Published in final edited form as:

J Speech Lang Hear Res. 2004 June ; 47(3): 552–571.

Sentence-Structure Priming in Young Children Who Do and Do Not Stutter

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Abstract

The purpose of this study was to use an age-appropriate version of the sentence-structure priming paradigm (e.g., K. Bock, 1990; K. Bock, H. Loebell, & R. Morey, 1992) to assess experimentally the syntactic processing abilities of children who stutter (CWS) and children who do not stutter (CWNS). Participants were 16 CWS and 16 CWNS between the ages of 3;3 (years; months) and 5;5, matched for gender and age (± 4 months). All participants had speech, language, and hearing development within normal limits, with the exception of stuttering for CWS. All children participated in a sentence-structure priming task where they were shown and asked to describe, on a computer screen, black-on-white line drawings of children, adults, and animals performing activities that could be appropriately described using simple active affirmative declarative (SAAD) sentences (e.g., “The man is walking the dog”). Speech reaction time (SRT) was measured from the onset of the picture presentation to the onset of the child's verbal response in the absence and presence of priming sentences, counterbalanced for order. Main findings indicated that CWS exhibited slower SRTs in the absence of priming sentences and greater syntactic-priming effects than CWNS. These findings suggest that CWS may have difficulty rapidly, efficiently planning and/or retrieving sentence-structure units, difficulties that may contribute to their inability to establish fluent speech-language production.

Keywords

stuttering; sentence-structure priming; syntactic priming; children; linguistic processing

In recent years, various studies have been conducted regarding the linguistic skills of children who stutter (CWS; for reviews, see Louko, Conture, & Edwards, 1999; Ratner, 1997), as well as linguistic determinants of instances of stuttering-like disfluencies (e.g., Howell, Au-Yeung, & Sackin, 1999; Hubbard & Prins, 1994; Zackheim & Conture, 2003). For example, when compared with children who do not stutter (CWNS), CWS have been found to score lower on measures of expressive and/or receptive language (Byrd & Cooper, 1989; Murray & Reed, 1977; Westby, 1974) and receptive vocabulary (e.g., Meyers & Freeman, 1985; Ryan, 1992; cf. Silverman & Ratner, 2002), as well as exhibit significantly more grammatical errors in their conversational speech (Westby, 1974) and simpler, less mature language (Howell & Au-Yeung, 1995; Wall, 1980). CWS have also been found to exhibit a quantifiably greater difference between measures of receptive/expressive language and receptive vocabulary than CWNS (Anderson & Conture, 2000), which suggests the possibility of an imbalance among components or aspects of the speech-language systems of CWS (see Tetnowski, 1998).

Conversely, longitudinal studies of preschool CWS have reported that CWS exhibit expressive language abilities near or above developmental expectations on the basis of comparisons with

normative data (Watkins & Yairi, 1997; Watkins, Yairi, & Ambrose, 1999). Watkins et al.'s (1999) findings would initially appear to contradict the above-referenced studies. However, the above-referenced studies generally reported that CWS tend to score lower than their normally fluent peers on various speech-language measures, but they still score within the average range of abilities. One main difference between the studies by Watkins et al. and those reported above is that the former compared the performance of CWS to published normative data, whereas the latter compared the performance of CWS to that of a control group of CWNS. Perhaps, therefore, these differences in methodology may have resulted in the appearance of a discrepancy in findings concerning the language abilities of CWS, but in actuality there appears to be no such discrepancy (see Anderson & Conture, 2000).

Based on much of the evidence reported above, some have begun to speculate that stuttering may be related to difficulties with phonological, lexical, and/or syntactic processing (e.g., Au-Yeung & Howell, 1998; Kolk & Postma, 1997; Ratner, 1997; Wijnen & Boers, 1994). One essential ingredient of psycholinguistic models of stuttering, such as the covert repair hypothesis (Kolk & Postma, 1997; Postma & Kolk, 1993), is the notion that disturbances in time contribute to stuttering, thereby implicating the “rate of initiation and/or production of speech as either an important originating or aggravating variable” (Conture, 2001, p. 37). Perhaps, therefore, subtle to more apparent temporal difficulties in the planning for and/or production of speech and language by CWS (Chang, Ohde, & Conture, 2002) may be sufficient enough to disrupt, stall, or freeze the forward flow of their planning for speech-language production, an event that might temporarily lead to repairs or corrections that are overtly manifest as hesitations, repetitions, and prolongations.

In fact, Garrett (1982) noted that “hesitations (filled and silent pauses) may reflect transient increases in processing load, normal advance planning and retrieval for an upcoming structural unit, or delay created by the momentary inaccessibility of a needed piece of information” (as cited in Bock, 1995, p. 201). Applying such speculation to young CWS, it may be possible that their increased frequency of hesitations and/or disfluencies reflect subtle to not-so-subtle difficulties with language formulation processes. Specifically, they may be more apt to experience transient increases in processing load, difficulty planning and retrieving a structural unit, and/or delay in accessing linguistic information. Consequently, these limitations in speech-language planning processes may increase the probability of speech disfluencies in their spontaneous speech.

Despite growing interest in the relationship between linguistic formulation processes and stuttering, to date, more attention seems to have been paid to the phonological, lexical/semantic, and syntactic processing abilities of adults who stutter rather than CWS (Bosshardt, 1993, 1994; Bosshardt, Ballmer, & de Nil, 2002; Bosshardt & Fransen, 1996; Burger & Wijnen, 1999; Cuadrado & Weber-Fox, 2003; Hartsuiker, Kolk, & Lickley, in press; Prins, Main, & Wampler, 1997; Wijnen & Boers, 1994). Findings from these studies generally suggest that the processing of semantic, syntactic, and/or phonological information may be slower and/or less efficient in adults who stutter when compared with their normally fluent peers. However, it is unclear whether these findings can be generalized to CWS because as Yairi (1993) noted, “Advanced stuttering is markedly different from the incipient form” (p. 198), and only a minority of children will continue to stutter into adulthood, the latter of which is consistent with Andrews and Harris's (1964) findings of a 79% “natural recovery rate” among CWS. In essence, adults who stutter represent only a proportion of those who stuttered as children, and thus directly extrapolating findings from one age grouping to the other must be done with considerable caution given the developmental, changing nature of stuttering across the life span.

Indeed, it is somewhat surprising that there have not been more experimental investigations of the syntactic processing abilities of CWS, considering the fact that, as mentioned above, descriptive studies have typically shown, for example, that CWS produce more speech disfluencies (stuttering-like and/or other disfluencies) on longer or more syntactically complex utterances (e.g., Logan & Conture, 1995, 1997; Melnick & Conture, 2000; Ratner & Sih, 1987; Yaruss, 1999), as well as on utterances longer than their mean length of utterance (Zackheim & Conture, 2003). Likewise, young children have been shown to exhibit increases in speech disfluency (stuttering-like and other disfluencies) when attempting to produce difficult or newly acquired morphosyntactic structures (e.g., Colburn & Mysak, 1982a, 1982b; Gordon, Luper, & Peterson, 1986; Ratner, 1997; Ratner & Sih, 1987; Wijnen, 1990). Findings of a consistent relationship between speech disfluencies, utterance length, and syntactic complexity seemingly suggest that young CWS may experience some degree of difficulty quickly and/or efficiently formulating morphosyntactic structures.

Given that descriptive studies have consistently shown a relation between utterance output characteristics (e.g., utterance length and complexity) and instances of stuttering-like disfluencies, it seems quite possible that an experimental study of the syntactic processes of CWS may provide further insights into the speech-language production variables associated with the onset and development of stuttering in children. One means of experimentally assessing the syntactic processing abilities of CWS would be to use a sentence-structure priming paradigm, a procedure sometimes referred to as *structural* or *syntactic priming* or *syntactic persistence* (Pickering & Branigan, 1999). Such paradigms have been used in psycholinguistic research to examine syntactic processing in adults with typical language production (e.g., Bock, 1986, 1989, 1990; Bock & Griffin, 2000; Bock & Loebell, 1990; Bock et al., 1992; Branigan, Pickering, Liversedge, Stewart, & Urbach, 1995; Smith & Wheeldon, 2001) and atypical language production (Hartsuiker & Kolk, 1998; Saffran & Martin, 1997). Furthermore, this methodology has been adapted to study syntactic processing of young language users (Brooks & Tomasello, 1999; Leonard et al., 2000, 2002).

During a typical sentence-structure priming paradigm in spoken language production, participants first listen to and then repeat a priming sentence composed of a specific syntactic form (e.g., see Bock, 1986). After the participant repeats the sentence, he or she is immediately presented with a picture that is semantically unrelated to the priming sentence and is then asked to describe the pictured event. Findings from these studies generally indicate that participants have the tendency to describe the picture with the same syntactic form as the preceding priming sentence (i.e., syntactic persistence). For example, the priming sentence, "The girl is giving the bone to the dog" (a prepositional dative) would tend to be followed by a picture description such as, "The boy is kicking the ball to the girl" (also a prepositional dative). This tendency to use a previously presented syntactic form has also been shown to reduce the amount of time dedicated to the generation of syntactic structure (Smith & Wheeldon, 2001). Importantly, results of empirical research in this area generally suggest that syntactic persistence cannot be attributed to lexical (i.e., types of words), thematic (i.e., types of events), or metrical/prosodic (i.e., sound patterns) similarities between primes and targets, but rather it appears to be associated with certain aspects of syntactic representation (e.g., the retrieval and assembly of the sentence frame's component structure; Bock, 1989; Bock & Loebell, 1990; Pickering & Branigan, 1999; Smith & Wheeldon, 2001).

As mentioned above, recent adaptations of this structural priming paradigm have been used to assess syntactic persistence among very young language users. For example, Brooks and Tomasello (1999) found that when 2.5- to 3-year-old children repeatedly heard novel verbs used in passive and active transitive constructions, they were much more likely to use these constructions in their subsequent utterances. Similarly, young children with specific language impairment (SLI) have been found to make greater use of grammatical morphemes (e.g.,

auxiliary *is*) when given a prime employing the syntactic frame and prosodic structure required in the target sentence (e.g., prime: “The birds are building the nest”; target: “The horse is kicking the cow”) than when given a prime that differed from the target in its syntactic frame and prosody (e.g., prime: “The doctor smiled”; target: “The horse is driving the car”; Leonard et al., 2000). These findings suggest, according to the authors, that “some portion of the grammatical morpheme limitations of children with SLI can be traced to production processes” (Leonard et al., 2000, p. 375).

Most sentence-structure priming studies of adults and children have used the frequency of occurrence of a given syntactic structure as the main dependent measure. However, syntactic persistence in spoken language production has also been examined in adults using the dependent measure of response latencies to target sentences (i.e., speech reaction time [SRT]; Smith & Wheeldon, 2001). Smith and Wheeldon (2001) recorded response latencies during two conditions: (a) target sentences preceded by a syntactically related prime (syntactically related condition) and (b) target sentences preceded by syntactically unrelated primes (syntactically unrelated condition). They found that speech response latencies were significantly faster (by 55 ms) in the syntactically related condition than in the syntactically unrelated condition and that this facilitation effect was apparently not due to priming of processes involved with visual perception, conceptualization, lexical access, or phonological planning. According to Smith and Wheeldon, these findings provide support for the hypothesis that “the function of syntactic persistence is to reduce the processing costs of the speaker and so to promote the fluency and rapidity of utterance generation” (p. 157).

In a preliminary study to that currently reported, Anderson (2001) developed an age-appropriate version of the sentence-structure priming paradigm to assess the online syntactic processing abilities of 3- to 5-year-old typically developing CWNS ($N = 11$). Specifically, these children were asked to describe, as quickly as possible, 17 black-on-white line drawings of children, adults, and animals performing activities that could be appropriately be described by means of simple active affirmative declarative (SAAD) sentences (e.g., “The man is walking the dog”) on a computer screen. SRT was measured from the onset of the picture presentation to the onset of the child's verbal response in the absence and presence of priming sentences. Results revealed that 8 of the 11 (73%) participants demonstrated faster SRTs in the presence rather than the absence of priming sentences, while only 3 (27%) exhibited slower SRTs. This pilot study demonstrated the feasibility of using this paradigm to study the speed of morphosyntactic construction in young children.

In summary, developing lines of evidence appear to suggest that subtle to not-so-subtle difficulties in quickly, efficiently planning and producing speech-language may contribute to the problems young CWS have establishing reasonably fluent oral communication. Perhaps employing the methodology used to study such processing abilities, as discussed above (e.g., a modified or age-appropriate version of the sentence-structure priming paradigm developed by Anderson, 2001, for use with preschoolers), may help us better understand selective aspects of the temporal component of linguistic processing in young CWS, particularly those associated with syntactic processing. Of course, one cannot completely disassociate the contributions of other linguistic processes, such as semantic and phonological encoding, to the overall efficiency and/or time course of syntactic processing. However, as previously suggested, the manipulation of syntactic processes (i.e., syntactic priming) has been shown to change (i.e., speed up or reduce) the amount of time dedicated to the generation of syntactic structure because of its effect on grammatical formulation (Smith & Wheeldon, 2001). Thus, it seems reasonable to suggest that such an investigation could provide meaningful, initial insights into the temporal syntactic production abilities of children who stutter.

Specifically, in the present study, we attempted to assess whether there was a significant difference between CWS and CWNS in SRT and accuracy for picture descriptions in the absence and presence of priming sentences, as well as syntactic-priming effects (as measured by SRT in the no-prime condition minus SRT in syntactic prime condition). It was also considered to be of some interest to assess whether measures of SRT in the experimental tasks were associated with stuttering-like disfluencies in conversational speech. Thus, measures of stuttering-like disfluencies for CWS were examined relative to SRT in the no-prime and syntactic-priming conditions, as well as syntactic-priming effects.

Method

Participants

Participants were 32 children between the ages of 3;3 (years; months) and 5;5 who do ($n = 16$) and do not stutter ($n = 16$) matched for gender (4 girls, 12 boys) and age (CWS: mean age = 53.0 months, range = 39.0–64.0 months; CWNS: mean age = 52.8 months; range = 39.0–65.0 months). All participants were native speakers of American English with no apparent or reported history of neurological, psychological, speech-language, or intellectual problems per parent report and examiner observation. Children were identified for participation in this study by their parents who had heard about it through (a) an advertisement in a parent-oriented magazine (*Nashville Parent*); (b) speech-language pathologists, health care providers, daycare centers, and so forth in the middle Tennessee area; and (c) referral to the Vanderbilt Bill Wilkerson Hearing and Speech Center (VBWC) for the assessment of childhood stuttering. All CWNS and approximately 60% of CWS were identified through the magazine advertisement. The remaining CWS were identified through referral from the middle Tennessee professional community or the VBWC. This study was reviewed and approved by the Vanderbilt University Institutional Review Board.

Classification and Inclusion Criteria

CWS—A child was assigned to the CWS group if he or she (a) exhibited three or more stuttering-like disfluencies (part-word repetitions, single-syllable word repetitions, sound prolongations, blocks, and tense pauses) per 100 words of conversational speech (Yairi & Ambrose, 1992) and (b) received a total overall score of 11 or above (a severity equivalent of at least “mild”) on the Stuttering Severity Instrument—3 (SSI-3; Riley, 1994; CWS had a mean score of 16.13, $SD = 3.48$, a severity equivalent of “mild–moderate”). Similar indexes of stuttering have been reported elsewhere (e.g., Yairi, 1981; Yairi & Ambrose, 1992; Yairi & Lewis, 1984), with the specific definition of the “constituent members” or different disfluency types representative of stuttering-like disfluencies also described elsewhere (Johnson, 1961; Williams, Silverman, & Kools, 1968).

CWNS—A child was assigned to the CWNS group if he or she (a) exhibited two or fewer stuttering-like disfluencies per 100 words of conversational speech (Yairi & Ambrose, 1992) and (b) received a total overall score of 8 or below (a severity equivalent of less than “mild”) on the SSI-3 (CWNS had a mean score of 6.75, $SD = 1.00$, a severity equivalent of “very mild”).

Speech, Language, Motor, and Hearing Abilities—To be included in this study, all participants were required to score at the 20th percentile or higher on four standardized speech-language tests: (a) the Peabody Picture Vocabulary Test—Third Edition (PPVT-III; Dunn & Dunn, 1997), a measure of receptive vocabulary; (b) the Expressive Vocabulary Test (EVT; Williams, 1997), a measure of expressive vocabulary; (c) the Test of Early Language Development—3 (TELD-3; Hresko, Reid, & Hamill, 1999), a measure of expressive and receptive language ability; and (d) the Sounds in Words subtest of the Goldman–Fristoe Test

of Articulation–2 (GFTA-2; Goldman & Fristoe, 2000), a measure of speech sound development (see Table 1). Children were also required to pass (a) a general and oral motor functioning screening test (the Selected Neuromotor Task Battery [SNTB]; Wolk, Edwards, & Conture, 1993; after Wolk, 1990) and (b) a bilateral hearing screening (pure tones at 20 dB sound pressure level for 500, 1000, 2000, and 4000 Hz; impedance audiometry at 800 to 3,000 ohms).

Procedure

Participants were tested on two occasions, in their homes and in a clinic room. During the home visit, the standardized speech and language tests and SNTB were administered to the children during data collection sessions lasting 1 to 1.5 hr. Participants visited the clinic approximately 1 week later to participate in an informal parent–child conversational interaction for the analysis of speech disfluencies (a 300-word conversational speech sample was obtained during the parent–child interaction), to participate in the sentence-structure priming task (see below), and to complete the hearing screening. All participants were audio- and video-recorded during the clinic visit, which lasted approximately 1 to 1.5 hr.

Sentence-Structure Priming Task: General Overview—SRT data (in milliseconds) were obtained for all participants during a sentence-structure priming task consisting of two conditions—a no-prime and syntactic-priming condition. The order of presentation of the two conditions was counterbalanced across all children, and a brief 1- to 2-min break occurred between conditions to permit preparation of the next condition.

In each of the two conditions, participants responded to the same 27 pictures, which consisted of 5 practice pictures, 17 experimental pictures, and 5 filler pictures (to be described below; see Figure 1). Previous pilot work (Anderson, 2001) had shown that the 17 experimental pictures were named by 3- to 5- year old children ($N = 23$) with 80% or greater accuracy. All pictures were selected from the Webber® Verbs & More! Cards (Super Duper® Publications, 1998) and involved both an agent and an object undergoing the action. Typical actions, for example, included hugging, sitting, and petting, which were performed in the context of events such as a boy hugging a dog, a girl sitting in a chair, and a girl petting a cat. All pictures were similar in complexity and size so that responses reflected the linguistic stimuli rather than visual demands; similarly, the nouns and verbs associated with these pictures were roughly similar in frequency and length so that responses reflected syntactic processes rather than lexical access time (McKee, 1996).

The same five practice pictures were included at the beginning of each of the two conditions to give the children an opportunity to practice the picture description task. During these practice trials, if the child did not describe the picture accurately and/or completely, the experimenter modeled the correct picture description for the child. Data from these five practice trials, which preceded the two conditions (for a total of 10 practice pictures), were not analyzed.

Following the 5 practice pictures, participants responded to an identical distribution of 17 experimental pictures and 5 filler pictures in each condition. The experimental pictures consisted of pictures that children could readily describe using a SAAD structure (e.g., “The boy is hugging the dog”), an active transitive construction. The filler pictures depicted actions that could be described using a different sentence form (i.e., a negative sentence form). Fillers are generally used to camouflage the structural relationship between experimental prime sentences and picture descriptions (Bock & Loebell, 1990; McKee, 1996). The filler pictures were arranged so that no more than 3 experimental pictures occurred consecutively. SRT data from these filler pictures, which occurred in both conditions (for a total of 10 filler pictures), were not analyzed.

The experimental and filler pictures were in the same relative position in each condition, because recent research has suggested that sentence-structure priming may persist over intervening sentences (Chang, Dell, Bock, & Griffin, 2000). For example, Bock and Griffin (2000) reported that structural priming occurred over 10 intervening sentences, whereas Boyland and Anderson (1998) found a priming effect when primes and targets were separated by a period of 20 min. Thus, in the present study, the order of picture presentation was held constant for both conditions (no-prime and syntactic-prime conditions). Although this procedure does not preclude the possibility that priming could occur as a result of the child's description or response to preceding pictures, its influence would at least be the same in both conditions. For example, Picture A was in the 10th position for the no-prime as well as the syntactic-prime condition. In this way, while priming due to the child's responses to preceding pictures may have influenced the child's accuracy and speed of responding to Picture A in the no-prime condition, the same degree of influence would be expected for Picture A in the other, that is, syntactic-prime, condition.

Sentence-Structure Priming Task: Priming Conditions

No-prime (silent) condition: In the no-prime condition, children were asked to describe the 17 experimental pictures and 5 filler pictures as quickly as possible. Specifically, children were instructed, "Tell me what you see in the picture as fast as you can." Each picture was presented for 3,000 ms, and the time interval between successive targets was 4,000 ms. Children's responses were recorded using a voice-activated microphone, the output of which was inputted into a New Experimental Stimulus Unit (NESU) coprocessor. NESU was used to collect and analyze chronometric data and was developed by the Max Planck Institute for Psycholinguistics, University of Nijmegen, Nijmegen, the Netherlands. The NESU coprocessor was interfaced, synchronized, and run simultaneously with the Pentium 200 MHz computer. The latency of the child's picture description (i.e., SRT) was recorded in milliseconds using the NESU hardware and software.

Syntactic-prime condition: In the syntactic-prime condition, children were shown the same pictures as in the no-prime condition (i.e., the 17 experimental pictures and 5 filler pictures). However, 2,000 ms prior to the onset of presentation of the picture, the child was presented with an auditory priming sentence composed of a SAAD structure (e.g., "The boy is walking the dog") or a negative structure (e.g., "The boy is not walking the dog") that in all obvious respects appeared dissimilar to the picture (e.g., a picture of a girl throwing a stick; see Figure 1 and Appendix). Children were told, "Don't pay attention to the man talking from the speakers—just tell me what you see in the picture as fast as you can." Instructing children not to pay attention was based on pilot work (Anderson, 2001) that indicated that many children, without such instruction, repeated the priming sentence rather than describing the picture, essentially rendering their response unusable for further analysis.

The 2,000 ms temporal distance between prime and target was used to ensure that there was no temporal overlap between the beginning, middle, or end of the auditorily presented prime and the visual onset of the picture word stimuli. As with the no-prime condition, each picture was presented, one at a time, for 3,000 ms, with time interval between successive targets of 4,000 ms. Each participant's SRT associated with their description of the picture was recorded in milliseconds using the NESU hardware and software system. All auditory priming sentences contained the same grammatical morpheme structure—for example, a contractible auxiliary, such as *is*, with or without negation combined with a present progressive (e.g., an *ing* verb form). In addition, for each priming sentence and picture pair, attempts were made to ensure that there were no semantic or phonological similarities between the priming sentence and picture description and that the syllable structure and length were identical.

Preadalysis Data Preparation—To ensure that all picture descriptions to be included in the final data corpus were accurate depictions of each picture and had the same grammatical structure associated with each picture, we assessed the accuracy of the children's responses to the pictures after experimental testing. Children's responses to each of the pictures in the no-prime and syntactic-priming conditions were considered accurate if they (a) contained all three components of the SAAD sentence structure (subject, contractible auxiliary and present progressive verb combination, and object; omissions of sentence-initial articles were permitted) and (b) were relevant to the pictured event.

Errors: A picture description response was regarded as an error (and not included in the final data corpus) if the response contained one or more of the following: (a) it lacked any of the three components of the SAAD sentence structure; (b) it was not relevant to the pictured event; (c) it did not trigger the voice-activated microphone (i.e., the child spoke too softly or failed to verbally respond to the picture); (d) it was associated with an extraneous voice signal and/or noise in the environment that triggered the voice-activated microphone before the child responded; and/or (e) it contained stuttering-like disfluencies (part-word repetitions, single-syllable word repetitions, sound prolongations, blocks, and tense pauses) or other disfluencies (polysyllabic word repetitions, phrase repetitions, and revisions). Responses containing stuttering-like or other disfluencies were considered errors to ensure that any differences in SRT between the two talker groups could not be accounted for by the presence of speech disfluencies. If a child had less than five useable tokens (i.e., picture descriptions) per 17 experimental pictures for either condition, his or her entire data were excluded from the study's final data corpus.

Accurate picture description responses in which the child produced only an interjection somewhere in the sentence were included in the final analysis of SRT for both CWS and CWNS. This allowed for the fact that all children of this age, on the basis of our experience and observation of preschoolers' picture description responses, frequently produce picture descriptions with an interjection. There were, however, no significant differences between the two talker groups in mean SRT between fluent responses and responses with an interjection for either the no-prime, $t(9) = .29, p = .78$, or the syntactic-priming condition, $t(7) = .73, p = .49$.

Trimming or exclusion of outliers: As discussed by Ratcliff (1993), there are no absolutes when trying to determine the presence of outliers in SRT data and the means by which to exclude them. However, exclusion of outliers is an important consideration with SRT data because the researcher wants to be reasonably sure that the values contained in the analyzed data are those “that are most likely to come from real processes under consideration and also most likely to be critical in testing hypotheses and models” (p. 511). Given these considerations and repeated observations of the general latency/time window associated with children's accurate picture description responses, SRTs below 900 ms and above 2,800 ms in both the no-prime and syntactic-priming condition were excluded from the final data pool. Values below 900 ms were 1.2 standard deviations below the mean for all accurate picture description responses and, most importantly, were excluded because these would be average for similar responses by adults (Smith & Wheeldon, 2001) and/or so rapid as unlikely to be associated with young children's picture description responses. Values above 2,800 ms were 2.0 standard deviations above the mean for all accurate picture description responses and most likely associated with inattention and/or errors—values extraneous to and/or not associated with the linguistic process being studied. These cutoff scores excluded 9.3% (CWS = 8.8%; CWNS = 9.7%) of the total maximum tokens possible (i.e., 272 tokens per condition $\times$ 4 conditions = 1,088 total possible tokens), a finding well within Ratcliff's (1993) guideline for the percentage of data points or scores that can be reasonably eliminated from the total corpus of data (see Table 2).

Exclusion of participants: Fifty children initially participated in this study. Of these 50 children, 18 children, representing 36% of the total participants, were excluded as final participants (11 CWS and 7 CWNS). These children were excluded because they either failed to meet participant inclusion criteria (i.e., their scores on standardized speech-language tests rendered them unusable as participants; 3 CWS and 1 CWNS) and/or were unable to complete the sentence-structure priming task with no more than 70% errors and/or inaccurate responses (8 CWS and 6 CWNS). After all errors, (a) through (d) described above, and outliers were excluded from the data pool (see Table 2), the 16 CWS who participated in this study had 152 useable tokens in the no-prime condition and 141 in the syntactic-priming condition (a maximum of 272 tokens possible in each condition). Similarly, the 16 CWNS produced 157 useable tokens in the no-prime condition and 170 in the syntactic-prime condition.

Analysis of Main Dependent Measures

SRT: SRT data (in milliseconds) were obtained during each of the two experimental conditions. SRT was measured from the visual onset of the picture to the acoustic onset of the child's verbal response triggered via the voice-activated microphone. During the no-prime and syntactic-priming conditions, the computer controlled the rate of picture and syntactic prime presentation and recorded the latency of the child's vocal picture description in milliseconds. Again, each child's SRT for each of the 17 experimental pictures in the no-prime and syntactic-priming conditions was analyzed only for accurate picture description responses.

Sentence accuracy: Sentence accuracy in the no-prime and syntactic-priming conditions was analyzed for both CWS and CWNS. For this analysis, children's responses to the pictures were considered accurate if they contained a subject, a contractible auxiliary–present progressive verb combination, and an object. Responses containing stuttering-like or other disfluencies were included in the analysis, provided that they contained the targeted sentence structure (e.g., a response such as, “The the girl is hu...hu...hugging the dog”). These otherwise accurate but disfluent responses were included in the analysis of sentence accuracy because of the fact that CWS have more speech disfluencies in their responses, which would artificially decrease the number of accurate responses that could be subsequently analyzed.

Speech disfluency measures: To determine the relationship between speech disfluency measures and SRT for CWS (and to determine talker group classification), the 300-word conversational speech sample was analyzed for each participant for the mean frequency of stuttering-like disfluencies per 100 words. Measures of speech disfluency were based on the children's conversational speech, given the observation that speech disfluencies for children are significantly fewer during picture naming or picture description tasks (Wolk, 1990) than during conversation.

Data analysis: SRT data in each of the two conditions for both talker groups were tabulated in terms of the mean SRT for accurate responses and then analyzed using a 2×2 (Group $\times$ Condition) analysis of variance (ANOVA), and follow-up *t* tests, as needed. Additional analyses included the use of ANOVAs to examine the effects of presentation order on SRT and accuracy, to examine prosodic similarities between primes and target sentences on SRT, and to examine linear trends in SRT. Mean accuracy scores in the no-prime and syntactic-priming conditions for both talker groups were analyzed using 2×2 (Group $\times$ Condition) ANOVAs. Finally, for the group of CWS, Pearson product–moment correlation coefficients were used to examine the relationship between (a) mean frequency of stuttering-like disfluencies and mean SRT and (b) mean frequency of stuttering-like disfluencies and syntactic-priming effects (i.e., SRT in no-prime condition minus SRT in syntactic-priming condition).

Intra- and interjudge measurement reliability: Intra- and interjudge reliability measures were obtained for total disfluencies (stuttering-like plus other disfluencies) and stuttering-like disfluencies, as well as response accuracy measures. For the speech disfluency measures, 8 participants were randomly selected from both the CWS and CWNS groups ($n = 16$). The 300-word conversational speech samples from these participants, representing approximately 50% of the total data corpus (300 words per participant for a total of 4,800 words), were then used for intra- and interjudge measurement reliability. Specifically, intrajudge reliability was assessed by having the first author judge each speech sample for the mean frequency (i.e., the average frequency per 100 words) of total and stuttering-like disfluencies on two different occasions, separated by a period of 1 month. Interjudge reliability was assessed by having the first author and a doctoral student, both of whom are certified speech-language pathologists and experienced in the assessment of stuttering, judge each speech sample for total and stuttering-like disfluencies. Intra- and interjudge reliability scores for the two speech disfluency measures were assessed across participants using the following formula: smaller disfluency count/larger disfluency count $\times 100$. Intrajudge reliability for the mean frequency of total disfluencies (both stuttering-like and other disfluencies) and stuttering-like disfluencies was 94% and 93%, respectively, whereas interjudge reliability for the overall mean frequency of total and stuttering-like disfluencies was 91% and 89%, respectively.

For the measure of response accuracy, 8 other participants were randomly selected from both the CWS and CWNS groups ($n = 16$). Six responses per subject (three responses from the no-prime condition and three responses from the syntactic-priming condition) were selected randomly. This resulted in approximately 17% of the total data (6 responses $\times$ 16 participants = 96 responses) being used for intrajudge and interjudge measurement reliability for response accuracy. Intrajudge reliability was assessed by having the first author judge each response for accuracy on two separate occasions, separated by a period of 2 months. Interjudge reliability was assessed by having the first author and a trained observer judge each response for response accuracy. Intrajudge and interjudge reliability for the response accuracy measures was 97% and 97%, respectively.

Results

Descriptive Information

Stuttering/Speech Disfluencies—As would be expected on the basis of participant selection criteria, CWS exhibited significantly greater mean total disfluencies (i.e., stuttering-like plus other disfluencies): $M = 11.06$, $SD = 5.18$, $t(30) = 6.28$, $p = .00$, as well as stuttering-like disfluencies: $M = 8.15$, $SD = 5.19$, $t(30) = 5.19$, $p = .00$, compared with CWNS—total: $M = 2.52$, $SD = 1.67$; stuttering-like: $M = 1.29$, $SD = 0.99$. These data pertaining to speech disfluencies are based on the aforementioned 300-word conversational speech sample.

Speech and Language Abilities—Although all participants scored within normal limits (i.e., at or above the 20th percentile) on a variety of standardized speech-language tests (PPVT-III, EVT, TELD-3, and GFTA-2) (see Table 1), a multivariate analysis of variance (MANOVA) revealed significant between-group differences on one of these measures. In particular, CWS scored lower than CWNS on both the Expressive, $F(1, 24) = 11.77$, $p = .002$, and Receptive, $F(1, 24) = 7.99$, $p = .009$, subtests of the TELD-3. Interestingly, although CWS consistently scored lower than CWNS on all speech-language measures, findings did not replicate those of Pellowski, Conture, Anderson, and Ohde (2001), who found that CWS scored significantly lower than CWNS on the GFTA-2.

Correlations of Speech-Language Measures and SRT—There were no significant correlations between the TELD-3 subtests and SRT associated with the no-prime condition, syntactic-priming condition, or syntactic-priming effects (p values ranged from .15 to .93). In

other words, although there were significant differences between CWS and CWNS in their TELD-3 subtest scores, there was no systematic relationship between this measure of expressive and receptive language ability and the study's main dependent measure, that is, SRT. Thus, it would seem that this between-group difference in expressive and receptive language ability cannot be readily used to explain any potential differences between the two groups on the primary dependent variable in this study.

SRT (in ms)

SRT data were subjected to an ANOVA with talker group (CWS and CWNS) as a between-subjects variable and condition (no-prime and syntactic-priming) as a within-subjects variable (see Figure 2A). Results indicated a significant main effect for condition—that is, SRT was slower in the no-prime condition than in the syntactic-priming condition for all participants, $F(1, 30) = 10.74, p = .003$ —but no significant between-subjects effects, $F(1, 30) = 1.71, p = .20$. Results further revealed a significant Group $\times$ Condition interaction effect, $F(1, 30) = 4.03, p = .05$. In other words, as shown in Figure 2B, there appears to be a significant difference between CWS and CWNS in syntactic-priming effects. Follow-up t tests (Bonferroni adjusted) revealed that CWS were significantly faster by approximately 212 ms ($SD = 259$ ms) in the syntactic-priming condition than in the no-prime condition, $t(15) = 3.27, p = .005$; however, for CWNS, the 51 ms ($SD = 189$ ms) difference in SRT between the no-prime and syntactic-priming condition was not significantly different, $t(15) = 1.08, p = .30$. Therefore, these findings suggest that CWS tend to benefit more, in absolute terms, from syntactic primes than do CWNS.

Informal assessment of the individual performances of CWS revealed that 13 of the 16 (81.3%) children demonstrated a tendency for faster SRTs (on average, 269 ms faster) in the syntactic-priming condition than in the no-prime condition. Similarly, 10 of the 16 (62.5%) CWNS exhibited faster SRTs in the syntactic-priming condition (on average, 151 ms faster). Three (18.8%) CWS and 6 (37.5%) CWNS demonstrated a tendency for slower SRTs in the syntactic-priming than in the no-prime condition (on average, 122 ms slower). Thus, on a purely descriptive basis, these data suggest that although both CWS and CWNS tended to demonstrate faster SRTs in the syntactic-priming condition than in the no-prime condition, CWS were almost 50% faster in the syntactic-priming condition than CWNS.

Additional follow-up t tests (Bonferroni adjusted) revealed a significant between-group difference for the no-prime condition, $t(30) = 2.43, p = .02$, but not for the syntactic-priming condition, $t(30) = 0.16, p = .87$. Thus, CWS were significantly slower than CWNS in the no-prime condition (CWS: $M = 1,694, SD = 201$; CWNS: $M = 1,518, SD = 207$), a difference that was essentially nullified in the syntactic-priming condition (CWS: $M = 1,482, SD = 268$; CWNS: $M = 1,467, SD = 256$). A $2 \times 2 \times 2$ (Group $\times$ Condition $\times$ Order) ANOVA also revealed no main effect of presentation order for SRT in the no-prime, $F(1, 28) = 0.30, p = .59$, and syntactic-priming conditions, $F(1, 28) = 3.66, p = .07$. Furthermore, there was no significant Presentation Order $\times$ Group interaction in the no-prime, $F(1, 28) = 0.70, p = .41$, and syntactic-priming conditions, $F(1, 28) = 0.17, p = .68$. These results indicate that the presentation order of the two conditions, which had been counterbalanced across all children, had no significant effect on SRT in the no-prime and syntactic-priming conditions for children in the two talker groups.

Although studies with adult participants have essentially ruled out the possibility that syntactic-priming effects could be due to prosodic similarities between primes and targets (e.g., Bock & Loebell, 1990), a twoway ANOVA was conducted to examine whether any prosodic similarities between the prime and target sentences could possibly have influenced our findings. For this analysis, mean SRT for accurate responses that had the same number of syllables as the prime was compared to responses in which the number of syllables in the prime and response were different (only 35% of the useable responses for both talker groups had a

different number of syllables than the priming sentence). The ANOVA revealed no significant main effect for syllable number, $F(1, 58) = 1.03, p = .32$, and no Group $\times$ Syllable interaction, $F(1, 58) = 0.01, p = .93$. These results indicate that the number of syllables in the child's picture description response relative to the priming sentence had no appreciable effect on SRT.

As previously mentioned, the order of the experimental and filler pictures was held constant for both conditions because recent research has indicated that sentence-structure priming may persist over intervening sentences (Chang et al., 2000). Although keeping the pictures in the same relative position in each condition minimized any potential differences between the two conditions in terms of the influence of priming from the child's responses to preceding pictures, there was still the possibility that SRT data might have been influenced by factors within each condition (i.e., listwise priming). To determine whether these factors had any effect on picture description latencies, a one-way ANOVA was used to analyze linear trends in SRT across the 17 experimental pictures for both CWS and CWNS. For CWS, the analysis revealed no significant linear trends in SRT means for the 17 experimental pictures in both the no-prime, $F(16, 132) = 1.48, p = .25$, and syntactic-priming conditions, $F(16, 120) = 0.12, p = .72$. Similarly, for CWNS, the ANOVA revealed no significant linear trends for SRT in the no-prime, $F(16, 140) = 1.45, p = .23$, and syntactic-priming conditions, $F(16, 154) = 1.74, p = .19$. Thus, it would appear that SRT for the two talker groups does not vary linearly with subsequent picture presentations during the two experimental conditions.

Sentence Accuracy During No-Prime and Syntactic-Priming Conditions

Between-group differences in the number of accurate responses in the no-prime and syntactic-priming condition were analyzed using a 2×2 (Group $\times$ Condition) ANOVA. As previously mentioned, responses containing stuttering-like or other disfluencies were included in this analysis, provided that they were otherwise accurate. The ANOVA revealed no significant main effect for condition, $F(1, 30) = 0.94, p = .34$, or Group $\times$ Condition interaction, $F(1, 30) = 0.00, p = .99$. However, there was a significant between-subjects effect, $F(1, 30) = 4.85, p = .04$, and follow-up t tests (Bonferroni adjusted) revealed that CWS produced significantly fewer accurate responses than CWNS in the syntactic-priming condition (CWS: $M = 12.25, SD = 2.46$; CWNS: $M = 13.81, SD = 2.01$): $t(30) = -1.97, p = .05$, but not in the no-prime condition (CWS: $M = 11.88, SD = 2.80$; CWNS: $M = 13.44, SD = 1.71$): $t(30) = -1.90, p = .07$, although this latter difference approached significance (see Figure 3). There was no main effect of presentation order for accuracy in the no-prime, $F(1, 28) = 3.20, p = .09$, and syntactic-priming conditions, $F(1, 28) = 0.80, p = .38$, and no significant Presentation Order $\times$ Group interaction in the no-prime, $F(1, 28) = 1.57, p = .22$, and syntactic-priming conditions, $F(1, 28) = 2.56, p = .12$. These findings generally indicate that CWS tended to produce fewer accurate responses than CWNS during the sentence-structure priming task.

Relationship of SRT to Stuttering

Stuttering-like disfluencies during the conversational speech of CWS were significantly correlated to mean SRT in the no-prime condition ($r = .58, p = .02$), but not in the syntactic-priming condition ($r = .37, p = .15$; see Figures 4A and 4B). There were also no significant correlations between stuttering-like disfluencies and syntactic-priming effects ($r = .06, p = .82$) for CWS (see Figure 4C). These findings suggest that CWS who produced more stuttering-like disfluencies tended to exhibit slower picture description latencies in the absence of a prime than did children who produced fewer stuttering-like disfluencies; however, syntactic-priming effects had no appreciable relationship to conversational stuttering-like disfluencies of CWS. In other words, the frequency of conversational stuttering-like disfluencies had no significant relationship to the degree to which CWS benefited from syntactic primes.

Discussion

The primary purpose of this investigation was to examine experimentally the time course of syntactic production processes in young CWS and CWNS. This study was prompted, in part, by speculation that stuttering may be related to slowness, inefficiencies, or dyssynchronies within linguistic formulation components (Perkins, Kent, & Curlee, 1991; Postma & Kolk, 1993), as well as various empirical studies indicating that stuttering events appear to be related, at least in part, to the linguistic features of an utterance (e.g., Melnick & Conture, 2000; Yaruss, 1999; Zackheim & Conture, 2003). A modified version of the sentence-structure priming paradigm (Bock, 1990; Bock et al., 1992) was used to examine experimentally the time course of syntactic processes in CWS and CWNS, the findings of which are considered below.

Main Findings: An Overview

The present study resulted in four main findings: (a) temporal processing of sentences for 3- to 5-year-old children appears to be influenced by experimental manipulation (i.e., syntactic priming) of sentence retrieval, integration, and/or production; (b) CWS demonstrated a greater syntactic-priming effect (approximately 212 ms) than CWNS (approximately 51 ms); (c) CWS produced fewer accurate responses than CWNS during the sentence-structure priming task; and (d) CWS who produced more stuttering-like disfluencies during conversational speech exhibited slower SRTs (during accurate picture descriptions) in the absence of a syntactic prime, but there was no apparent relationship between the frequency of conversational stuttering and a syntactic-priming effect. The general implications of each of these four findings will be discussed immediately below.

Syntactic Priming Is a Viable Method to Study Linguistic Processing of Preschool Children—

First, the present findings suggest that temporal processing of sentences for 3- to 5-year-old children is influenced by experimental manipulation (i.e., syntactic priming) of sentence retrieval, integration, and production. This finding is consistent with Smith and Wheeldon's (2001) finding that adults exhibited faster picture description latencies in a syntactically related condition compared to a syntactically unrelated condition. It is also consistent with Melnick, Conture, and Ohde's (2003) finding that 3- to 5-year-old CWS and CWNS produced faster SRTs during a picture-naming task when given a phonological prime than in the absence of such a prime. However, Melnick et al. (2003) also reported no significant difference between CWS and CWNS in terms of SRT, whether in the absence or presence of phonological primes, a finding that contrasts with the present results that CWS were significantly slower than CWNS in the absence of a priming sentence. However, the present findings are generally consistent with phonatory and manual reaction-time studies of school-aged children in which CWS are reportedly slower than CWNS in response to tones (see Bloodstein, 1995, for a review of these studies). Although speech motor contributions to the present findings cannot be categorically ruled out, it should be noted that given the similarity of the spoken task in both conditions, any such contributions would affect both the control and experimental conditions alike. Such events would only be an issue for our study if they differentially influenced the control and experimental conditions; however, there is no apparent evidence that speech motor events differentially influenced our two priming conditions, whether within or between talker groups.

CWS Appear to Exhibit a Greater Syntactic-Priming Effect Than CWNS—Second, CWS demonstrated a greater syntactic-priming effect (approximately 212 ms) than CWNS (approximately 51 ms). In terms of absolute amount of priming effect, present findings with CWNS (i.e., a syntactic-priming effect of 51 ms) are quite consistent with those of Smith and Wheeldon (2001), who found that adults were, on average, 55 ms faster in a syntactically related condition than in a syntactically unrelated condition. The finding that CWS exhibited greater

syntactic-priming effects than CWNS is consistent with a structural-priming study of grammatical morpheme variability in children with SLI (Leonard et al., 2000). Specifically, Leonard et al. (2000) found that when given a prime containing the syntactic frame required for a target sentence, children with SLI produced the auxiliary *is* significantly more often than their typically developing peers. In other words, the children with SLI appeared to benefit more from the syntactic primes than typically developing children. It should be noted, however, the dependent measures and those used by Leonard et al. (2000) and the present investigators differed. That is, in Leonard et al. (2000), syntactic-priming effects were based on the frequency of children's use of the auxiliary *is*, whereas for the current study, these effects were based on syntactic-priming effects (i.e., SRT differences between the two conditions).

Findings of a greater syntactic-priming effect for CWS also parallel those of Hartsuiker and Kolk (1998), who reported that Dutch speakers with Broca's aphasia exhibited syntactic priming, whereas normal adult speakers did not. This finding suggests, according to Pickering and Branigan (1999), that individuals with Broca's aphasia still have some knowledge of language, even though they do not always use it appropriately, and that syntactic priming is an automatic, implicit process. Pickering and Branigan have further speculated that syntactic priming is likely to be highly effective in children with less developed language abilities. In this respect, "Skilled language-users might be less susceptible to syntactic priming, because they have more computational resources available and hence are much more active about developing their communicative goals in syntactic detail" (Pickering & Branigan, 1999, p. 141). According to this line of reasoning, if CWS are relatively less skilled in morphosyntactic construction processes, they may benefit more from syntactic priming because they presumably have fewer computational resources available for syntactic processing. Consequently, these children would be more likely to take advantage of a previously presented syntactic prime, as it requires less active processing on their part. On the other hand, CWNS presumably would not benefit as much from syntactic primes because they may have relatively more resources available for syntactic processing, which allows them to more actively participate in syntactic processes.

CWS Appear to Produce Fewer Accurate Responses Than CWNS—Third, CWS produced fewer accurate responses than CWNS during the sentence-structure priming task. This finding, coupled with the fact that the time course of syntactic priming is much slower for CWS than it is for CWNS, provides further evidence in support of the hypothesis that CWS may have difficulty quickly and/or efficiently formulating morphosyntactic structures. In their phonological priming study of young CWS and CWNS, Melnick et al. (2003) examined the converse of accuracy—that is, the number of errors that occurred during the picture-naming task—and found no significant differences in the number of errors between CWS and CWNS. If no differences were found between CWS and CWNS in the number of errors they produced during the picture-naming task, one might infer that there would be no between-groups differences in the number of accurate responses produced during the task. The difference between our findings and those of Melnick et al. may relate to the nature of the task that the children performed—that is, Melnick et al.'s participants named pictures, a task that one could reasonably argue is less difficult than one requiring children to describe what is happening in pictures. Perhaps, therefore, it should not be surprising that differences in accuracy between CWS and CWNS were found for the picture description task, but not for the picture-naming task. The more challenging picture description task presumably places greater demands on linguistic resources than picture naming and thus is more likely to elicit speech-language planning and production differences, if present. In other words, whatever linguistic differences do exist between CWS and CWNS in terms of speech-language planning processes are probably more apt to be observed as communicative task demands increase (e.g., telling a story about an event that took place yesterday) and less apt to be noticed when communicative task demands are lessened (e.g., naming a picture).

Although the main dependent measure in the present study was SRT, it is interesting to note that both groups of children produced slightly more accurate SAAD responses in the syntactic-priming condition than in the no-prime condition, but this difference was not significant. In other words, there was no clear tendency for the SAAD sentence structure to be produced more frequently following a syntactic prime than in the absence of such a prime. This is somewhat surprising given that in most studies, syntactic-priming effects with adults and children are typically based on whether or not a particular target structure is produced more often following a syntactic prime. Findings from these studies have generally indicated that target sentences are produced more frequently following the presentation of a syntactic prime. However, unlike other studies in this area, our study did not require children to repeat the prime following its initial presentation, and this may have accounted for why the syntactic-priming condition did not result in significantly more accurate (i.e., SAAD) responses than the no-prime condition. In the present study, where the focus was on the temporal rather than accuracy aspects of participants' responses, it was not possible to have children repeat the prime, because the child's repetition of the prime would have triggered the voice-activated microphone. It may be that the repetition of a prime leads to greater and more persistent activation of the syntactic representation, because the prime is, by virtue of its repetition, more likely to be fixed in memory, thereby increasing the chance that an accurate response will be produced. On the other hand, failure to repeat the priming structure may result in less persistent activation.

Relationship of Stuttering to SRT—The fourth main finding indicated that CWS who produced more stuttering-like disfluencies during conversational speech exhibited slower SRTs (during accurate picture descriptions) in the absence of a syntactic prime than did CWS who produced less stuttering-like disfluencies. However, when the linguistic systems of these children were manipulated via syntactic primes, this relationship was no longer present. Interestingly, Pellowski and Conture (2004) reported similar findings for CWS during a lexical-priming task in which CWS who produced more stuttering-like disfluencies (on the basis of a conversational speech sample) had slower picture-naming latencies in the absence of a prime than did CWS who produced fewer stuttering-like disfluencies. Perhaps CWS who stutter more during conversational speech have greater difficulty quickly and efficiently generating and producing sentences, which would likely result in their producing slower picture description latencies. On the other hand, the grammatical systems of CWS with fewer stuttering-like disfluencies may be more developed, which would presumably result in faster picture description latencies.

Theoretical Implications of the Main Findings

In general, the present findings would seem to provide some degree of empirical support for the notion that linguistic variables may contribute to childhood stuttering. This suggestion is based on the finding that CWS, when compared to CWNS, benefit more from syntactic primes to the point where their syntactic processing speeds more closely approximate those of CWNS. Although various explanations could be used to account for the relationship between childhood stuttering and possible differences in syntactic processing, a brief explication of the following three alternative explanations appears warranted in our attempt to account for some of the linguistic processes that could potentially contribute to childhood stuttering.

Difficulties With Syntactic Formulation Processes—On the basis of current findings, it is not unreasonable to suggest that some CWS have difficulty with morphosyntactic construction processes, which in turn lead to delays in the production of sentences. Such slow rates of activation may reflect problems with the retrieval of a syntactic frame (syntactic rules) or the integration and assembly of a syntactic frame's component structure. If CWS have relatively more difficulties with syntactic representation, perhaps they are more likely to benefit from syntactic priming than CWNS who exhibit no such difficulties, because syntactic priming

facilitates the formulation and production of sentences. One might further posit that difficulties with syntactic planning and/or retrieval processes could result in frequent hesitations, repetitions, and prolongations during conversational speech. According to this conceptualization, such speech disfluencies would reflect a speaker's attempt to buy time for further syntactic processing functions. In contrast, there may be a trade-off between morphosyntactic construction processes and speech fluency. In this case, if CWS have difficulty with sentence-level production operations, they may have to exert more attention, effort, and memory to these operations during syntactic processing (see Just & Carpenter, 1992, for a related discussion of individual differences in working memory capacity for cognitive and related tasks). Expending such resources on syntactic processing may result in fewer resources being available for the production of fluent speech, which could, at least theoretically, result in increased speech disfluencies.

Difficulties With Lexical or Phonological Encoding Processes—A second alternative explanation suggests that CWS may not have difficulty with syntactic formulation processes, but rather with those processes involved with the encoding of lexical and/or phonological information. For example, some children who stutter may have difficulty accessing a lemma (syntactic word) or its lexeme (phonological aspects of the word; see Levelt, Roelofs, & Meyer, 1999, for further discussion of the distinction between lemma and lexeme). Such difficulty, one might reasonably speculate, could result in or contribute to further delays and/or disruptions in the generation of the surface structure. This possibility is based on Levelt's (1989) model of speech-language production, which states that the activation of a lemma triggers various syntactic procedures to build a “proper syntactic environment” (p. 235). Thus, if the lemma was slow to be activated, the syntactic procedures would also fail to be triggered in a timely manner, resulting in a less-than-ideal syntactic environment. If CWS do have difficulty with lexical and/or phonological encoding, the fact that syntactic primes have a facilitative effect for CWS can be explained, as previously suggested, in terms of changes in the distribution of resources. That is, speech production could be marked by frequent hesitations, repetitions, and prolongations in an attempt to obtain additional processing time for lexical and/or phonological encoding or as a result of trade-offs between lexical and phonological formulation processes and speech fluency.

Difficulties With a Combination of Linguistic Formulation Processes—A third possible explanation might be that CWS have activation and/or planning difficulties (i.e., initiating and/or performing the procedures in a formulation process) with a combination of linguistic formulative processes. Perhaps this combination of subtle difficulties may be ultimately expressed as an imprecise or delayed phonetic plan for connected speech (i.e., the end product of the formulation component, which includes segmental, metrical, and intonational form representations; Levelt, 1989, 1992). Accordingly, CWS could exhibit one or more areas of difficulty when accessing, organizing, and/or planning material for speech-language production. This might mean that there are subgroups of CWS with different combinations of underlying problems. It might also mean that the problem for individual CWS could be different at different times, depending on the nature of the particular conversational interaction. However, regardless of the original source of the problem, the hypothesis is that the resulting phonetic plan for connected speech would be disrupted, resulting in temporal delays in the production of sentences. If problems with the activation and/or planning of a combination of formulative processes negatively impact the generation of phonetic plans for connected speech, the forward flow of speech production could be disrupted, resulting in disfluent speech.

Caveats

As with any empirical investigation, several different issues should be considered when evaluating and interpreting the present findings. These include issues pertaining to (a) the syntactic-priming effect for CWNS, (b) nonlinguistic contributions to the present findings, (c) the possible influence of temporal cuing on SRT data, and (d) the production of speech disfluencies during the sentence-structure priming task for CWS and CWNS.

Syntactic-Priming Effects—As we have stated, although CWNS were approximately 51 ms faster in the syntactic-priming condition than in the no-prime condition, this difference was not statistically significant. Because the syntactic prime did not significantly facilitate the syntactic encoding processes of CWNS, at least from a statistical standpoint, one might question whether the syntactic primes were actually tapping into the temporal aspects of their sentence-level processing. However, as previously mentioned, present findings for CWNS are similar to those of Smith and Wheeldon (2001), who found that adults were significantly faster (by approximately 55 ms) in a syntactically related condition than in a syntactically unrelated condition. Furthermore, findings are consistent with those of Hartsuiker and Kolk (1998), who found that normal Dutch speakers failed to demonstrate a syntactic-priming effect, whereas Broca's aphasics did. Perhaps the syntactic-priming effect for CWNS failed to achieve statistical significance because young children tend to be more highly variable, resulting in greater dispersion of scores (i.e., higher standard deviation).

On the other hand, it may be that the target sentence structure used in this study—a SAAD structure—is not sufficiently difficult for these children. In other words, the CWNS who participated in this study may already be operating at their maximal potential for SAAD sentences. Therefore, the presentation of a syntactic prime had no significant benefit in helping them process this simple sentence structure (for more detailed discussion of theoretical and methodological considerations regarding the syntactic priming of more accessible or established grammatical structures, see Bock & Griffin, 2000; Chang et al., 2000). Hartsuiker and Kolk (1998) proposed a similar argument to explain the fact that their normal speakers did not demonstrate a syntactic-priming effect. Specifically, they suggested that the normal speakers may have had “activation levels that are closer to the threshold.... Therefore, any input (as a result of priming) has limited effects on the activation level” (p. 245). In essence, finding no significant syntactic-priming effect for CWNS need not be problematic for the current study, as the effects of priming for these children appear similar to those of adults and may be related to considerable variation in behavior and/or the level of difficulty associated with the sentence-structure priming task.

Nonlinguistic Contributions—Although the present findings are consistent with a linguistic account of stuttering, they neither implicitly nor explicitly suggest that stuttering is only related to difficulties with linguistic formulation processes. However, the paradigm used in the present study involves the auditory presentation of a syntactic prime that facilitates linguistic encoding processes. It is thought that if aspects of the motor control system are problematic, they should be equally problematic in both the no-prime and syntactic-priming conditions. In other words, because the communicative tasks or demands were identical for the two conditions for all participants, any speech motor contributions should be the same for the control and experimental conditions, leaving the syntactic-priming effect intact. More to the point, and as mentioned above, motoric difficulties are only an issue in this study if they differentially influenced the control and experimental conditions. However, there is no empirical evidence that such events differentially influenced our conditions, within or between talker groups. Thus, it is not highly probable that difficulties with speech motor control processes made appreciable contributions to the present findings of between-group differences.

in syntactic-priming effects, making such results most consistent with a linguistic interpretation.

Temporal Cuing—As will be recalled, no auditory prime was presented in the no-prime condition, unlike the syntactic-priming condition. Thus, it is possible that the mere presentation of a syntactic prime may have served as an alerting cue that directed participants' attention to the task. Because there was an absence of such a prime in the no-prime condition, one might argue that a child's attention might wander between trials, resulting in slower than normal picture description latencies during the no-prime condition. To counteract this potential problem, we could have used an alternate or unrelated prime (e.g., a prime that consisted of a sentence structure different than the targeted sentence structure) as a comparison or baseline condition to measure the effects of syntactic priming (see Smith & Wheeldon, 2001). However, the presentation of an alternate prime (e.g., "The girl talked") could potentially facilitate the use of other sentence structures (e.g., the child could respond by saying, "The boy pulled," instead of "The boy is pulling the wagon"). For an alternate prime to be a useful comparison condition, children must be able to produce enough samples of the targeted sentence structure (i.e., the SAAD sentence structure). Considering the age range of the prereading, preliterate children participating in this study, it is likely that alternative primes would result in an insufficient amount of SAAD responses to be of any meaningful use as a comparison condition. In fact, findings from a pilot study confirmed this likelihood, as only 25% of children's responses to such alternative primes were SAAD sentence structures.

Speech Disfluencies—In general, only 3% of all children's ($N = 32$) otherwise accurate picture descriptions were disfluent (i.e., there were 162 disfluent words out of 5,269 words contained within the children's picture descriptions). Furthermore, picture description responses containing these disfluent words, as mentioned above, were not included in the final SRT data corpus. It seems reasonable to suggest, therefore, that this low frequency of occurrence of speech disfluencies precludes meaningful assessment of differences in SRT between accurate fluent and accurate disfluent responses for both CWS and CWNS using inferential statistical procedures. Of course, this low frequency of occurrence of speech disfluencies is not altogether surprising, considering the fact that children tend to be more fluent in picture naming and description tasks than in other speaking conditions (e.g., Yaruss, 1997). In essence, further analyses, at least for this study, seem inappropriate because of the very few speech disfluencies produced by very few children in either talker group during the experimental tasks.

Conclusion

Stuttering tends to manifest itself when children begin to string words together to produce sentences or when they begin to produce more complex utterances, typically beginning between the ages of 30 and 36 months (Månsson, 2000; Yairi & Ambrose, 1992; Yaruss, LaSalle, & Conture, 1998). This association between speech fluency and emerging morphosyntactic skills may be taken to suggest that CWS have subtle to not-so-subtle difficulties with various speech-language formulation processes. Such difficulties may make it more likely that they will experience an increase in processing load, an increase in the difficulty of planning and retrieving a structural unit, and/or a delay in accessing linguistic information. Findings from the current study would seem to support such a speculation because the experimental manipulation of sentence retrieval, integration, and production processes had a significant influence on the temporal processing speeds of CWS. More research is needed, however, particularly using processing measures similar to that employed in the present study to better circumscribe the number and nature of speech-language planning and production processes, if any, that may be germane to the problem of childhood stuttering. It is believed that results from this line of inquiry, as shown in the present study, should help researchers

better understand if CWS have difficulty rapidly and efficiently planning and/or retrieving sentence-structure units, and whether any such difficulties may contribute to these children's inabilities to establish fluent speech-language production.

Acknowledgments

This article is based on a doctoral dissertation completed at Vanderbilt University in 2002 by Julie D. Anderson, who is now at Indiana University, Bloomington. This research was supported in part by a National Institutes of Health Grant DC00523 to Vanderbilt University. We thank Kathryn Bock, Stephen Camarata, Lee Ann Golper, and Robert Wertz for their thoughtful and insightful reviews of earlier versions of this manuscript. We would especially like to thank Herman Kolk for his early encouragement, guidance, and support to pursue this line of investigation. We also give special thanks to Mark Pellowski for his help with creating the computerized experiment and interjudge measurement reliability and Courtney Zackheim for her help with the data collection process. We are also very grateful to the parents and children who participated in this research, without whom there would be no study.

Appendix

Auditory primes for the 17 experimental pictures in the syntactic-priming condition.

Trial	Auditory prime	Target sentence
1	The girl is printing the letter.	The dog is sniffing the flower.
2	The boy is washing the dog.	The worm is eating the leaf.
3	The mom is rocking the baby.	The boy is pulling the wagon.
4	The man is walking the doggie.	The girl is picking the flowers.
5	The girl is drinking lemonade.	The boy is playing basketball.
6	The bird is watching the people.	The boy is holding the balloon.
7	The pig is drawing a picture.	The boy is making a snowman.
8	The girl is dressing her doll.	The man is cutting his hair.
9	The cat is chasing the rabbit.	The boy is eating a sandwich.
10	The man is sawing the wood.	The girl is petting the cat.
11	The girl is carrying the cake.	The boy is hugging the dog.
12	The cow is singing a song.	The boy is driving a car.
13	The boy is hitting the ball.	The girl is holding the cat.
14	The dog is digging a hole.	The girl is painting the fence.
15	The boy is throwing the Frisbee.	The girl is blowing the candles.
16	The man is writing a letter.	The bear is eating an apple.
17	The girl is catching the ball.	The man is mopping the floor.

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Figure 1.

Sequence of events in the no-prime condition (A) and syntactic-priming condition (B); a filler picture in the syntactic-priming condition (C). These pictures are from Webber® Verbs & More! ©1998 by Super Duper® Publications. Reprinted with permission.

Figure 2.

(A) Mean speech reaction time (SRT; in milliseconds) in the no-prime and syntactic-priming condition and (B) mean syntactic-priming effects (no-prime minus syntactic-priming condition) for 3-, 4-, and 5-year-old children who stutter (CWS; $n = 16$) and children who do not stutter (CWNS; $n = 16$). Error bars represent standard error of the mean.

Figure 3.

Mean number of accurate responses (includes both fluent and disfluent responses) in the no-prime and syntactic-priming conditions for 3-, 4-, and 5-year-old CWS ($n = 16$) and CWNS ($n = 16$). Error bars represent standard error of the mean.

Figure 4. Linear regression lines depict the relationship between (A) mean speech reaction time (SRT; in milliseconds) in the no-prime condition and stuttering-like disfluencies (based on the conversational speech sample), (B) mean SRT (in milliseconds) in the syntactic-priming condition and stuttering-like disfluencies, and (C) mean syntactic-priming effect (in milliseconds; no-prime minus syntactic prime) and stuttering-like disfluencies for 16 CWS between 3 and 6 years of age.

Table 1

Percentile ranks (means and standard deviations) by participant group (CWS and CWNS) for the standardized speech-language tests.

Speech-language test	CWS (%)		CWNS (%)	
	M	SD	M	SD
PPVT-III	71	19.8	84	16.5
EVT	72	15.9	85	15.0
TELD-3				
Expressive subtest	57	23.7	84	10.9
Receptive subtest	72	22.9	93	6.0
GFTA-2	73	21.7	84	14.0

Note. CWS = children who stutter; CWNS = children who do not stutter; PPVT-III = Peabody Picture Vocabulary Test–Third Edition; EVT = Expressive Vocabulary Test; TELD-3 = Test of Early Language Development–3; GFTA-2 = Goldman–Fristoe Test of Articulation–2.

Table 2

Number and percentage of error types and outliers for all picture description responses in the no-prime and syntactic-priming condition by participant group (CWS and CWNS).

Error types	CWS				CWNS			
	No prime		Syntactic prime		No prime		Syntactic prime	
	No.	%	No.	%	No.	%	No.	%
Non-SAAD sentence structure	31	11.4	47	17.3	25	9.2	22	8.1
Nonrelevant response	12	4.4	6	2.2	9	3.3	8	2.9
Voice key failed to trigger	29	10.7	8	2.9	21	7.7	16	5.8
Extraneous environmental noise	4	1.5	3	1.1	11	4.0	6	2.2
Disfluent response	15	5.5	19	7.0	16	5.9	8	2.9
Combination of two or more errors	13	4.8	16	5.9	10	3.7	12	4.4
Outliers	16	5.8	32	11.8	23	8.4	30	11.0
Total	120	44.1	131	48.5	115	42.2	102	37.5

Note. SAAD = simple, active, affirmative, declarative.