory to the Byrd et al. study as the age ranges tested in these studies are different. Byrd et al. tested much younger children between 3 and 5 years of age while the CWS in the present study were between 7 and 13 years of age. It is likely that younger CWS exhibit difficulties in segmental encoding which resolve in later years. For instance, Paden, Ambrose, & Yairi (2002) reported differences in phonological skills in children closer to stuttering onset which resolved later even though these children persisted in stuttering.

For both groups the rhyme monitoring condition was markedly easier. In other words, the provision of the rhyme prior to seeing the picture, "primed" the children's ability to correctly encode the presence of that particular group of sound segments in the target picture. This finding was unexpected as we had presumed that (at least) the CNS would have found the phoneme monitoring task to be more facilitative. Our hypothesis was based on the presumption that children shift from holistic to incremental processing at an age that is younger than the age of the participants of the present study. Perhaps methodological differences could explain the performance difference in this study compared to the Byrd et al. (2007) study. The target incremental phoneme in the Byrd et al. study always occurred in the initial position of the word. By comparison, in the present study, the incremental phoneme occurred across both initial and final positions in a syllable. Thus, one could argue that the incremental task used in the present study was significantly more challenging than the comparable task in Byrd et al. Therefore, any point in the word beyond that initial sound in the word would arguably be significantly more challenging to monitor.

Additionally, the nature of the silent monitoring task in general may have contributed to the increased difficulty of the phoneme monitoring task. Studies using overt speech production in tasks, such as, picture naming and nonword repetition, have demonstrated a significant difference between CWS and CNS in phonological processing abilities (e.g. Anderson et al., 2006; Byrd et al., 2007; Hakim & Ratner, 2004). The fact that this same relationship was not seen in the current study may point to the more complex nature of accessing such phonemic representations without the benefit of overt production.

4.1.1. Complexity effects

Despite the lack of differences between CWS and CNS in the rhyme and segmentation tasks, there is still some preliminary support from the present findings that CWS may have difficulty in segmental monitoring abilities with increasing phonemic complexity of the stimuli that are being processed. This was evident as a trend for an increase in phoneme monitoring time of consonant clusters compared to singletons, particularly those located in the syllable offset position. This trend is particularly noteworthy considering that the groups did not differ significantly in any of the formal or informal tests of skills, such as, vocabulary, short-term memory, phonological awareness, and rhyming, that may have influenced phoneme monitoring performance. The finding corroborates earlier reports of increasing stutter events and errors in stimuli of increasing phonemic complexity in individuals who stutter (e.g. Louko et al., 1990; Paden et al., 1999; Wolk et al., 2000). A delay in segmentation skills in production can be hypothesized to have an effect on the timely performance of phonological encoding. Therefore, the present findings do not completely rule out the possibility of a phonological encoding deficit in CWS. Rather, the findings indicate that complexity may be one factor to consider in interpreting the mixed findings of past studies. Group differences may become evident with increasing phonemic complexity of the target stimuli. For instance, using complex stimuli such as bisyllabic words, phonological words, and sentences, and comparing performance between CWS and CNS while monitoring for target segments and rhymes within such stimuli may shed some light on the role of increasing task complexity on monitoring performance in CWS.

4.2. Future directions

Future research should consider (at least) the following four key questions. First, does word position of the target phoneme affect monitoring? Intuitively we may assume yes, word-initial phonemes will be most easy to monitor, followed by word-final, then word-medial. This follows the typical trajectory of development for children's phonological awareness skills. But is it any different for children who stutter? In future studies we aim to investigate phoneme monitoring in each word position, as well as comparing children who stutter to those who do not stutter.

Second, does place, manner, or voicing affect phoneme monitoring? It is possible that performance may vary between targets based on the distinctive features of the given phoneme. Perhaps stops/plosives are easier to monitor than fricatives, or maybe velar sounds are more challenging than bilabials. Though no overt production may take place, we know that motor speech areas of the brain are activated during other silent tasks, such as subvocal rehearsal; thus it would make sense that sounds and sound sequences that are more difficult to produce might be more difficult or take more time to access in a silent naming task. This hypothesis could be explored in greater depth with an experimental paradigm that controlled for place, manner, and voicing of targets.

Third, does severity of stuttering impact monitoring skills? The current study, though small, included CWS participants representing a broad range of stuttering severities. While such terms as mild, moderate, and severe are relative by nature, future research into the frequency or severity of stuttering and its correlation to speed and accuracy of phonological processing in individuals would be very valuable. In addition, this relationship should be observed on an item-by-item basis, reporting the accuracy, speed, and fluency upon overt naming for monitoring tasks. This would provide the opportunity to compare not only different degrees of stuttering, but also the correlation between disfluent productions and performance on encoding tasks.

In conclusion, the findings from the present study indicate that CWS may be comparable to CNS in rhyme and segmentation, skills which are considered to underlie phonological encoding abilities. Although this finding does not support theories such as the CRH, which postulate a phonological encoding deficit in stuttering, caution is warranted in arriving at this conclusion as there is some preliminary evidence from this study indicating that difficulties in segmentation skills may begin to emerge with increasing task complexity in CWS. This finding alludes to a role for phonological encoding in explanations of stuttering. Potential limitations of the present study include the wide age range (7–13 years) and the small sample size. As mentioned earlier, it is possible that the older participants in both groups were performing at ceiling thereby resulting in less divergence between groups. Comparing phoneme monitoring performance between younger children who stutter who are not yet at mastery for the task with older children might aid in teasing apart potential age-related differences. Future studies also need to test the effect of task complexity on segmentation skills using the phoneme monitoring task in order to understand further the role of phonological encoding in stuttering.

CONTINUING EDUCATION

A preliminary investigation of segmentation and rhyme abilities of children who stutter

QUESTIONS

1. Rhyme and segmentation abilities are skills underlying which process?
   a. Semantic encoding
   b. Motor planning
   c. Motor execution
   d. Phonological encoding
   e. Naming
2. Which of the following have been observed in past studies of segmentation and rhyme abilities in CWS?
   a. Unequivocal support for a phonological encoding deficit in CWS.
   b. Unequivocal support for the absence of a phonological encoding deficit in CWS.
   c. Equivocal support for a phonological encoding deficit in CWS.
   d. Some support for difficulties in rhyme abilities in CWS.
   e. Some support for segmentation difficulties in CWS.
3. In the current study which of the following tasks were used to investigate segmentation and rhyme abilities in CWS and CNS?
   a. Priming
   b. Rhyme judgment
   c. Nonword repetition
   d. Phoneme and rhyme monitoring
   e. Picture naming

4. Results from the current study show that:
   a. CWS are comparable to CNS in the speed of phoneme and rhyme monitoring.
   b. CWS are slower in phoneme monitoring but comparable in rhyme monitoring to CNS.
   c. CWS are slower in rhyme monitoring but comparable in phoneme monitoring to CNS.
   d. CWS are faster in both phoneme and rhyme monitoring compared to CNS.
   e. CWS are slower in both phoneme and rhyme monitoring compared to CNS.
5. The findings of a trend for slower monitoring of consonant clusters in CWS compared to CNS may be indicative of:
   a. Poor rhyming skills in CWS.
   b. Segmentation difficulties associated with increasing complexity of target stimuli in CWS.
   c. Poor response to the nonverbal monitoring task in CWS.
   d. Better segmentation and/or rhyming abilities in CWS.
   e. Faster production of consonant clusters in CWS.

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Appendix A.

List of items and Snodgrass and Vandervart (1980) norms for the target pictures.

Phonemes	Nonwords	Pictures	Image agreement		Familiarity		Kucera–Francis	Age of acquisition
			M	SD	M	SD		
k	lat	[a]cat (CVC)	3.8	0.9	4.2	0.9	23	1.4
	stown	[b]clown (CCVC)	3.3	0.9	2.6	1.2	3	–
	zuck	[c]duck(CVC)	3.9	0.9	2.8	1.1	9	–
	bork	[d]fork (CVCC)	4.2	0.9	4.8	0.5	14	2.2
r	ning	ring (CVC)	3.1	0.9	1.5	0.9	3	–
	drush	brush (CCVC)	3.2	1.3	3.8	1.1	44	–
	gair	chair (CVC)	3.2	1.3	4.6	0.9	66	1.9
	chirt	shirt (CVCC)	3.9	1.0	4.6	0.7	27	–
l	veg	leg (CVC)	3.6	1.1	4.7	0.8	58	–
	zrag	flag (CCVC)	3.2	1.2	2.9	1.3	16	–
	thowl	bowl (CVC)	3.8	0.9	4.2	0.9	23	–
	lelt	belt (CVCC)	4.1	1.0	4.1	1.1	29	–
d	zeer	deer (CVC)	3.7	1.1	2.2	1.2	13	–
	klum	drum (CCVC)	3.7	1.1	2.6	1.2	11	2.5
	ged	bed (CVC)	3.7	1.1	2.0	1.0	57	2.4
	jird	bird (CVCC)	3.3	1.1	3.6	1.2	31	–
t	dop	top (CVC)	3.5	1.1	1.9	1.0	204	–
	klar	star (CCVC)	4.4	1.1	3.4	1.3	25	–
	voot	boot (CVC)	2.3	1.0	3.4	1.2	13	–
	leart	heart (CVCC)	4.5	1.0	3.7	1.2	173	–
n	kail	nail (CVVC)	4.7	0.6	3.3	1.2	6	3.6
	drail	snail (CCVC)	3.3	1.2	1.9	1.1	1	5.1
	hion	lion (CVC)	3.9	1.0	2.0	1.1	17	2.8
	zorn	corn (CVCC)	4.1	0.9	3.5	1.1	34	2.9
f	gish	fish (CVC)	3.6	1.1	3.3	1.2	35	2.6
	plog	frog (CCVC)	3.6	1.0	2.5	1.1	1	3.2
	neaf	leaf (CVC)	3.9	1.1	4.3	0.8	12	2.6
	kolf	wolf (CVCC)	Item not present in Snodgrass and Vandervart					

Note. '–' norms unavailable for age of acquisition of corresponding concepts.

[a] Initial singleton.
[b] Initial cluster.
[c] Coda singleton.
[d] Coda cluster.

References

Anderson, J. D., Wagovich, S. A., & Hall, N. E. (2006). Nonword repetition skills in young children who do and do not stutter. *Journal of Fluency Disorders*, *31*, 177–199.

Arnold, H. S., Conture, E. G., & Ohde, R. N. (2005). Phonological neighborhood density in the picture naming of young children who stutter: Preliminary study. *Journal of Fluency Disorders*, *30*, 125–148.
Bakhtiar, M., Ali, D. A., & Sadegh, S. P. (2007). Nonword repetition ability of children who do and do not stutter and covert repair hypothesis. *Indian Journal of Medical Sciences*, *61*, 462–470.
Besner, D. (1987). Phonology, lexical access in reading, and articulatory suppression: A critical review. *Quarterly Journal of Experimental Psychology*, *39A*, 467–478.
Bernstein Ratner, N. (1997). Stuttering: A psycholinguistic perspective. In R. Curlee, & G. M. Siegel (Eds.), *Nature and treatment of stuttering: New directions* (2nd ed., pp. 99–127). Boston, MA: Allyn & Bacon.
Blackmer, E. R., & Mitton, J. L. (1991). Theories of monitoring and the timing of repairs in spontaneous speech. *Cognition*, *3*, 173–194.
Bock, K., & Levelt, W. J. M. (1994). Language production. Grammatical encoding. In M. A. Gernsbacher (Ed.), *Handbook of psycholinguistics* (pp. 945–984). San Diego: Academic Press.
Bonte, M., & Blomert, L. (2004). Developmental changes in ERP correlates of spoken word recognition during early school years: A phonological priming study. *Clinical Neurophysiology*, *115*(2), 409–423.
Brooks, P., & MacWhinney, B. (2000). Phonological priming in children's picture naming. *Journal of Child Language*, *27*, 335–366.
Byrd, C. T., Conture, E. G., & Ohde, R. N. (2007). Phonological priming in young children's picture naming: Holistic versus incremental processing. *American Journal of Speech, Language, Pathology*, *16*(1), 43–53.
Coch, D., Grossi, G., Coffey-Corina, S., Holcomb, P. J., & Neville, H. J. (2002). A developmental investigation of ERP auditory rhyming effects. *Developmental Science*, *5*(4), 467–489.
Dunn, L., & Dunn, L. (1997). *Peabody picture vocabulary test* (3rd ed.). Circle Pines, MN: American Guidance Service.
Gathercole, S., Willis, C., Baddeley, A., & Emslie, H. (1994). The Children's Test of Nonword Repetition: A test of phonological working memory. *Memory*, *2*, 103–127.
Goswami. (2002). In the beginning was the rhyme? A reflection on Hulme, Hatcher, Nation, Brown, Adams, and Stuart (2002). *Journal of Experimental Child Psychology*, *82*, 47–57.
Hakim, H. B., & Ratner, N. B. (2004). Nonword repetition abilities of children who stutter: An exploratory study. *Journal of Fluency Disorders*, *29*, 179–199.
Howell, P. (2004). Assessment of some contemporary theories of stuttering that apply to spontaneous speech. *Contemporary Issues in Communication Sciences and Disorders*, *31*, 123–141.
Howell, P., Au-Yeung, J., & Sackin, S. (2000). Internal structure of content words leading to lifespan differences in phonological difficulty in stuttering. *Journal of Fluency Disorders*, *25*(1), 1–20.
Jusczyk, P. W. (1993). From general to language-specific capacities—The Wrapsa model of how speech-perception develops. *Journal of Phonetics*, *21*(1–2), 3–28.
Levelt, W. J. M. (1989). *Speaking: From intention to articulation*. Cambridge, MA: MIT Press.
Levelt, W. J. M., Roeloffs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. *Behavioral and Brain Sciences*, *22*, 1–75.
Lindamood, C. H., & Lindamood, P. C. (1979). *The Lindamood auditory conceptualization test (LAC)* (revised ed.). Allen, TX: DLM Teaching Resources.
Louko, L. H., Edwards, M. L., & Conture, E. G. (1990). Phonologic characteristics of young stutterers: Preliminary findings. *Journal of Fluency Disorders*, *15*, 191–221.
Melnick, K. S., Conture, E. G., & Ohde, R. N. (2003). Phonological priming in picture naming of young children who stutter. *Journal of Speech, Language, and Hearing Research*, *46*(6), 1428–1444.
Metsala, J. L. (1997). An examination of word frequency and neighborhood density in the development of spoken-word recognition. *Memory and Cognition*, *25*(1), 47–56.
Metsala, J. L. (1999). Young children's phonological awareness and nonword repetition as a function of vocabulary development. *Journal of Educational Psychology*, *91*(1), 3–19.
Metsala, J. L., & Walley, A. C. (1998). Spoken vocabulary growth and the segmental restructuring of lexical representations: Precursors to phonemic awareness and early reading ability. In J. L. Metsala, & L. C. Ehri (Eds.), *Word recognition in beginning literacy* (pp. 89–120). Mahwah, NJ: Erlbaum.
Paden, E., Yairi, E., & Ambrose, N. (1999). Early childhood stuttering. II. Initial status of phonological abilities. *Journal of Speech, Language, and Hearing Research*, *42*, 1113–1124.
Paden, E. P., Ambrose, N., & Yairi, E. (2002). Phonological progress during the first 2 years of stuttering. *Journal of Speech, Language, and Hearing Research*, *45*, 256–267.
Perkins, W. H., Kent, R. D., & Curlee, R. F. (1991). A theory of neuropsycholinguistic function in stuttering. *Journal of Speech and Hearing Research*, *34*(4), 734–752.
Postma, A., & Kolk, H. (1993). The covert repair hypothesis: Prearticulatory repair processes in normal and stuttered disfluencies. *Journal of Speech and Hearing Research*, *36*(3), 472–487.
Sasisekaran, J., & Weber-Fox, C. (2012). Cross-sectional study of phoneme and rhyme monitoring abilities in children between 7 and 13 years. *Applied Psycholinguistics*, *33*, 253–279.
Snodgrass, J. G., & Vandervart, M. (1980). A standardized set of 260 pictures: Names for name agreement, familiarity and visual complexity. *Journal of Experimental Psychology*, *6*, 174–215.
Walley, A. C., Metsala, J. L., & Garlock, V. M. (2003). Spoken vocabulary growth: Its role in the development of phoneme awareness and reading ability. *Reading and Writing: An Interdisciplinary Journal*, *16*, 5–20.
Weber-Fox, C., Spruill, J. E., Spencer, R., & Smith, A. (2008). Atypical neural functions underlying phonological processing and silent rehearsal in children who stutter. *Developmental Science*, *11*(2), 321–337.
Wechsler, D. (1997). *WAIS-III administration and scoring manual*. San Antonio, TX: The Psychological Corporation.
Wingate, M. E. (1988). *The structure of stuttering*. New York: Springer.
Wolk, L., Blomgren, M., & Smith, A. B. (2000). The frequency of simultaneous disfluency and phonological errors in children: A preliminary investigation. *Journal of Fluency Disorders*, *25*(4), 269–281.
Yaruss, J. S. (1998). Real-time analysis of speech fluency: Procedures and reliability training. *American Journal of Speech–Language Pathology*, *7*(2), 25–37.

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