Published in final edited form as:
J Fluency Disord. 2010 September ; 35(3): 216–234. doi:10.1016/j.jfludis.2010.04.003.

Relationships Among Linguistic Processing Speed, Phonological Working Memory, and Attention in Children Who Stutter

Julie D. Anderson and
Indiana University

Stacy A. Wagovich
University of Missouri

Abstract

Relatively recently, experimental studies of linguistic processing speed in children who stutter (CWS) have emerged, some of which suggest differences in performance among CWS compared to children who do not stutter (CWNS). What is not yet well understood is the extent to which underlying cognitive skills may impact performance on timed tasks of linguistic performance. The purpose of this study was to explore possible relationships between measures of linguistic processing speed and two aspects of cognition: phonological working memory and attention. Participants were 9 CWS and 14 CWNS between the ages of 3;6 and 5;2. Children participated in a computerized picture naming task (an index of linguistic processing speed) and a nonword repetition task (an index of phonological working memory). Parents completed a temperament behavior questionnaire, from which information about the children's attentional skills was collected. Findings revealed that the groups did not differ from each other on speed of picture naming or attention; however, the CWS performed significantly worse in nonword repetition. In addition, after partialling out the effects of age, (a) for CWS only, there was a significant negative relationship between picture naming speed and nonword repetition; (b) there were no significant relationships for either group between aspects of attention and picture naming speed; and (c) only the CWNS showed a significant relationship between nonword repetition and focused attentional skills. These results underscore the need to consider the underlying skills associated with lexically-related aspects of language production when examining the task performances of CWS and CWNS.

Keywords

Stuttering; Linguistic Processing Speed; Phonological Working Memory; Attention; Children

1. Introduction

There has been an increasing interest over the last twenty years in the interaction between language factors and fluency in children who stutter (CWS). Most research in this area has

Correspondence To: Julie D. Anderson, Ph.D., CCC-SLP, Department of Speech and Hearing Science, Indiana University, 200 South Jordan Avenue, Bloomington, IN 47405-7002, *Office phone*: (812) 856-1240, judander@indiana.edu.

A portion of this research was presented at the annual meeting of the American Speech-Language-Hearing Association, New Orleans, LA, November, 2009.

focused on young CWS as they acquire language. As approaches to the measurement of language have become more sophisticated, there has been an increasing emphasis on linguistic processing skills and the measurement of processing speed (e.g., Anderson, 2008; Arnold, Conture, & Ohde, 2005; Byrd, Conture, & Ohde, 2007; Hartfield & Conture, 2006; Pellowski & Conture, 2005; Melnick, Conture, & Ohde, 2003). Studies that incorporate a reaction time component can often detect subtle language processing issues. The underlying skills that enable one to respond quickly to a linguistic prompt are not well understood, however. For instance, theoretically, having a strong vocabulary should aid performance on a naming task, but other factors, including a range of cognitive factors, may play a role as well. Thus, the primary focus of this article is to explore the extent to which two factors in particular, phonological working memory and attentional skills, play a role in linguistic processing speed for CWS and their typically fluent peers. We begin with a discussion of several semantic and phonological processing studies that have most directly informed the present study.

1.1. Linguistic Processing Speed in CWS

Reaction time studies are employed to go beyond analysis of linguistic accuracy by examining an individual's speed of processing within a particular domain (e.g., phonological, lexical, syntactic). Thus, reaction time is viewed as a sensitive means of examining the efficiency with which a person processes and responds to a language-based stimulus, such as a picture or word. Several recent studies of speech reaction time (SRT) in CWS are relevant to the present study (Anderson & Conture, 2004; Byrd et al., 2007; Hartfield & Conture, 2006; Melnick et al., 2003; Pellowski & Conture, 2005). Anderson (2008) provides a review of these, but to summarize, results of phonological priming SRT studies have been mixed. For example, Melnick, Conture, and Ohde (2003) found that, given a phonologically related prime (the initial CV or CCV of the target word), both CWS and CWNS, ages 3 to 5, had faster SRTs than when they were given no prime or an unrelated prime, and that in both groups, older children had faster SRTs than younger children. There were no significant differences, however, in SRT between the two groups of children. In contrast, Byrd et al. (2007) used SRT to study the effects of incremental priming (i.e., the first sound of the target word) versus holistic priming (i.e., the rest of the word) in CWS and CWNS, ages 3 to 5. In their cross-sectional study, they found that the CWNS tended to shift from a holistic priming advantage among the younger children in the group to an incremental priming advantage for the older CWNS. The CWS, however, tended to show the fastest SRTs in response to holistic priming regardless of age.

Few studies have examined SRTs for semantically related primes. However, findings from these studies generally suggest that CWS have slower speech reaction times compared to peers (Hartfield & Conture, 2006; Pellowski & Conture, 2005) and that they do not benefit from semantically related primes, whereas CWNS do (Pellowski & Conture). Of interest, Pellowski and Conture found that, for CWNS, faster (shorter) SRTs corresponded to higher receptive vocabulary scores, but for CWS, there was no relationship between vocabulary scores and SRT.

Given these findings, Anderson (2008) hypothesized that perhaps differences between CWS and CWNS lie, to some extent, in the process of mapping semantic representations with phonological representations. She examined this possibility using a picture naming task in which preschool children named pictures of early- and late-acquired words in two consecutive stages. Relevant to the present study, she found that even though there was no significant difference between CWS and CWNS in SRT or on standardized measures of vocabulary, CWNS exhibited a significant, positive relationship between SRT and vocabulary (in contrast with Pellowski & Conture, 2005), but CWS did not (consistent with Pellowski & Conture). For CWNS, these findings were interpreted to suggest that perhaps children who had richer vocabularies experienced greater lexical competition and, thus, had slower reaction times than those with poorer vocabularies. However, the fact that CWNS exhibited this association but CWS did not further suggested that some other factor related to lexical processing, such as phonological working memory, may have mediated the observed correlation (or lack thereof). Phonological working memory (as measured through nonword repetition) was targeted as a potential mediating variable, because (a) vocabulary development has been consistently associated with the ability to accurately repeat nonwords (Coady & Evans, 2008; Gathercole, 2006; Gathercole & Baddeley, 1989; Gathercole, Service, Hitch, Adams, & Martin, 1999; Gathercole, Willis, Emslie, & Baddeley, 1992), and (b) CWS have been shown to be less successful than CWNS in their ability to correctly repeat nonwords, suggesting that they may have difficulties with phonological working memory (see section 1.2.3.; Anderson, Wagovich, & Hall, 2006; Hakim & Ratner, 2004; cf. Bakhtiar, Ali, & Sadegh, 2007). Moreover, the ability to respond quickly with the label for a lexical item, it would seem, requires that the item be stored appropriately in memory, to enable efficient retrieval. Indeed, Montgomery and Windsor (2007) found that, for both children with SLI and typical peers, response time and nonword repetition were significantly related.

Several authors have theorized about the nature of the relationship between processing speed and memory capacity (e.g., see Montgomery & Windsor, 2007, for a discussion). There is evidence that increases in children's processing speed over development are associated with growth in working memory capacity (e.g., Fry & Hale, 1996; see Fry & Hale, 2000, for a discussion). Fry and Hale's *developmental cascade model* suggests that, as processing speed increases with age, it enables greater short-term memory capacity,[1] which then impacts fluid intelligence (reasoning, problem solving, etc.). In contrast, Luna and colleagues (Luna, Garver, Urban, Lazar, & Sweeney, 2004) suggest that the two abilities develop, for the most part, independently.

In the present study, a follow-up to Anderson (2008), we explore the possibility that in CWS, phonological working memory, as measured through nonword repetition, is associated with processing speed, as measured through SRT, in CWS. In addition, because lexical processing requires a degree of selective attention to the task, we explore the possibility that attentional abilities are related to processing speed. As will be discussed below, phonological working memory and attention have been theoretically linked in models of working memory.

1.2. Phonological Working Memory and the Role of Attentional Processes

Baddeley's (2003; also see Baddeley, 1986; Gathercole & Baddeley, 1993) model of phonological working memory provides a reasonable conceptualization of how incoming phonological information is processed/stored in memory. Specifically, according to Baddeley's model, the *phonological loop* enables short-term storage and rehearsal. Indeed, it seems that most studies of nonword repetition focus interpretation of findings on the phonological loop component of the model. However, as Bajaj (2007) pointed out in his recent review of the working memory literature in relation to stuttering, consideration of the *central executive* component of Baddeley's model is critical, as well. The *central executive* is responsible for managing information and regulating attention.

Other models of working memory also describe the role of attention. For example, Cowan (1999) discussed *attention-free* and *attention-focused* storage, with attention-focused storage being limited in its capacity. Cowan et al. (2005) emphasizes that the *scope of attention*, defined as "the capacity of the focus of attention" (p. 49), is important to consider and measure in

[1]It should be noted that, while short-term memory and working memory are similar, short-term memory refers to storage of information temporarily without manipulation of the information, whereas working memory refers to storing *and manipulating* the information.

working memory studies. Moreover, some have argued that working memory tasks are truly measures of attentional control (Engle & Kane, 2004; Redick and Engle, 2006).

Clearly, an individual's ability to attend to the target stimulus is critical if processing of the stimulus is to occur. Thus, in examining children's performance in nonword repetition, it is also important to characterize attentional abilities. The sections that follow provide a review of the literature in the areas of nonword repetition and attention. We begin with a brief review of the literature of children with SLI. This literature has focused on nonword repetition and aspects of attention to a greater extent than the literature related to CWS and can potentially inform work in these areas pertaining to stuttering. Thus, prior work in SLI serves to motivate the present study. Following this discussion, we turn to studies of individuals who stutter.

1.2.1. Nonword Repetition in Children with SLI—Interest in the nonword repetition skills of children with SLI perhaps initially stemmed from findings from typically developing children that nonword repetition corresponded to vocabulary development (Gathercole & Baddeley, 1989; Gathercole et al., 1992). Indeed, there is a robust literature focusing on nonword repetition in children with SLI (e.g., Bishop, North, & Donlan, 1996; Conti-Ramsden, 2003; Ellis Weismer, Tomblin, Zhang, Buckwalter, Chynoweth, & Jones, 2000; Montgomery & Windsor, 2007; Munson, Kurtz, & Windsor, 2005; see Estes, Evans, & Else-Quest, 2007, for a comprehensive list of studies in this area). Estes et al. performed a meta-analysis of studies comparing nonword repetition in children with SLI with that of typical language peers, finding that the effect size of between group differences was large. In addition, relevant to the present study, they found that, of the nonword repetition measures used across studies, the *Children's Nonword Repetition Test* (CNRep; Gathercole, Willis, Baddeley, & Emslie, 1994) yielded the largest effect sizes, indicating that this measure is the most sensitive of those employed in these earlier studies. Also relevant was the finding that the effect sizes of the differences between groups for 3- and 4-syllable nonwords were large, whereas those for 1- and 2-syllable nonwords were medium. Thus, it appears that, across studies, the longer nonwords distinguished groups the best, as would be expected.

1.2.2. Attention Processes in Children with SLI—Theorists and researchers have emphasized attention as an important construct to consider, in addition to or as part of understanding phonological working memory (e.g., Baddeley, 2003; Cowan, 1999; Cowan et al., 2005; Engle & Kane, 2004; Redick & Engle, 2006). Within the SLI literature, in particular, there has been a call to look carefully at central executive functioning, which includes aspects of attention, rather than focusing exclusively on phonological working memory. The argument is that, if processing limitations are observed in children with SLI relative to peers, and these limitations extend beyond verbal tasks to spatial processing as well (Hoffman & Gillam, 2004), perhaps central executive functioning should be examined as a broader construct by which to explain processing differences in children with SLI.

Montgomery, Evans, and Gillam (2009) contrasted two types of attention tasks employed within the SLI literature: those that focus on attentional capacity or allocation (e.g., Ellis Weismer, Evans, & Hesketh, 1999; Hoffman & Gillam, 2004; Mainela-Arnold & Evans, 2005; Marton & Schwartz, 2003; Montgomery et al., 2009) and those that focus on sustained or selective attention (e.g., Hanson & Montgomery, 2002; Montgomery et al., 2009; Spaulding, Plante, & Vance, 2008; Stevens, Sanders, & Neville, 2006). An attentional capacity/allocation task might require that an individual hold a word in memory while processing language in some way. For example, the *Competing Language Processing Task* (Gaulin & Campbell, 1994), requires individuals to listen to sentences of different lengths and judge whether the sentences are true or false, while holding in memory the last word of each sentence in the block of trials. In general, children with SLI perform more poorly than their peers on the "memory" component of these tasks, in particular.

In contrast, a sustained selective attention task might involve listening to linguistic stimuli and responding whenever a target word is heard. For example, the *Auditory Continuous Performance Test* (Keith, 1994) requires participants to listen to a set of 600 words, responding each time the word *dog* is heard. In studies that employ procedures of this type, there is conflicting evidence of differences between the performance of children with SLI and their peers. For example, Hanson and Montgomery (2002) found that school-age children with SLI did not differ in their correct/incorrect response rates compared to age-matched peers. However, Spaulding et al. (2008), who developed visual, nonverbal auditory, and linguistic sustained selective attention tasks, found that with background noise, children with SLI performed worse on the linguistic and nonverbal auditory stimuli than peers.

Taken as a whole, it seems that children with SLI do show some differences, relative to peers, in aspects of attention, as well as nonword repetition. Although children who stutter generally are not observed to have clinical language disorders, they have been observed to show subtle differences in language performance (e.g., see Hall, Wagovich, & Bernstein Ratner, 2007, for a discussion). In this paper, we argue that a more complete understanding of memory and attention processes may provide needed insight into performance differences observed in the processing of linguistic stimuli by CWS.

1.2.3. Nonword Repetition in Children who Stutter—In contrast to the SLI literature, studies of phonological working memory in CWS are considerably fewer. To our knowledge, only three studies have directly examined phonological working memory, measured through nonword repetition with CWS (Anderson et al., 2006; Bakhtiar et al., 2007; Hakim & Ratner, 2004). Results have been somewhat conflicting. Hakim and Ratner found that CWS, ages 4 to 8, produced significantly fewer 3-syllable nonwords accurately, compared to age- and gender-matched peers, and they produced significantly more phoneme errors on 3-syllable stimuli than peers. Nonword stimuli of 2, 4, and 5 syllables resulted in no between-groups differences. Similarly, Anderson et al. examined nonword repetition in a younger group of CWS, ages 3 to 5. They found that the CWS produced significantly fewer 2- and 3-syllable nonwords correctly, with significantly more phoneme errors on 3-syllable nonwords.

In contrast to the aforementioned studies, different results were obtained in a recent study by Bakhtiar et al. (2007). This study examined nonword repetition and the phonological skills of CWS and their peers. Participants were 5 to 7 years of age and monolingual speakers of Persian. Stimuli were 2- and 3-syllable nonwords. Findings were that the CWS did not differ from peers in the number of phonological errors produced in repeating the nonwords. All three studies were with CWS who did not differ from peers in language scores, and all three incorporated 3-syllable nonwords (on which between-groups differences were found for two of the studies). Thus, there is some methodological similarity across studies. It is possible that the stimuli across studies differed in overall complexity for the children. For example, the *Children's Nonword Repetition Test* (CNRep; Gathercole et al., 1994), employed by Hakim and Ratner (2004) and Anderson et al. (2006), tends to reveal robust differences among children with language impairments and their peers (Estes et al., 2007). We do not know if this is the case for the nonword repetition task developed by Bakhtiar and colleagues although, based on the description of stimuli development, it appears that the nonwords were carefully developed. In sum, the evidence to date does not present a clear picture of the nonword repetition skills of CWS relative to peers.

1.2.4. Attention in Children and Adults who Stutter—Most of the fluency disorders literature that focuses on attentional processes has been conducted with adults and has used a dual task paradigm (e.g., Bosshardt, 2002; Bosshardt, Ballmer, & De Nil, 2002; Caruso, Chodzko-Zajko, Bidinger, & Sommers, 1994; Smits-Bandstra & De Nil; 2009; Vasic & Wijnen, 2005; see Bosshardt, 2006; Bajaj, 2007, for discussions). For example, Bosshardt et al. asked adults who stutter and typically fluent adults to generate sentences using two target words, while simultaneously making rhyming and category judgments about separate pairs of words. Performance between groups did not differ in the accuracy or speed of rhyme and category decisions. However, the adults who stutter generated sentences with significantly fewer propositions in this dual task condition, compared to the single task condition (sentence generation alone). Typically fluent adults did not show this discrepancy. Findings were interpreted to suggest that perhaps those who stutter, relative to those typically fluent, have greater difficulty directing resources effectively under cognitively demanding conditions. Although this study does not directly speak to the role of attention, it is clear that attention is one of many resources tapped in cognitively complex, dual task experiments.

There has also been an emphasis on automaticity in adults who stutter (e.g., De Nil, Kroll, & Houle, 2001; Smits-Bandstra & De Nil, 2007; Smits-Bandstra, De Nil, & Rochon, 2006). Achieving automaticity involves directing attentional resources to learning a specific motor skill, so these studies inform our understanding of attentional resources in individuals who stutter, as well. For example, Smits-Bandstra, DeNil, and Rochon employed a single/dual task paradigm with adults who stutter and fluent counterparts. Participants were asked to type sequences of 10 numbers. For the dual task condition, each number sequence changed colors; once the participants typed a number sequence, they were asked whether the same color occurred more than once during the presentation (yes/no). The findings, as pertain to automaticity and attention, were that, while adults who do not stutter showed a steep learning curve in the single task condition (for example, reducing their reaction time with increased practice), adults who stutter demonstrated a shallow learning curve, although overall reaction time did decrease. Of interest, neither group showed substantial learning under dual task conditions (i.e., when attentional skills were taxed). See Smits-Bandstra and De Nil for an overview of this research program.

In contrast to the adult literature, it appears that the literature pertaining to children has focused on attentional skills more indirectly. Studies of temperament have referenced aspects of attention. The temperament of CWS has most often been assessed through parent-report questionnaires (e.g., Anderson, Pellowski, Conture, & Kelly, 2003; Embrechts, Ebben, Franke, & van de Poel, 2000; Karrass et al., 2006). Anderson et al. used the *Behavioral Style Questionnaire* (BSQ; McDevitt & Carey, 1978) to examine aspects of temperament in CWS, ages 3 to 5, and their peers. They found that the group of CWS obtained higher scores on the attention/persistence dimension of the questionnaire, suggesting greater persistence and lesser attentional flexibility than peers. Similarly, Karrass et al., using the same measure and the same age range of children, found that the CWS were less able to control attention (i.e., less able to shift focus or disengage, as needed).

These findings of reduced attentional flexibility and attentional control in CWS are similar to the findings of Embrechts et al. (2000). They used a different temperament questionnaire, the *Children's Behavior Questionnaire* (CBQ; Rothbart, Ahadi, Hershey, & Fisher, 2001), and examined a wider age range of 3 to 8 years. However, despite these differences, they found (as pertains to the present study) that the CWS and CWNS differed significantly in *Attentional Focusing*, with CWS showing a lesser degree of attentional focus than their peers. Thus, these three temperament studies that utilized parent questionnaires seem to present a similar picture, that CWS differ from peers in aspects of attention.

In contrast to the aforementioned studies, Schwenk, Conture, and Walden (2007) examined attention directly in CWS and CWNS, ages 3–5. They compared the number of times the children disengaged from conversational interaction with parents to look at the movement of a mounted video camera in the room. Results revealed that, although the number of camera movements did not differ between groups, the proportion of times the children disengaged from the activity to look at the camera movement was significantly greater for the CWS than the CWNS. Findings were interpreted to suggest that CWS react to a greater extent to environmental stimuli and that they are perhaps less able to regulate responses to changes within their environment. These findings seem to point to potential differences in selective attention.

Careful study of attention processes in CWS is needed (e.g., see Bajaj, 2007, for a discussion of this issue). Although this study is not intended to address that need directly, it provides some insight into the potential correspondence between attention and linguistic processing, to inform future work in this area. As argued above, it is reasonable to hypothesize that attentional characteristics, as well as nonword repetition skills, may be related to linguistic processing tasks, particularly those with a time component, such as SRT. Thus, the purpose of this project was to examine whether nonword repetition and/or attention may relate to children's SRT. Given findings of Anderson (2008) of a positive relationship between the vocabulary measures and SRT in the CWNS but no significant relationship between these variables for the CWS, we hypothesized that, for CWS, nonword repetition and/or attentional characteristics would be associated with SRT performance. Our reasoning was that, if CWS (as a group) show greater variability or weakness in nonword repetition (Anderson et al., 2006; Hakim & Ratner, 2004) and attention (Anderson et al., 2003; Embrechts et al., 2000; Karrass et al., 2006; Schwenk et al., 2007), as the literature suggests, perhaps these measures would be more associated with SRT than measures of vocabulary that do not have a time component. The following research questions were posed:

- **a.** Does nonword repetition performance relate to SRT in CWS and CWNS?
- **b.** Do aspects of attention, in particular, *Attentional Focusing*, *Impulsivity*, and *Inhibitory Control* (*Children's Behavior Questionnaire—Short Form*, CBQ-SF), Putnam & Rothbart, 2006), relate to SRT in CWS and CWNS?

2. Method

2.1. Participants

Participants were selected from among a pool of children who had participated in two previous studies that examined nonword repetition (Anderson et al., 2006) and repetition priming (Anderson, 2008).[2] From this pool of participants, all children who had completed *both* the nonword repetition and repetition priming studies, and were otherwise typically developing in their speech, language, and hearing (see Section 2.1.2.) were selected for inclusion in this study. This resulted in a total of 9 CWS (3 girls, 6 boys) and 14 CWNS (8 girls, 6 boys) between the ages of 3;6 and 5;2 (years; months). All 9 CWS and 8 of the 14 (57%) CWNS had participated in *both* of the aforementioned studies. The remaining 6 CWNS had participated in the repetition priming study, but not the nonword repetition study, although data had been collected for these children.[3] All 9 CWS and 14 CWNS had complete parent-rated CBQ-SF data available from their participation in Anderson and Bates (2007; see Section 2.2.3.).

The two groups of children could not be statistically distinguished by age or parental socioeconomic status. In particular, CWS had a mean age of 51.33 months (SD = 5.66) and CWNS had a mean age of 52.93 months (SD = 6.17), a non-significant difference, $t(21) = -.62$, $p = .54$. Parental socioeconomic status was calculated using Hollingshead's Index of Social Position (Myers & Bean, 1968). CWS had a mean social position score of 32.00 (SD = 14.22; Hollingshead classification III [middle]) and CWNS a mean of 36.57 (SD = 15.09;

[2]Although based on existing data, all analyses presented in this study are new.

[3]These 6 CWNS did not participate in Anderson et al. (2006), because there was no CWS match for them.

Hollingshead classification III [middle]), a non-significant difference, $t(21) = -.73$, $p = .48$. None of the participants had a history of neurological, speech-language (other than stuttering), hearing, or intellectual problems, based on parent report and examiner observation or testing. All participants were native speakers of American English.

2.1.1. Group Classification Criteria—Children were classified as CWS or CWNS based on the combined frequency of part-word repetitions, single-syllable word repetitions, sound prolongations, and/or blocks produced during a parent-child conversational interaction. These disfluency types (herein referred to as stuttered disfluencies) are typically considered to be the hallmark of stuttered speech, as they occur more frequently in the speech of individuals who stutter than those who do not stutter (Pellowski & Conture, 2002; Yairi & Ambrose, 1992, 1999, 2005). Children were also classified by the level of parental concern about the child's speech fluency and stuttering severity (for CWS only). The conversational interaction consisted of parents and their children verbally interacting with each other for a period of 20 to 30 minutes while playing with a set of age-appropriate toys. A 300-word speech sample was obtained during this interaction and later analyzed for frequency of stuttered disfluencies, as defined above, and stuttering severity for CWS using the *Stuttering Severity Instrument-3* (SSI-3; Riley, 1994).[4]

2.1.1.1. Children who stutter: Children who were classified as CWS exhibited three or more stuttered disfluencies per 100 words of conversational speech and received a score of 12 or higher on the SSI-3 ($M = 18.44$, $SD = 6.43$; 5 were classified as "mild," 2 "moderate," and 2 "severe"). The parents of children in this group all expressed concern about their child's speech fluency, reporting an average time since initial onset (TSO) of stuttering of 16.89 months ($SD = 9.48$ months; Range = 7 to 33 months). TSO was measured using the "bracketing" procedure described by Yairi and Ambrose (1992; cf. Anderson et al., 2003). None of the CWS had received treatment for stuttering prior to their participation in this study.

2.1.1.2. Children who do not stutter: Children who were classified as CWNS exhibited fewer than three stuttered disfluencies per 100 words of conversational speech and none of their parents expressed concern about their children's speech fluency.

As a testament to the adequacy of the group classification criteria, a Mann-Whitney test revealed that CWS exhibited significantly more stuttered disfluencies than CWNS, $z = -3.98$, $p < .001$ (see Table 1). This suggests that the two groups of children were clearly differentiated on the basis of their stuttering behavior.

2.1.2. Inclusion Criteria

2.1.2.1. Speech-language tests: To participate, children had to receive a standard score of 85 or higher on four standardized speech-language tests to ensure that their speech and language skills were typically developing, with the exception of fluency in the CWS group. The following tests were administered: (a) *Peabody Picture Vocabulary Test-III* (PPVT-III; Dunn & Dunn, 1997), a measure of receptive vocabulary; (b) *Expressive Vocabulary Test* (EVT; Williams, 1997), a measure of expressive vocabulary; (c) *Test of Early Language Development-3* (TELD-3; Hresko, Reid, & Hammill, 1999), a measure of receptive and expressive language skills; and (d) "Sounds-in-Words" subtest of the *Goldman-Fristoe Test of Articulation-2* (GFTA-2; Goldman & Fristoe, 2000), a measure of speech sound articulation. Although CWS scored lower than CWNS on all four speech-language tests (see Table 1), these differences were not statistically significant (PPVT-III: $F[1,21] = 1.19$, $p = 0.29$; EVT: $F[1,21]$

[4]Our conceptualization of stuttering differs from that of Riley (1994) in that all single-syllable word repetitions are considered stuttered (see Pellowski & Conture, 2002; Yairi & Ambrose, 2005).

= .19, $p = 0.67$; TELD-3 Spoken Language: $F[1,21] = 0.85$, $p = 0.37$; GFTA-2: $F[1,21] = 0.10$, $p = 0.76$).

2.1.2.2. Hearing screening: To participate, children had to pass a hearing screening. Each child's hearing was screened using bilateral pure tone testing at 20 dB SPL for 500, 1000, 2000, and 4000 Hz (American Speech and Hearing Association, 1990).

2.2. Procedures

Each child was assessed in a quiet room on two separate occasions in the Speech Disfluency Laboratory at Indiana University. At least one week prior to the visiting the laboratory, parents received a child temperament behavior questionnaire in the mail, which they completed at home and then returned at the time of the first visit. During the first visit, the child engaged in the parent-child interaction, responded to the standardized speech and language tests, and completed the hearing screening, as described above. During the second visit, the child completed a nonword repetition task (Anderson et al., 2006), a computerized picture naming task (Anderson, 2008), and another task unrelated to the present investigation. The parent-child interaction, nonword repetition task, and picture naming task were videotaped using two color video cameras (EV1-D30), Unipoint AT853 Rx Miniature Condenser Microphone, and Panasonic DVD/HD video recorder (Model N. DMR-HS2). What follows is a brief overview of the two experimental tasks of interest in the current study, as well as the child temperament behavior questionnaire.

2.2.1. Nonword Repetition Task—Phonological working memory skills were measured using the *Children's Test of Non-Word Repetition* (CNRep; Gathercole et al., 1994; see Anderson et al., 2006, for further details). The CNRep consists of 40 nonwords, 10 each containing 2-, 3-, 4-, and 5-syllables. Children were told that they would hear some "funny, made-up words," which they should try to repeat. The 40 nonwords were presented in a common random order using a portable cassette player. Children were given 4 seconds to respond to each nonword before being prompted by the experimenter.

Each child's repetition attempt was scored as phonologically correct or incorrect. Responses that were dialectical variants of Standard American English were scored as correct, as were responses containing a *consistently* misarticulated phoneme(s) (see Adams & Gathercole, 1995; Gathercole et al., 1999; Edwards & Lahey, 1998). Responses containing disfluencies were also scored as correct, provided that all phonemes within the nonword had otherwise been produced correctly. If a child attempted to self-correct an incorrect response and the response attempt contained no inconsistent phoneme errors, the self-corrected attempt was scored as correct. The number of correct repetition attempts were then tallied and summed for each syllable length and across all syllable lengths (i.e., total number of correct responses). Anderson et al. had reported a mean interjudge reliability of 88.3% for the accuracy of the CNRep scoring procedure.

2.2.2. Picture Naming Task—Linguistic processing speed was measured using a computerized picture naming task, developed using E-Prime v.1.1. software by Psychology Software Tools, Inc. (PST) (see Anderson, 2008, for further details). In brief, the picture naming task consisted of two randomly intermixed sets of 30 pictures of simple objects from the Snodrass and Vanderwart (1980) picture corpus. The first picture set included 20 experimental and 10 filler pictures. Of the 20 experimental items, 10 were early acquired words (e.g., hat, lion) and 10 were late acquired words (e.g., bell, nose), matched for word frequency, name agreement, familiarity, phoneme length, and visual complexity. The second picture set consisted of the same 20 experimental pictures, but 10 different filler pictures. Filler pictures were included in each picture set to reduce the predictability of repetition.

Children were seated in front of a computer and told to name the pictures as fast as they could. Children began the experiment with four practice trials and then named the first set of pictures. Each picture was displayed for 2000 ms, with an inter-stimulus interval of 2500 ms. After a five minute break, children named the second set of pictures. The latency of each child's picture naming response (i.e., SRT) was measured in milliseconds from the onset of the picture to the onset of the child's verbal response using a voice-activated microphone that was directly connected to the computer via a PST Serial Response Box.

For the present study, the mean response time of each child's accurate responses to the early acquired words from the first picture set served as the measure of linguistic processing speed. These responses were chosen so as to minimize the potential confound of cognitive-linguistic demand (see Montgomery & Windsor, 2007, for related discussion) of processing later acquired words and the effects of repetition priming. Prior to analyzing the SRT data, all errors and outliers were culled from the data set for both groups of children (see Anderson, 2008, for further details regarding the coding of errors). An outlier was defined as any response that was greater than two standard deviations above or below the mean of all children's responses (see Ratcliff, 1993).

2.2.3. Temperament Behavior Questionnaire—The attentional system was measured using the short form of the *Children's Behavior Questionnaire* (CBQ-SF; Putnam & Rothbart, 2006). The CBQ-SF assesses the temperament behavior patterns of 3–8 year old children along 15 scales. Parents rated their children on 94 items using a 7-point Likert scale, with 1 being "extremely untrue of your child" and 7 "extremely true of your child." Scores for each item were averaged to form each temperament scale. Only the attention-related temperament scales were used in the present study: *Attentional Focusing*, *Impulsivity*, and *Inhibitory Control*. Brief descriptions of these scales are as follows (see Rothbart, Ahadi, Hershey, & Fisher, 2001):

1. *Attentional Focusing:* capacity to maintain attentional focus during tasks (Sample item: "Is easily distracted when listening to a story").
2. *Impulsivity:* speed of response initiation (Sample item: "Usually rushes into an activity without thinking about it").
3. *Inhibitory Control:* capacity to stop, moderate, or refrain from behaviors under instruction or in novel or uncertain situations (Sample item: "Is good at following instructions").

Higher ratings on these scales reflect a stronger presence of the characteristic. Thus, high attentional focusing scores are associated with an increased ability to resist distractions, high impulsivity scores are associated with faster behavioral activation (i.e., more impulsivity), and high inhibitory control scores reflect an increased ability to inhibit responses to irrelevant stimuli. The CBQ-SF scales reportedly have good internal consistency, with alpha coefficients on the three scales ranging from .66 to .72.

Attentional focusing and inhibitory control are considered to be components of effortful control, which refers to the ability to inhibit a dominant response in favor of a subdominant one (Rothbart & Bates, 2006; Rothbart & Rueda, 2005). Effortful control and its subcomponents have been associated with executive attention, which is involved in maintaining goal-directed behavior in the face of potential distractions (Zentner & Bates, 2008). The temperament trait of impulsivity, on the other hand, has been likened to the reverse of effortful control (Zenter & Bates), and high impulsivity has been associated with symptoms of attention deficit hyperactivity disorder, along with low attentional focusing and low inhibitory control (Foley, McClowry, & Castellanos, 2008). While we acknowledge that these temperament scales (i.e., attentional focusing, impulsivity, and inhibitory control) may also be subsumed under the broader heading of executive control, for the purposes of this manuscript,

NIH-PA Author Manuscript

NIH-PA Author Manuscript

we are considering them attention-related, given their aforementioned association with executive attention. Therefore, henceforth, we will refer to these scales as measuring aspects of attention.

3. Results

The primary purpose of this study was to examine the relationships among measures of phonological working memory, linguistic processing speed, and attention for children in the CWS and CWNS groups. However, before examining these results, data were first analyzed for between-group effects in each of the main dependent variables. These analyses were conducted to ensure that the nonword repetition and SRT performance of the children in the current study matched those obtained in Anderson et al. (2006) and Anderson (2008), as cross-study consistency was important for establishing motivation and strengthening the interpretability of the main research questions in the current study. The between-group analyses of the attention-related temperament scales had not been performed in Anderson and Bates (2007).

3.1. Between Group Differences in Nonword Repetition, Speech Reaction Time, and Attention

Between-group differences in nonword repetition performance, speech reaction time (SRT), and attention were analyzed using multivariate and/or univariate analyses of covariance (MANCOVA and ANCOVA, respectively). Chronological age served as the covariate in these analyses, because previous research has revealed that increases in chronological age are associated with increases in processing speed, phonological short-term memory, and sustained attention in typically-developing children and children with SLI (Montgomery, Evans, & Gillam, 2009; Montgomery & Windsor, 2007). Prior to performing these analyses, data were evaluated to ensure that they met the assumptions of the MANCOVA and/or ANCOVA—namely, homogeneity of variance, covariance matrices, and regression slopes. As a measure of the strength of the association, the effect size indicator partial eta square (partial eta^2) is reported for each statistical comparison, with a partial eta^2 of .14 representing a “large” effect, .06 a “medium” effect, and .01 a “small” effect (Cohen, 1988).

3.1.1. Nonword Repetition—Between-group differences in the number of correct responses produced on the CNRep across each nonword length (2-, 3-, 4-, and 5-syllables) were analyzed using MANCOVA and ANCOVA, with chronological age as the covariate. Using Pillai’s trace, the omnibus MANCOVA test revealed a significant main effect of group on the number of correct responses produced across syllable lengths, $V = .18$, $F(4, 17) = 3.03$, $p = .05$, partial eta^2 = .42. Separate univariate ANCOVAs revealed that CWS repeated significantly fewer 2-syllable ($M = 5.4$, $SD = 1.8$), $F(1, 20) = 13.03$, $p = .002$, partial eta^2 = .39, and 3-syllable ($M = 4.3$, $SD = 2.8$), $F(1, 20) = 5.87$, $p = .02$, partial eta^2 = .23, nonwords correctly than CWNS (M = 8.3 and 6.9, SD = 1.8 and 2.1, respectively). However, no significant between-group differences were found for the repetition of 4-syllable, $F(1, 20) = 3.81$, $p = .06$, partial eta^2 = .16, and 5-syllable, $F(1, 20) = 1.71$, $p = .21$, partial eta^2 = .08, nonwords, even though CWS (M = 2.7 and 2.3, SD = 2.0 and 2.5, respectively) scored lower than CWNS (M = 4.9 and 4.2, SD = 2.7 and 3.2, respectively) at each syllable length. These results are consistent with the original findings of Anderson et al. (2006), who reported that CWS produced significantly fewer correct 2- and 3-syllable nonword repetitions than CWNS. However, unlike Anderson et al., a separate ANCOVA, covarying for age, further revealed a significant between-group difference in the total number of nonwords correctly produced, $F(1, 20) = 6.64$, $p = .02$, partial eta^2 = .25, with CWS producing fewer total nonwords correct than CWNS (Table 2).

3.1.2. Speech Reaction Time—After partialling out the effect of age, a univariate ANCOVA revealed no significant between-group effect in SRT, $F(1, 20) = .001$, $p = .97$, partial eta^2 = .001, a finding consistent with the original finding of Anderson (2008). Thus, even though CWS named pictures slightly more slowly than CWNS, this difference was not statistically significant (Table 2).

3.1.3. Attention—Between-group differences on the *Attentional Focusing*, *Impulsivity*, and *Inhibitory Control* scales were analyzed using MANCOVA, with chronological age again serving as the covariate (Table 2). Using Pillai's trace, the omnibus MANCOVA test revealed no significant main effect of group on parent-reported ratings across the three attention-related temperament scales, $V = .12$, $F(3, 18) = .81$, $p = .50$, partial eta^2 = .12. Separate univariate ANCOVAs revealed no significant group effects for *Attentional Focusing*, $F(1, 20) = 2.17$, $p = .16$, partial eta^2 = .10, *Impulsivity*, $F(1, 20) = .14$, $p = .71$, partial eta^2 = .007, and *Inhibitory Control*, $F(1, 20) = .08$, $p = .78$, partial eta^2 = .004.

3.2. Correlational Analyses

All correlational analyses among measures of linguistic processing speed, phonological working memory, and attention were conducted both with and without chronological age (in months) serving as a covariate. This was done to determine if any of the significant bivariate correlations could be accounted for by covariation with age. Chronological age was also included as an additional measure in the bivariate correlation analyses due to its anticipated covariance with the main dependent variables. Although multiple correlational analyses were conducted, Bonferroni corrections were not applied. The present study was designed to test specific hypotheses, rather than to explore general trends within the data. It has been argued that applying such adjustments to hypothesis driven experiments increases the probability of Type II errors, especially when power is low (e.g., Curtin & Schulz, 1998; Garamszegi, 2006; Nakagawa, 2004; Perneger, 1998). Preliminary analyses were performed to ensure no violation of the assumptions of normality, linearity, and homoscedasticity. The bivariate and partial correlation matrices for each group of children appear in Tables 3 (CWS) and 4 (CWNS).

3.2.1. Nonword Repetition and Speech Reaction Time—Bivariate and partial correlation analyses were conducted for SRT and the number of correct responses produced at each nonword length (2-, 3-, 4-, and 5-syllables) and across all stimulus items (i.e., total) for CWS and CWNS (Tables 3 and 4, respectively). For CWS, SRT was significantly correlated with the repetition of 3-syllable ($r = -.75$, $p = .02$) and 5-syllable ($r = -.78$, $p = .01$) nonwords, as well as with total nonword repetition scores ($r = -.76$, $p = .02$). However, there were no significant correlations between SRT and the repetition of 2- and 4-syllable nonwords. For CWNS, there were no significant correlations between SRT and nonword repetition performance, with p-values ranging from .08 to .75. After adjusting for age, however, (partial) correlations between SRT and the repetition of 4-syllable ($r = .74$, $p = .004$) and total ($r = .63$, $p = .02$) nonwords were significant, but positive for CWNS. All other correlations for CWNS remained non-significant (p-values = .06 to .24). For CWS, on the other hand, the (partial) correlations between SRT and 3- and 5-syllable nonwords and total nonword repetition scores continued to remain significant, while correlations between SRT and 2- and 4-syllable nonwords remained non-significant. Thus, it would seem that, for CWS, covarying for age had no appreciable influence on the results.

3.2.2. Attention and Speech Reaction Time—Bivariate and partial correlation analyses were conducted for the parent-reported measures of attention (*Attentional Focusing*, *Impulsivity*, and *Inhibitory Control*) and SRT for CWS and CWNS. For CWS, there were no significant correlations between SRT and *Attentional Focusing*, *Impulsivity*, or *Inhibitory Control*. Furthermore, including age as a covariate in the partial correlational analyses had no effect on the results, with *p*-values remaining in the range of .11 to .97. For CWNS, a significant, positive correlation was found between SRT and *Attentional Focusing* (r = .61, p = .02), but not *Impulsivity* or *Inhibitory Control*. However, after covarying for age, the (partial) correlation between SRT and *Attentional Focusing* was no longer significant, suggesting that age had accounted for the initial bivariate association.

3.2.3. Nonword Repetition and Attention—Bivariate and partial correlation analyses were conducted for the parent-reported measures of attention (*Attentional Focusing*, *Impulsivity*, and *Inhibitory Control*) and the number of correct responses at each nonword length (2-, 3-, 4-, and 5-syllables) and across all stimulus items for both groups of children (Tables 3 and 4). For CWS, there were no significant correlations between measures of attention and nonword repetition, with *p*-values ranging from .31 to .99. For CWNS, *Impulsivity* scores were significantly, positively correlated with the repetition of 3-syllable nonwords (r = .53, p = .05), 5-syllable nonwords (r = .69, p = .006), and total nonword repetition scores (r = .58, p = .03). All other correlations failed to reach significance, with *p*-values ranging from .10 to .92. As with the previous set of correlation analyses, including age as a covariate for CWS had no effect on the results, as all (partial) correlations between parent-reported measures of attention and nonword repetition continued to remain non-significant (*p*-values = .10 to .99). For CWNS, on the other hand, partialling out the effect of age resulted in significant (partial) correlations between *Attentional Focusing* and the repetition of 2-syllable (r = .65, p = .01), 3-syllable (r = .65, p = .01), and 4-syllable (r = .62, p = .02) nonwords, as well as total nonword repetition scores (r = .57, p = .04). However, covarying for age also had the effect of making the previously significant correlation between *Impulsivity* and the repetition of 3-syllable and total nonwords non-significant, suggesting that age had accounted for at least some of the association between these variables. The correlation between *Impulsivity* and the repetition of 5-syllable nonwords remained significant (r = .71, p = .007). All other (partial) correlations failed to reach significance, with *p*-values ranging from .12 to .90.

3.2.4. Chronological Age and Nonword Repetition, Speech Reaction Time, and Attention—Bivariate correlation analyses were calculated for chronological age and measures of nonword repetition, SRT, and the three attention-related temperament scales. Chronological age was significantly correlated with 3-syllable nonword repetition (r = .60, p = .02), SRT (r = −.55, p = .04), and *Impulsivity* (r = .74, p = .003) for CWNS, but not for CWS (*p*-values = .16 to .82). All other correlations between chronological age and each of the main dependent variables failed to reach significance for both CWS (*p*-values = .08 to .82) and CWNS (*p*-values = .12 to .44).

4. Discussion

The purpose of the present study was to examine whether two areas of performance, nonword repetition and attention, might be associated with performance on a picture naming SRT task for CWS and CWNS. The study was motivated by the finding of Anderson (2008) that vocabulary scores were associated with SRT in CWNS, but not CWS (cf. Pellowski & Conture, 2005). Based on the literature in phonological working memory and attention, we hypothesized that, for CWS, SRT would be associated with variables other than vocabulary score, namely, nonword repetition and aspects of attention. In contrast, we hypothesized that for CWNS, SRT would be associated with vocabulary performance (as previously shown in Anderson, 2008) but not nonword repetition or attention. The findings support some but not all of these predictions. We begin with a review of group comparisons, followed by a review of the correlational analyses used to test the hypotheses.

4.1. Group Performance in Phonological Working Memory, Linguistic Processing Speed, and Attention

Because nonword repetition, SRT, and attention are each areas that develop with age, we performed analyses with age inserted as a covariate. Thus, findings take into account and control for children's age. As expected from our previous study (Anderson et al., 2006), which contained some of the same children in the current study, nonword repetition scores were significantly higher for the CWNS, compared to the CWS. With age as a covariate, 2- and 3-syllable words as well as total nonword repetition score differed significantly between groups. Also expected, based on the findings of Anderson (2008), the groups did not differ in SRT. The CWS named pictures more slowly, on average, but the difference was not statistically significant. Thus, even with participant samples that differed somewhat from prior research, the findings matched those obtained in previous studies. These findings strengthen the interpretability of the main research questions, because the motivation for the present study is based on the findings of the prior studies.

Finally, there were no significant group differences on any of the three attention scales, *Attentional Focusing*, *Impulsivity*, or *Inhibitory Control*. However, the effect size for *Attentional Focusing* is medium to large (with CWS scoring lower, on average, than controls). Although we do not wish to inflate the importance of this nonsignificant finding, it suggests to us that, of these three aspects of attention, perhaps careful, direct examination of sustained selective attention in CWS may be warranted. That is, perhaps direct study of sustained focused attention (rather than indirect questionnaire-based study) would uncover differences that were not apparent in the present investigation. Given that the literature on temperament in CWS suggests a difference in attention relative to peers (e.g., Embrechts et al., 2000; Schwenk et al., 2007), further examination of attentional focus would seem to be appropriate.

4.2. Relationship between Speech Reaction Time and Nonword Repetition

Findings for the group of CWS with respect to SRT and nonword repetition were supportive of our hypothesis. The total nonword repetition score, as well as two of the individual length scores, correlated significantly with SRT. CWS who had higher nonword repetition scores had shorter SRTs. In fact, even when age was controlled using partial correlations, the correlations remained significant.

The CWNS presented quite a different picture. There were no significant correlations between SRT and nonword repetition. However, once age was controlled with partial correlations, total nonword repetition (and repetition of 4-syllable words alone) correlated positively with SRT, such that higher nonword repetition scores were associated with longer SRTs.

These findings across groups are intriguing. Recall that Anderson (2008) reported that CWNS, but not CWS, showed correspondence between vocabulary scores and SRT. She suggested that nonword repetition may have mediated the relationship between vocabulary knowledge and SRT for CWS. Indeed, it appears that this is the case.

The findings for the group of CWNS are somewhat more difficult to interpret at first glance. It is curious that, when age is controlled, there is a *positive* relationship between nonword repetition and SRT. However, the results of the present study should be placed within the context of Anderson (2008), in which typically developing children were found to have a positive relationship between vocabulary and SRT. Taken together, the two studies suggest that vocabulary knowledge and nonword repetition are related in that they are both associated with SRT. Indeed, there is a substantial literature that supports a strong relationship between vocabulary skills and nonword repetition in typically developing children (e.g., Gathercole & Baddeley, 1989; Gathercole et al., 1992). Thus, given the relationship between these variables, established within the literature prior to this investigation, it is not surprising that *both* nonword repetition and vocabulary performance should be related to SRT and in the same direction.

4.3. Relationship between Linguistic Processing Speed and Attention

Analyses of the relationship between linguistic processing speed and attention were motivated theoretically from the suggestion that *semantic* development, in particular, may hinge on *controlled processing*, in which the child directs attention to words and their referents (Spaulding et al., 2008). As such, we expected a relationship between aspects attention and the SRT task, given that it is a lexical/semantic task.

Findings related to aspects of attention and SRT were similar across groups. Once age was taken into account, there were no significant correlations between any of the three aspects of attention studied (i.e., *Attentional Focusing*, *Impulsivity*, and *Inhibitory Control*) and SRT. Because there is reason to expect that both processing speed and attention will increase with age, controlling for the contribution of age prior to evaluating correspondences between variables seems critical to the interpretation of the findings. The fact that there were no significant relationships for either group once age was taken into account is noteworthy. Again, however, it should be emphasized that attention was measured by parent questionnaire only, whereas the other variables were measured directly. Therefore, before we draw the conclusion that attention is unrelated to SRT, careful, direct examination of attention in relation to this variable is needed.

Prior research with children and adults who stutter suggests that attentional skills are a potentially important consideration in understanding underlying processes in relation to stuttering (e.g., see Bajaj, 2007; Bosshardt, 2006, for discussions). In the adult fluency literature, dual task paradigms have shed light on the impact of attention on the performance of a range of tasks. Moreover, in the literature on children with SLI, various aspects of attention have been examined in some detail, as described at the outset (e.g., Spaulding et al., 2008). What is needed, then, is careful, direct examination of attentional processes in children who stutter.

4.4. Relationship between Nonword Repetition and Attention

Although characterizing the relationship between nonword repetition and attention in CWS was not a primary aim of this study, these analyses were motivated by models that suggest the close tie between memory and attention (e.g., Baddeley, 2003; Cowan et al., 2005; Engle & Kane, 2004; Redick and Engle, 2006). If these two aspects of cognition have considerable overlap – clearly most experimental tasks measure aspects of both rather than one or the other – they should be highly correlated. To use our own study as an example of the overlap, while parents were asked about aspects of attention alone, both of the experimental tasks (nonword repetition and SRT) rely on attention for performance. Therefore, we expected that nonword repetition and attention measures would be correlated.

Our findings were, in part, consistent with this prediction in that the CWNS, when age was taken into account, showed significant correlations between the *Attentional Focusing* scale and total nonword repetition score. (There were also significant correlations between *Attentional Focusing* and three of the individual length scores for nonword repetition.) Thus, CWNS who were judged by their parents as having a higher capacity for attentional focusing tended to repeat nonwords more accurately than those who whose parents rated them lower in attentional focusing. In addition, there was a significant correlation between 5-syllable nonwords (the longest) and *Impulsivity*. For the CWS, however, there were no significant correlations between nonword repetition and any of the attention scales, whether age was taken into account or not.

We view this as a rather dramatic finding, because it points to the possibility that for CWS, the interaction between nonword repetition and attention in task performance may be different from that of their peers. From a theoretical standpoint, perhaps in developing future investigations of CWS it would be useful to adopt a model, such as Baddeley's (2003), that considers attentional processes as separate (i.e., as part of the *central executive*) from the storage and rehearsal processes of the phonological loop. In any event, as mentioned earlier, these findings seem to point to the need for careful, direct examination of attentional skills of CWS. Such examination would lead to a fuller understanding of the finding in this study that attentional processes and nonword repetition do not significantly relate in CWS.

4.5. Consideration of Chronological Age

From a theoretical perspective, it seems critical to account for age in describing children's development in linguistic and cognitive skills. For this reason, we analyzed correspondences in performance using partial correlations with age as a covariate, in addition to bivariate correlations. In assessing the relationship between age and the variables under study, however, we found that, while the CWNS showed several significant correspondences between age and nonword repetition, attention, and SRT, CWS did not. This could be a difference between groups that extends across studies. For example, Byrd et al. (2007), in their study of holistic versus incremental processing, found that in CWNS, there was a developmental shift in priming advantage from holistic to incremental, but for the CWS, no developmental shift occurred. The findings of Byrd et al., along with those of the present study, point to the possibility that CWS may not show the same age-related progression of language or language-related skills as their normally-fluent peers.

4.6. Conclusions, Limitations, and Future Directions

In sum, the main findings of the present study were that (a) the groups did not differ from each other on attention or SRT, but CWS did perform significantly worse in nonword repetition; (b) for CWS, there was a significant negative relationship between SRT and nonword repetition; (c) taking age into account, there were no significant relationships for either group between aspects of attention and SRT; and (d) taking age into account, the CWNS, but not CWS, showed a significant relationship between nonword repetition and *Attentional Focusing*. These findings support the prediction by Anderson (2008) that, for CWS, nonword repetition (rather than vocabulary) is, indeed, associated with SRT. It would seem that these findings are not unrelated to robust findings within the literature of differences in language performance among CWS and CWNS. Rather, if nonword repetition ability mediates performance on certain linguistic tasks, then nonword repetition performance is relevant to understanding observed differences in language between groups.

As highlighted earlier, present findings also point to a need to examine aspects of attention directly in CWS. In this respect, the literature of CWS has lagged behind that of adults who stutter; there is already a considerable literature on attention in relation to dual processing tasks with adults.

We acknowledge several limitations of the present study. First, the sample size of CWS is rather small, but reflective of the fact that we needed to find children (in both groups) who had completed all of the measures under study in the present investigation: SRT, nonword repetition, and attention scales. Second, we present results of a temperament behavior questionnaire, as a preliminary assessment of attentional skills of CWS. It should be noted that the larger series of studies (e.g., Anderson et al., 2006; Anderson, 2008) was not designed to assess attention; rather, this focus emerged from Anderson (2008) and recently published studies of attention (e.g., Montgomery et al., 2009; Spaulding et al., 2008). Of course, direct measurement of attention in CWS is needed as an important next step, especially given repeated findings of differences between CWS and CWNS in parental ratings of attention (Anderson et al., 2003; Embrechts et al., 2000; Karrass et al., 2006).

Third, a common criticism of nonword repetition tasks is that they do not take the motor or phonological complexity of nonwords into account (e.g., Bajaj, 2007). We acknowledge that motor or phonological complexity may have been an intervening variable. At the same time, nonword repetition tasks are currently the gold standard for estimating phonological working memory. Therefore, what we gain by the ability to compare our results to other studies makes up for what is lost by not being able to fully account for these potentially extraneous variables.

One central theme that is emerging from this line of research (Anderson, 2008; Anderson et al., 2006), including the present study, is the idea that understanding the lexical, phonological working memory, linguistic processing, and perhaps attentional skills of CWS requires a more sophisticated approach than simple analyses of group differences. In this study, our approach was to examine the groups separately for potential mediating factors that may contribute to performance within a particular domain of interest (i.e., linguistic processing speed). For each group, we examined the role of age and of aspects of processing (working memory and attention), without making the assumption that the relationships among these variables would be the same for both groups. This approach allows us to examine whether groups differ in the *way* they accomplish a task of interest, which may be even more interesting than any between-group difference observed in accomplishing the task.

Acknowledgments

This research was supported by a research grant (DC006805) to Indiana University from the National Institute on Deafness and Other Communication Disorders. The authors would like to thank the parents and children who participated in this study, as well as Rebecca Hendricks for her help with data collection.

Biographies

Julie Anderson, Ph.D., CCC-SLP, is an associate professor at Indiana University. Her research interests include the study of spoken language production and fluency development in young children who do and do not stutter. She is currently an associate editor of the *Journal of Speech, Language, and Hearing Research*.

Stacy Wagovich, Ph.D., CCC-SLP, is an associate professor at the University of Missouri. Her research interests are in childhood fluency disorders, as well as developmental language disorders, for which she is funded by the NIDCD. She is currently an associate editor of the *Language, Speech, and Hearing in the Schools*.

References

Adams AM, Gathercole SE. Phonological working memory and speech production in preschool children. Journal of Speech and Hearing Research 1995;38:403–414. [PubMed: 7596106]

American Speech-Language-Hearing Association. Guidelines for screening for hearing impairment and middle-ear disorders. ASHA 1990 April;32 suppl. 2:17–24.

Anderson JD. Age of acquisition and repetition priming effects on picture naming of children who do and do not stutter. Journal of Fluency Disorders 2008;33:135–155. [PubMed: 18617053]

Anderson, JD.; Bates, JE. Temperament, parenting styles, and childhood stuttering. In: Au-Yeung, J.; Leahy, M., editors. Proceedings of the Fifth World Congress on Fluency Disorders: Research, Treatment, and Self-Help in Fluency Disorders: New Horizons. Dublin, Ireland: International Fluency Association; 2007. p. 179-185.

Anderson JD, Conture EG. Sentence structure priming in young children who do and do not stutter. Journal of Speech, Language, and Hearing Research 2004;47:552–571.

Anderson JD, Pellowski MW, Conture EG, Kelly EM. Temperamental characteristics of young children who stutter. Journal of Speech, Language, and Hearing Research 2003;46:1221–1233.

Anderson JD, Wagovich SA, Hall NE. Nonword repetition skills in young children who do and do not stutter. Journal of Fluency Disorders 2006;31:177–199. [PubMed: 16814376]

Arnold HS, Conture EG, Ohde RN. Phonological neighborhood density in the picture naming of young children who stutter: Preliminary study. Journal of Fluency Disorders 2005;30:125–148. [PubMed: 15949541]

Baddeley, AD. Working memory. Oxford: Clarendon Press; 1986.

Baddeley AD. Working memory and language: An overview. Journal of Communication Disorders 2003;36:189–208. [PubMed: 12742667]

Bajaj A. Working memory involvement in stuttering: Exploring the evidence and research implications. Journal of Fluency Disorders 2007;32:218–238. [PubMed: 17825670]

Bakhtiar M, Ali DAA, Sadegh SPM. Nonword repetition ability of children who do and do not stutter and covert repair hypothesis. Indian Journal of Medical Sciences 2007;61:462–470. [PubMed: 17679736]

Bishop DVM, North T, Donlan C. Nonword repetition as a behavioural marker for inherited language impairment: Evidence from a twin study. Journal of Child Psychology and Psychiatry and Allied Disciplines 1996;37:391–403.

Bosshardt H-G. Effects of concurrent cognitive processing on the fluency of word repetition: Comparison between people who do and do not stutter. Journal of Fluency Disorders 2002;27:93–114. [PubMed: 12145987]

Bosshardt H-G. Cognitive processing load as a determinant of stuttering: Summary of a research programme. Clinical Linguistics and Phonetics 2006;20:371–385. [PubMed: 16728334]

Bosshardt H-G, Ballmer W, De Nil LF. Effects of category and rhyme decisions on sentence production. Journal of Speech, Language, and Hearing Research 2002;45:844–857.

Byrd CT, Conture EG, Ohde RN. Phonological priming in young children who stutter: Holistic versus incremental processing. American Journal of Speech-Language Pathology 2007;16:43–53. [PubMed: 17329674]

Caruso AJ, Chodzko-Zajko WJ, Bidinger DA, Sommers RK. Adults who stutter: Responses to cognitive stress. Journal of Speech and Hearing Research 1994;37:746–754. [PubMed: 7967559]

Coady JA, Evans JL. Uses and interpretations of non-word repetition tasks in children with and without specific language impairments. International Journal of Language and Communication Disorders 2008;43:1–40. [PubMed: 18176883]

Conti-Ramsden G. Processing and linguistic markers in young children with specific language impairement (SLI). Journal of Speech, Language, and Hearing Research 2003;46:1029–1037.

Cohen, J. Statistical power analysis for the behavioral sciences. 2nd ed.. Hillsdale, NJ: Lawrence Erlbaum; 1988.

Cowan, N. An embedded-processes model of working memory. In: Miyake, A.; Shah, P., editors. Models of working memory: Mechanisms of active maintenance and executive control. Cambridge, UK: Cambridge University Press; 1999. p. 62-101.

Cowan N, Elliott EM, Saults JS, Morey CC, Mattox S, Hismjatullina A, Conway ARA. On the capacity of attention: Its estimation and its role in working memory and cognitive aptitudes. Cognitive Psychology 2005;51:42–100. [PubMed: 16039935]

Curtin F, Schulz P. Multiple correlations and Bonferroni's correction. Biological Psychiatry 1998;44:775–777. [PubMed: 9798082]

De Nil LF, Kroll RM, Houle S. Functional neuroimaging of cerebellar activation during single word reading and verb generation in stuttering and nonstuttering adults. Neuroscience Letters 2001;302:77–80. [PubMed: 11290391]

Dunn, L.; Dunn, L. Peabody Picture Vocabulary Test-III (PPVT-III). 3rd ed.. Circle Pines, MN: American Guidance Service, Inc; 1997.

Edwards J, Lahey M. Nonword repetitions of children with specific language impairment: Explorations of some explanations for their inaccuracies. Applied Psycholinguistics 1998;19:279–309.

Ellis Weismer S, Evans J, Hesketh LJ. An examination of verbal working memory capacity in children with specific language impairment. Journal of Speech, Language, and Hearing Research 1999;42:1249–1260.

Ellis Weismer S, Tomblin JB, Zhang X, Buckwalter P, Chynoweth JG, Jones M. Nonword repetition performance in school-age children with and without language impairment. Journal of Speech, Language, and Hearing Research 2000;43:865–878.

Embrechts, M.; Ebben, H.; Franke, P.; van de Poel, C. Temperament: A comparison between children who stutter and children who do not stutter. In: Bosshardt, HG.; Yaruss, JS.; Peters, HFM., editors. Proceedings of the Third World Congress on Fluency Disorders: Theory, research, treatment, and self-help. Nijmegen: The Netherlands: University of Nijmegen Press; 2000. p. 557-562.

Engle, RW.; Kane, MJ. Executive attention, working memory capacity, and a two-factor theory of cognitive control. In: Ross, BH., editor. The psychology of learning and motivation. Vol. Vol. 44. New York: Elsevier; 2004. p. 145-199.

Estes KG, Evans JL, Else-Quest NM. Differences in the nonword repetition performance of children with and without specific language impairment: A meta-analysis. Journal of Speech, Language, and Hearing Research 2007;50:177–195.

Foley M, McClowry SG, Castellanos FX. The relationship between attention deficit hyperactivity disorder and child temperament. Journal of Applied Developmental Psychology 2008;29:157–169.

Fry AF, Hale S. Processing speed, working memory, and fluid intelligence: Evidence for a developmental cascade. Psychological Science 1996;7:237–241.

Fry AF, Hale S. Relationships among processing speed, working memory, and fluid intelligence in children. Biological Psychology 2000;54:1–34. [PubMed: 11035218]

Garamszegi LZ. Comparing effect sizes across variables: Generalization without the need for Bonferroni correction. Behavioral Ecology 2006;17:682–687.

Gathercole SE. Nonword repetition and word learning: The nature of the relationship. Applied Psycholinguistics 2006;27:513–543.

Gathercole SE, Baddeley AD. Evaluation of the role of phonological STM in the development of vocabulary in children: A longitudinal study. Journal of Memory and Language 1989;28:200–213.

Gathercole, SE.; Baddeley, AD. Working memory and language. Hillsdale, NJ: Lawrence Erlbaum Associates; 1993.

Gathercole SE, Service E, Hitch GJ, Adams A, Martin AJ. Phonological short-term memory and vocabulary development: further evidence on the nature of the relationship. Applied Cognitive Psychology 1999;13:65–77.

Gathercole SE, Willis CS, Baddeley AD, Emslie H. The children's test of nonword repetition: A test of phonological working memory. Memory 1994;2:103–127. [PubMed: 7584287]

Gathercole SE, Willis CS, Emslie H, Baddeley AD. Phonological memory and vocabulary development during the early school years: A longitudinal study. Developmental Psychology 1992;28:887–898.

Gaulin CA, Campbell TF. Procedure for assessing verbal working memory in normal school-age children: some preliminary data. Perceptual and Motor Skills 1994;79:55–64. [PubMed: 7991333]

Goldman, R.; Fristoe, M. Goldman-Fristoe Test of Articulation-2 (GFTA-2). 2nd ed.. Circle Pines, MN: American Guidance Service, Inc; 2000.

Hakim HB, Ratner NB. Nonword repetition abilities of children who stutter: An exploratory study. Journal of Fluency Disorders 2004;29:179–199. [PubMed: 15458830]

Hall, NE.; Wagovich, SA.; Bernstein Ratner, N. Language considerations in childhood stuttering. In: Conture, EG.; Curlee, RF., editors. Stuttering and related disorders of fluency. 3rd ed.. New York, Thieme: 2007. p. 153-167.

Hanson RA, Montgomery JW. Effects of general processing capacity and sustained selective attention on temporal processing performance of children with specific language impairment. Applied Psycholinguistics 2002;23:75–93.

Hartfield KN, Conture EG. Effects of perceptual and conceptual similarity in lexical priming of young children who stutter: Preliminary findings. Journal of Fluency Disorders 2006;31:303–324. [PubMed: 17010422]

Hoffman LM, Gillam RB. Verbal and spatial information processing constraints in children with specific language impairment. Journal of Speech, Language, and Hearing Research 2004;47:114–125.

Hresko, W.; Reid, D.; Hammill, D. Test of Early Language Development-3 (TELD-3). Austin, Tx: PRO-ED; 1999.

Karrass J, Walden TA, Conture EG, Graham CG, Arnold HS, Hartfield KN, Schwenk KA. Relation of emotional reactivity and regulation to childhood stuttering. Journal of Communication Disorders 2006;39:402–423. [PubMed: 16488427]

Keith, R. Auditory Continuous Performance Task. San Antonio, TX: Psychological Corporation; 1993.

Luna B, Garver KE, Urban TA, Lazar NA, Sweeney JA. Maturation of cognitive processes from late childhood to adulthood. Child Development 2004;75:1357–1372. [PubMed: 15369519]

Mainela-Arnold E, Evans JL. Beyond capacity limitations: Determinants of word recall performance on verbal working memory span tasks in children with SLI. Journal of Speech, Language, and Hearing Research 2005;48:897–909.

Marton K, Schwartz R. Working memory capacity and language processes in children with specific language impairment. Journal of Speech, Language, and Hearing Research 2003;46:1138–1153.

McDevitt SC, Carey WB. The measurement of temperament in 3 7-year-old children. Journal of Child Psychology and Psychiatry and Allied Disciplines 1978;19:245–253.

Melnick KS, Conture EG, Ohde RN. Phonological priming in picture naming of young children who stutter. Journal of Speech, Language, and Hearing Research 2003;46:1428–1443.

Montgomery JW, Evans JL, Gillam RB. Relation of auditory attention and complex sentence comprehension in children with specific language impairment: A preliminary study. Applied Psycholinguistics 2009;30:123–151.

Montgomery JW, Windsor J. Examining the language performances of children with and without specific language impairment: Contributions of phonological short-term memory and speed of processing. Journal of Speech, Language, and Hearing Research 2007;50:778–797.

Munson B, Kurtz BA, Windsor J. The influence of vocabulary size, phonotactic probability, and wordlikeness on nonword repetitions of children with and without specific language impairment. Journal of Speech, Language, and Hearing Research 2005;48:1033–1047.

Myers, JK.; Bean, LL. A decade later: A follow-up of social class and mental illness. New York: John Wiley & Sons, Inc; 1968.

Nakagawa S. A farewell to Bonferroni: the problems of low statistical power and publication bias. Behavioral Ecology 2004;15:1044–1045.

Pellowski MW, Conture EG. Characteristics of speech disfluency and stuttering behaviors in 3- and 4-year-old children. Journal of Speech, Language, and Hearing Research 2002;45:20–35.

Pellowski M, Conture E. Lexical priming in picture naming of young children who do and do not stutter. Journal of Speech, Language, and Hearing Research 2005;48:278–294.

Perneger TV. What's wrong with Bonferroni adjustments. British Medical Journal 1998;316:1236–1238. [PubMed: 9553006]

Putnam SP, Rothbart MK. Development of short and very short forms of the Children's Behavior Questionnaire. Journal of Personality Assessment 2006;87:102–112. [PubMed: 16856791]

Ratcliff R. Methods for dealing with reaction time outliers. Psychological Bulletin 1993;114:510–532. [PubMed: 8272468]

Redick TS, Engle RW. Working memory capacity and Attention Network Test performance. Applied Cognitive Psychology 2006;20:713–721.

Riley, GD. Stuttering Severity Instrument for Children and Adults-3 (SSI-3). 3rd ed.. Austin, Tx: Pro-Ed; 1994.

Rothbart MK, Ahadi SA, Hershey KL, Fisher P. Investigations of temperament at three to seven years: The Children's Behavior Questionnaire. Child Development 2001;72:1394–1408. [PubMed: 11699677]

Rothbart, MK.; Bates, JE. Temperament. In: Eisenberg, N.; Damon, W.; Richard, LM., editors. Handbook of child psychology: Vol. 3, Social, emotional, and personality development. 6th ed.. Hoboken, NJ US: John Wiley & Sons Inc; 2006. p. 99-166.

Rothbart, MK.; Rueda, MR. The development of effortful control. In: Mayr, U.; Awh, E.; Keele, S., editors. Developing individuality in the human brain: A tribute to Michael I. Posner. Washington, D.C: American Psychological Association; 2005. p. 167-188.

Schwenk KA, Conture EG, Walden TA. Reaction to background stimulation of preschool children who do and do not stutter. Journal of Communication Disorders 2007;40:129–141. [PubMed: 16876188]

Smits-Bandstra S, De Nil LF. Sequence skill learning in persons who stutter: Implications for cortico-striato-thalamo-cortical dysfunction. Journal of Fluency Disorders 2007;32:251–278. [PubMed: 17963936]

Smits-Bandstra S, De Nil LF. Speech skill learning of persons who stutter and fluent speakers under single and dual task conditions. Clinical Linguistics and Phonetics 2009;23:38–57. [PubMed: 19148812]

Smits-Bandstra S, De Nil LF, Rochon E. The transition to increased automaticity during finger sequence learning in adult males who stutter. Journal of Fluency Disorders 2006;31:22–42. [PubMed: 16445973]

Snodgrass JG, Vanderwart M. A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. Journal of Experimental Psychology: Human Learning and Memory 1980;6:174–215. [PubMed: 7373248]

Spaulding TJ, Plante E, Vance R. Sustained selective attention skills of preschool children with specific language impairment: Evidence for separate attentional capacities. Journal of Speech, Language, and Hearing Research 2008;51:16–34.

Stevens C, Sanders L, Neville H. Neurophysiological evidence for selective auditory attention deficits in children with specific language impairment. Brain Research 2006;1111:143–152. [PubMed: 16904658]

Vasic, N.; Wijnen, F. Stuttering as a monitoring deficit. In: Hartsuiker, RJ.; Bastiaanse, R.; Postma, A.; Wijnen, F., editors. Phonological encoding and monitoring in normal and pathological speech. New York: Psychology Press; 2005. p. 226-247.

Williams, KT. Expressive Vocabulary Test (EVT). Circle Pines, MN: American Guidance Service, Inc; 1997.

Yairi E, Ambrose N. A longitudinal study of stuttering in children: a preliminary report. Journal of Speech and hearing Research 1992;35:755–760. [PubMed: 1405530]

Yairi E, Ambrose N. Early childhood stuttering I: Persistency and recovery rates. Journal of Speech, Language, & Hearing Research 1999;42:1097–1112.

Yairi, E.; Ambrose, N. Early Childhood Stuttering. Austin, TX: Pro-Ed; 2005.

Zenter M, Bates JE. Child Temperament: An Integrative Review of Concepts, Research Programs, and Measures. European Journal of Developmental Science 2008;2:7–37.

Table 1

Participant Characteristics

	PPVT-III	EVT	TELD-3	GFTA-2	Stuttered Disfluencies
CWS					
Mean	113.00	117.67	116.89	108.33	5.72
Standard Deviation	10.50	12.89	16.26	9.17	2.46
Range	94–130	91–133	86–140	95–120	3–11
CWNS					
Mean	117.93	119.64	122.00	109.57	0.96
Standard Deviation	10.59	8.83	10.44	9.22	0.80
Range	105–146	106–137	90–135	89–120	0–2.7

Note. PPVT-III = *Peabody Picture Vocabulary Test-III* (standard score); EVT = *Expressive Vocabulary Test (*standard score); TELD-3 = *Test of Early Language Development-3* (Spoken Language standard score); GFTA-2 = *Goldman-Fristoe Test of Articulation-2* (standard score); Stuttered disfluencies = mean frequency of part-word repetitions, single-syllable word repetitions, sound prolongations, and/or blocks per 100 words (percent); SSI-3 = *Stuttering Severity Instrument-3* (total score).

Table 2

Descriptive Statistics for CWS and CWNS on Measures of Phonological Working Memory, Linguistic Processing Speed, and Attention

			Attentional System		
	Total NWR Score	**SRT (ms)**	**Attentional Focusing**	**Impulsivity**	**Inhibitory Control**
CWS					
Mean	14.78	1198.68	4.94	3.95	5.00
Standard Deviation	8.11	193.64	0.99	0.94	0.84
Range	4–24	811–1456	2.5–6.0	2.2–5.2	3.7–6.5
CWNS					
Mean	24.36	1172.39	5.30	4.23	5.06
Standard Deviation	8.40	207.94	0.70	1.05	0.78
Range	7–36	862–1448	3.3–6.2	2.3–5.5	3.0–6.5

Note. NWR = nonword repetition; SRT = speech reaction time.

Table 3

Bivariate and Partial Correlations Among Measures of Phonological Working Memory, Linguistic Processing Speed, and Attention for Children Who Stutter

		Attentional System		
	SRT (ms)	**Attentional Focusing**	**Impulsivity**	**Inhibitory Control**
Bivariate Correlations				
SRT (ms)	----	.046	.486	−.079
2-Syllable NWR	−.641	−.364	.004	.252
3-Syllable NWR	−.750*	.059	−.219	.018
4-Syllable NWR	−.442	−.366	.276	−.150
5-Syllable NWR	−.775*	.385	−.096	−.300
Total NWR	−.763*	−.033	−.037	.007
Age (mos)	−.494	−.613	.089	.129
Partial Correlations (age removed)				
SRT (ms)	----	−.374	.611	−.018
2-Syllable NWR	−.522	−.083	−.047	.218
3-Syllable NWR	−.798*	.174	−.233	.002
4-Syllable NWR	−.292	−.143	.265	.105
5-Syllable NWR	−.816*	.609	−.110	−.325
Total NWR	−.737*	.212	−.069	−.035

Note. NWR = nonword repetition;

* $p \leq .05$.

Table 4

Bivariate and Partial Correlations Among Measures of Phonological Working Memory, Linguistic Processing Speed, and Attention for Children Who Do Not Stutter

		Attentional System		
	SRT (ms)	**Attentional Focusing**	**Impulsivity**	**Inhibitory Control**
Bivariate Correlations				
SRT (ms)	----	.605*	−.207	.114
2-Syllable NWR	.228	.400	.362	−.098
3-Syllable NWR	−.093	.211	.531*	−.175
4-Syllable NWR	.483	.450	.386	−.215
5-Syllable NWR	.214	.030	.690**	−.312
Total NWR	.264	.297	.581*	−.251
Age (mos)	−.545*	−.433	.735**	−.380
Partial Correlations (age removed)				
SRT (ms)	----	.488	.340	−.120
2-Syllable NWR	.530	.650*	.169	.039
3-Syllable NWR	.349	.653*	.166	−.072
4-Syllable NWR	.740**	.623*	.334	−.144
5-Syllable NWR	.489	.198	.708**	−.217
Total NWR	.631*	.572*	.458	−.11512

Note. NWR = nonword repetition;

* $p \leq .05$

** $p \leq .01$.