EFFECTS OF SYNTACTIC COMPLEXITY AND SENTENCE-STRUCTURE PRIMING ON SENTENCE PRODUCTION IN ADULTS WHO STUTTER

By

JIM TSIAMTSIOURIS

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Date	Helen Smith Cairns, Ph.D., Chair of Examining Committee
Date	Martin Gitterman, Ph.D., Executive Officer
	Richard G. Schwartz, Ph.D., Committee Member
	Martin Chodorow, Ph.D., Committee Member
	Barry E. Guitar, Ph.D., External Reviewer

THE CITY UNIVERSITY OF NEW YORK

ABSTRACT

EFFECTS OF SYNTACTIC COMPLEXITY AND SENTENCE-STRUCTURE PRIMING ON SENTENCE PRODUCTION IN ADULTS WHO STUTTER

by

Jim Tsiamtsiouris

Advisor: Professor Helen Smith Cairns

The purpose of this study was to examine the relationship between grammatical encoding and sentence production in the speech of adults who stutter. This was accomplished by two experiments. In the first experiment, prepared utterances that varied in syntactic complexity were examined for differences in speech initiation time and disfluency. The second experiment analyzed the facilitative effects of sentence-structure priming on sentence production in typical speakers and adults who stutter. Data from these experiments provided evidence that grammatical encoding in adults who stutter differs significantly from those of typical speakers. Relative to typical adults, the speech initiation time of adults who stutter became increasingly slower as syntactic complexity increased, and they exhibited greater facilitative effects of sentence-structure priming. In addition, adults who stutter showed a significant correlation between syntactic complexity and priming facilitation. Finally, data appear to support the notion that subgroups exist within the clinical population of adults who stutter.

DEDICATION

I would like to dedicate this dissertation to my brother, Ronnie Tsiamtsiouris. He taught me to reach for the stars, strive for the best, and live life to its fullest. His spirit provides me with an endless source of strength and inspiration.

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Perhaps the greatest debt of gratitude is owed to Helen Cairns, my dissertation chair and doctoral program advisor, for the significant contributions she made to all phases of this research and to my doctoral training. Her unending guidance, support, and inspiration at every step of my doctoral education will not be forgotten. Her immense knowledge and thoughtful discussions have provided me with an invaluable education that will last a lifetime.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

REVIEW OF LITERATURE

Introduction to Stuttering

The etiology of stuttering in adults is debatable, but most experts on stuttering agree that the onset in the majority of individuals occurs between the ages of two and five years (Guitar, 2006), during the years of rapid growth in the lexicon and syntax. Developmental language norms show that children begin to use multiword utterances at approximately two years of age. By their fifth birthday, children have learned ninety percent of the syntactic structures that they will use as adults (Owens, 2005). The time between two and five years of age is marked by rapid growth in lexical and syntactic use, and many children go through brief periods of stuttered speech as their lexicon grows exponentially and they begin using more complex syntax (Rispoli & Hadley, 2001). Fortunately, approximately eighty percent of the children who begin stuttering eventually recover and enter adulthood without a stuttering disorder (Guitar, 2006). However, a portion of children never recover, and this translates to approximately 1% of the adult population that has a stuttering disorder (Bloodstein, 1995).

Researchers have developed numerous theories over the years about the possible reasons why children begin stuttering and some continue to stutter into adulthood. One early idea, the cerebral-dominance theory (Guitar, 2006), attributes the origin of stuttering to brain function that lacks left-hemisphere dominance for speech production, which impairs speech motor coordination. Another proposal, the diagnosogenic theory (Johnson, 1961), faults the caregiver for calling attention to a child’s momentary lapses of fluency, which creates a sense of anxiety in the speaker. These are two theories that were popular for a major part of the 1900s (Guitar, 2006). However, a number of researchers have moved away from these theories and have begun to examine the role of linguistic and psycholinguistic abilities on the speech fluency of individuals who stutter. This makes sense because the onset of stuttering coincides with the explosive growth in the lexicon and the use of more complex syntax. In recent years, both theoretical formulations and empirical evidence have associated stuttering with atypical lexical, syntactic, and/or phonological processes (Anderson & Conture, 2004; Au-Yeung & Howell, 1998; Cuadrado & Weber-Fox, 2003; Melnick, Conture, & Ohde, 2003; Pellowski & Conture, 2002; Zackheim & Conture, 2003). A number of studies have shown that stuttering is somehow associated with word frequency (Hubbard & Prins, 1994), word type (Howell, Au-Yeung, & Sackin, 1999), sentence and clause boundaries (Bernstein-Ratner, 1997; Howell & Au-Yeung, 1995; Wall, Starkweather, & Cairns, 1981), utterance length and syntactic complexity (Anderson & Conture, 2004; Bernstein, 1981; Bernstein-Ratner & Sih, 1987; Cuadrado & Weber-Fox, 2003; Kadi-Hanifi & Howell, 1992; Logan & Conture, 1995; Logan & Conture, 1997; Logan & Lasalle, 1999; Rispoli, 2003;; Yaruss, 1997; Yaruss, 1999), lexical selection (Pellowski & Conture, 2005), and grammatical encoding (Anderson & Conture, 2004).

<u>The Influence of Syntax on Speech Fluency</u>

A relationship between syntax and stuttering has been hypothesized for a variety of reasons. One is the predictability of the loci of stuttered moments (Berstein-Ratner, 1997). One approach to testing this relationship is to examine the syntactic characteristics of stuttered conversational utterances. Results from several studies have shown that, in general, stuttering often coincides with utterance-initial and clause-initial words when compared to other areas within a sentence (Bernstein, 1981; Wall, Starkweather, & Cairns, 1981; Wingate, 1976). Within major clausal units, initial words of sentential constituents, such as noun phrases, verb phrases, and prepositional phrases have a greater likelihood of being stuttered (Bernstein, 1981) than do non-initial words. Among the phrases present in the spontaneous speech of individuals who stutter, data show (Bernstein, 1981) a higher frequency of stuttering on the initiation of verb phrase constituents. This suggests that building the structure of the verb phrase during sentence production is a more difficult task than building other sentence constituents. Verbs are an integral component of the sentence production process, as verbs limit the possible arguments that may accompany them (functional role assignment) (Bock & Levelt, 1994). In sum, these findings suggest that planning or executing phrases or clauses is more difficult for individuals who stutter than for those who do not, and these processes may be related to the occurance of stuttering (Bernstein-Ratner, 1997; Starkweather, 1987). Phrases and clauses are sentence constituents that are hierarchically structured. The initiation of such constituents follows the pre-production planning of that hierarchical structure. A plausible explanation for breakdowns in fluency is that syntactic planning is more difficult or not as efficient in stutterers compared to non-stutterers.

Another sign that individuals who stutter have difficulty with syntactic structures is seen when one examines fluency in more grammatically complex sentences relative to grammatically simple sentences. Sentence imitation tasks and spontaneous discourse analyses (Gordon & Luper, 1989; Gordon, Luper, & Peterson, 1986; Bernstein-Ratner & Sih, 1987; Gaines, Runyan, & Meyers, 1991; Logan & Conture, 1995; Logan & Lasalle, 1999; Weiss & Zebrowski, 1992) have shown that more difficult syntactic complexity is related to an increased frequency of stuttering (Bernstein Ratner & Sih, 1987). Moreover, morphemic length of utterance (a grammatical measure) is better at predicting the likelihood of stuttering than is syllabic length of utterance (an articulatory measure) (Brundage & Bernstein-Ratner, 1989).

Despite evidence that seems to implicate syntactic complexity with increased stuttering, there are some studies that do not support this relationship in older speakers who stutter (Klouda & Cooper, 1987; Logan, 2001, 2003). For example, in one study (Klouda & Cooper, 1987) of nine adults who stutter, there was no evidence that the presence of major syntactic boundaries led to an increase in stuttering frequency while reading sentences aloud. In addition, these adults who stutter produced the same durational cues to syntactic boundary location as those found in normally fluent speakers. However, critics of this study argue that oral reading does not have the same planning and production requirements that are found in more spontaneous language.

Another study (Silverman & Bernstein-Ratner, 1997) examined the fluency of thirteen adolescents who stutter in a task that auditorily presented length-matched sentences in which the syntactic structure of the subject constituent was systematically manipulated. Each sentence was followed by a tone that signaled the subject to repeat the sentence exactly as heard. Three different types of syntactic complexity were employed: Wh-question form (least complex), right-embedded relative clause (moderately complex), and a center-embedded relative clause (most complex). All sentences ranged in length from 10 to 12 syllables. Speech initiation times were not measured in this study, but results showed that adolescents who stutter and typically developing adolescents produced significantly more normal disfluencies and were less accurate when imitating the most complex sentences. However, there was no significant difference between groups. Apparently, certain sentence types present a linguistic challenge to both stuttering and nonstuttering adolescents, but an increase in syntactic complexity does not present a more significant challenge to adolescents who stutter. Silverman and Bernstein-Ratner (1997) acknowledge the possibility that more challenging syntactic structures or alternative methods of eliciting responses may demonstrate an effect of sentence structure on stuttering frequency. Also, the measurement of speech initiation times may have been a more sensitive measure than number of disfluencies. Finally, the nature of imitating auditorily presented sentences is at risk for phonological priming, which may lead to a reduction in speech errors and disfluency in stuttering and nonstuttering speakers.

The most recent study (Logan, 2003) that manipulated syntactic complexity in an attempt to confirm a relationship between syntax and stuttering examined speech initiation times as a window into the syntactic processing system of adults who stutter and adults who do not stutter. This study (Logan, 2003) was modeled after an older study (Ferreira, 1991) that found typical speakers took longer to initiate syntactically complex sentences when compared to syntactically simple sentences. In the more recent study (Logan, 2003), individuals who stutter were asked to read and memorize a series of individually presented sentences that were divided into four versions of a base sentence, with each version increasing in syntactic complexity. For example, the first version featured a subject phrase with a determiner, two conjoined adjectives, and a noun (e.g., The long and shiny car belongs to the girl). In the second version, the subject featured a determiner, noun, and prepositional phrase (e.g., The car on King's Highway belongs to the girl). A third version contained a determiner, noun, and relative clause (e.g., The car that was stolen belongs to the girl). In the fourth version the subject was a simple noun phrase consisting of a determiner and a noun; the object noun phrase was elaborated with either a prepositional phrase or a relative clause (e.g., The car belongs to the girl who plays soccer). The number of syllables and words contained in the subject in the first three sentence versions were matched.

The results of the Logan (2003) study supported the findings of other investigations (Adams & Hayden, 1976; Bakker & Brutten, 1989; Bishop, Williams, & Cooper, 1991; Cross & Luper, 1979; Dembowski & Watson, 1991; and Watson & Alfonso, 1987) that found significantly slower overall initiation times for adults who stutter relative to fluent speakers. The overall mean speech initiation time for the stuttering group was 132 milliseconds longer than that of the nonstuttering group. However, for neither group did speech reaction time vary in response to syntactic complexity. In other words, syntactic complexity did not seem to influence speech production components such as grammatical processing or fluency. Logan (2003) suggested that the delay in speech initiation times of simple sentences and more syntactically complex sentences for adults who stutter may not be a result of a delay or weakness in grammatical encoding. This suggestion should be interpreted with caution as Logan's (2003) methodology is examined more carefully.

It should be noted that Logan's (2003) pattern of results for typical speakers did not replicate the pattern of results found in the study by Ferreira (1991). Ferreira found that increased syntactic complexity (as measured by the number of nodes in a phrase structure tree) resulted in an increase in the time it took subjects to initiate an utterance.

For example, speech initiation times were significantly different when the low syntactic complexity condition was compared to the average of the medium and high syntactic complexity conditions (550 ms vs. 645 ms). In Logan's (2003) study, methodological issues may have influenced the outcome. For example, there were important differences in sample size and the complexity of the sentences. The complexity of the stimulus sentences in Logan's study was perhaps the most questionable variable. Logan's (2003) stimulus sentences were shorter and simpler with an average of 11 syllables per sentence, whereas Ferreira's (1991) sentences averaged 20 syllables per sentence. In fact, Logan's (2003) sentences were analogous to Ferreira's (1991) short sentences in length. This leaves the possibility that sentences were not sufficiently taxing to elicit the predicted effect. Another factor that may have influenced the data analyses is the number of subjects. Logan (2003) had eleven subjects in each group, whereas Ferreira (1991) had twenty-eight.

The majority of recent studies (Logan, 2001, 2003; Gordon & Luper, 1989; Gordon, Luper, & Peterson, 1986; Bernstein-Ratner & Sih, 1987; Gaines, Runyan, & Meyers, 1991; Logan & Conture, 1995; Logan & Lasalle, 1999; Weiss & Zebrowski, 1992) that investigated the relationship between syntax and stuttering focused on sentence production. Very few studies (Bosshardt, 1993, 1994; Cuadrado & Weber-Fox, 2003), however, have attempted to explore syntactic processing during sentence comprehension tasks in adults who stutter. The data from the very limited comprehension processing studies reveal a reduced proficiency in the processing time of individuals who stutter when they are required to make syntactic judgments about experimental stimuli (Bosshardt, 1993, 1994). In the most recent study (Cuadrado &

Weber-Fox, 2003), ungrammatical sentences consisting of errors such as subject-verb agreement violations were presented to subjects in two different conditions. In the first condition, sentences were presented on a computer screen, and at the end of each sentence the participants quickly pressed a yes or no button on a response box to indicate whether they thought the sentence was a "good English sentence." In the second condition, the participants read the sentences from a written list and were given as much time as they needed to complete the same judgment task. Interestingly, judgment accuracy for the second condition, which did not require fast grammatical processing, did not differ between adults who stutter and typical speakers. However, judgment accuracy of adults who stutter in the first condition was lower than that of typical speakers, particularly for verb-agreement violations that occurred in longer and more syntactically complex sentences. This particular study (Cuadrado & Weber-Fox, 2003) appears to be the first to document that syntactic processing without time constraints may not be sensitive enough to produce or detect subtle syntactic processing differences in adults who stutter, whereas on-line tasks or tasks with time constraints have the potential to produce or detect weaknesses or differences.

Rispoli and Hadley (2001) and Rispoli (2003) examined fluency disruptions and language production in younger speakers and make a case for a gap between a comfort zone and the leading edge. According to their characterization, a speaker's comfort zone consists of simple sentence structures that are easily processed within the linguistic system, thereby resulting in minimal delay in constructing those sentence structures. This results in minimal sentence disruptions. The syntactic system is not taxed as much in the comfort zone as it is with more complex sentence constructions. On the other hand, a speaker's leading edge consists of sentence structures that are not efficiently processed within the linguistic system. These sentence structures have an increased risk of sentence disruptions (Rispoli & Hadley, 2001; Rispoli, 2003).

The idea of a comfort zone and leading edge has been developed with younger, typically developing speakers in mind (Rispoli & Hadley, 2001; Rispoli, 2003), but the idea can apply to the clinical population of speakers who stutter. Many typically developing children go through a phase of increased sentence disruptions during the period of explosive grammatical development. A disruption in the forward flow of sentence production that does not add new lexical, grammatical, or phonological material is labeled a stall by Rispoli and Hadley (2001). When a stall materializes in overt speech production, it can be perceived as silent pauses or blocks, and repetitions of phonemes, syllables, words, and phrases. This is the behavior that is typically observed in children and adults who stutter. Rispoli and Hadley (2001) hypothesize that the main purpose of the stall is to buy time for the sentence production mechanism (i.e., grammatical encoder) to catch up. In contrast, a revision occurs when a speaker wants to make changes to the lexical content, syntax, or phonology of an utterance. The driving force of a revision is in response to something that has already been articulated, but that, for some reason, does not match the speaker's intention (See Rispoli & Hadley, 2001, and Rispoli, 2003, for a review). In general, stalls and revisions are frequent occurrences in the speech of typically developing young children as their use of complex sentence structures grows exponentially.

There is only one published study (Anderson & Conture, 2004) that utilized a sentence-structure priming paradigm with individuals who stutter in an attempt to ascertain whether there is a deficit in grammatical encoding. Very young children (ages 3-5) who stutter were shown and asked to describe drawings of children, adults, and animals performing activities. Target utterances consisted of simple, active, declarative sentences (e.g., "The man is walking the dog."). All of the target utterances were presented under two conditions: a no-prime condition and syntactic priming condition. In the priming condition, children were shown the same pictures as in the no-prime condition, but the children were also presented with an auditory priming sentence 2000 ms prior to the picture. The priming sentence matched the target utterance in terms of syntactic structure. Results revealed a significant difference between young children who stutter and children who do not stutter in syntactic priming effects. Children who stutter were approximately 212 ms faster in the syntactic priming condition when compared to their speech reaction times in the no-prime condition. Typically developing children, on the other hand, showed a significant difference of only 51ms between the two conditions. Speech initiation time was defined as the time that elapsed from the onset of the target pictures to the onset of voicing. Thus, findings suggest that children who stutter benefit more from syntactic primes than do children who do not stutter. They support Smith and Wheeldon's (2001) view that the function of syntactic priming "is to reduce the processing costs of the speaker and to promote the fluency and rapidity of utterance generation" (p.157).

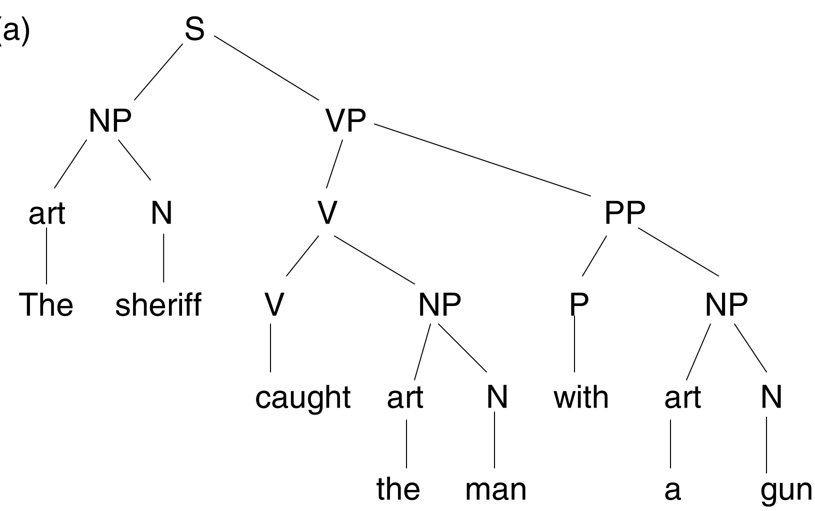
The findings of the sentence-structure priming study (Anderson & Conture, 2004) have important theoretical implications for individuals who stutter. At the very least, these data provide empirical evidence that linguistic variables contribute to stuttering. A finer analysis of the data indicates difficulty with syntactic formulation processes. This difficulty may center on the construction of a syntactic structure. As Anderson and Conture (2004) show in their study, individuals who stutter exhibit significant facilitation when exposed to a syntactic priming condition. Their explanation is that this facilitates the formulation of syntactic structures, reduces the processing costs of the speaker, and thereby promotes fluency. Unfortunately, these results do not easily generalize to the population of adults who stutter, as their language processes may operate more efficiently than do those of children who stutter. Needless to say, sentence-structure priming studies with adults who stutter is an area that is ripe for study.

In summary, fluency disruptions may arise out of minute breakdowns or delays that occur at the level of the intricate timing that is required to process and construct syntactic sentence structures during the planning of the speech utterance. Some have theorized that an increase in the processing load or delay in accessing syntactic units may lead to breaks in speech fluency and accuracy (Garrett, 1982; Bock, 1995; Bernstein-Ratner, 1997). In other words, a subtle delay or impairment in constructing sentence structures affects the unfolding speech plan negatively, thereby creating opportunities for disruptions in the forward flow of speech. This idea appears to be supported by the studies that show an increase in stuttering in more syntactically complex sentences (Logan & Conture, 1995, 1997; Melnick & Conture, 2000; Bernstein-Ratner & Sih, 1987; Yaruss, 1999). These findings may indicate an inefficient processing or construction of syntactic sentence structures in individuals who stutter.

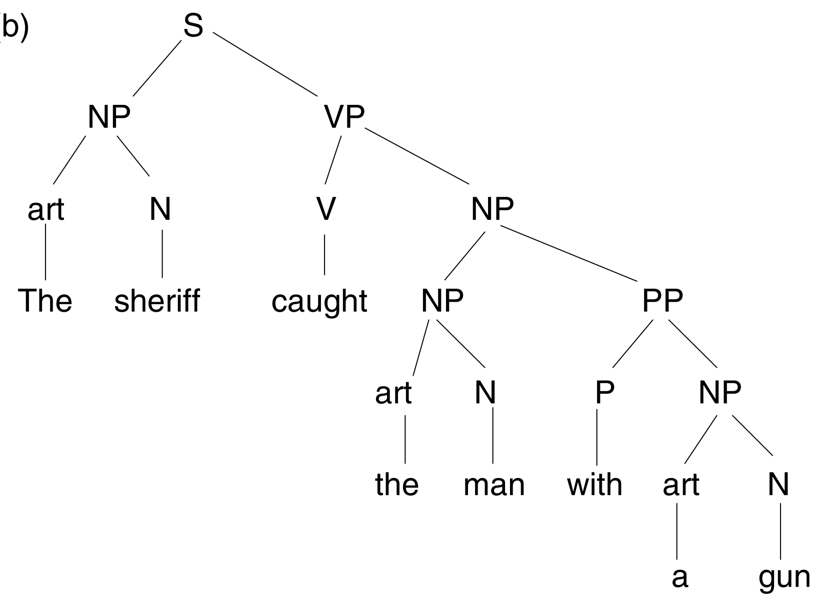
Distinct Operations and Representations in Grammatical Encoding

The meaning of a sentence is conveyed by its lexical items and their structural organization (Cairns, 1999). We can see how structure determines meaning by examining structurally ambiguous sentences, such as “The sheriff caught the man with a gun.” The lexical items are identical on each reading of the sentence, but the structures differ. The structure sketched in (a) below, “with a gun” is attached to the Verb Phrase and means that the Sheriff had a gun. The structure in (b), on the other hand, indicates that the Prepositional Phrase is attached to the Noun Phrase and relates to “the man,” indicating that the man had a gun.

(a)



(b)



On both readings the meanings of the individual lexical items are the same. Thus, we know that pre-production planning for an utterance must involve three kinds of operations: determination of the sentence's meaning, construction of an appropriate syntactic structure, and selection of the required lexical items. Determination of the meaning is presumably carried out by general cognitive processes. Construction of the syntactic structure is accomplished with reference to the syntactic component of the speaker's internalized grammar. Selection of the words requires their retrieval from the internal lexicon. A full theory of pre-production planning must address at minimum construction of a structure and retrieval of lexical items. The hypothesis put forward here is that stutterers have a deficit in the former.

Early research (Butterworth, 1980; Fromkin, 1971; Garrett, 1975, 1988; MacKay, 1970; Shattuck-Hufnagel, 1979) on processes in language production examined speech errors in an attempt to characterize the steps involved in planning language before it was produced. These early analyses showed that speech errors are constrained by grammatical and phonological rules, and the planning of a sentence requires a number of distinct operations and representations (Garrett, 1988; Levelt, 1989; Bock & Levelt, 1994; Levelt, Roelofs, & Meyer, 1999). In general, after a speaker formulates an idea but before the execution of overt articulation, lexical items are selected, a syntactic sentence structure is created, inflection and intonation are marked, and sound forms are generated.

The process of language production that creates the structure of an utterance is called grammatical encoding. In a frame-and-slot model of grammatical encoding (e.g., Bock, 1982; Dell, 1986; Garrett, 1975; MacKay, 1982), frames represent syntactic structures with slots labeled with the grammatical classes (e.g., noun or verb) or the lemmas that may fill them. Errors can occur when unintended words are selected for the slots. Certain errors such as word substitutions and exchanges tend to involve words of the same grammatical class, such as “please pass the fork,” in which “fork” replaces “salt,” keeping the utterance grammatical while altering the meaning (Garrett, 1975). This type of error is bound by syntactic constraints. It typically involves whole words and occurs almost exclusively for words of corresponding grammatical category (e.g., nouns exchange with nouns and verbs with verbs), fulfills similar grammatical function, and shows little evidence of phonological involvement (Garrett, 1988). Another example is when a speaker errs by saying, “rubber pipe and lead hose” in place of “rubber hose and lead pipe.” The sentence structure remains the same while one noun exchanges with another noun (Garrett, 1975). Within a frame-and-slot model, exchanges across grammatical classes such as “please salt the pass” are unlikely because they involve two violations: a noun in a verb slot and a verb in a noun slot. Also, it would be very unusual for a speaker to err by saying “pipe rubber hose and lead the.” This shows that exchanges are usually limited to words of the same grammatical class (content words do not exchange with function words; content words exchange with other content words) and that the language mechanism creates a syntactic sentence structure for the utterance before the utterance is spoken.

Another important finding from speech errors is a different level of representation between bound morphemes and their stems (Garrett, 1988; Bock & Levelt, 1994). A speaker may say, “You ordered up ending,” instead of saying, “You ended up ordering.” In this type of speech error, the words were exchanged but the bound morphemes –ed and –ing were not exchanged with the words. In addition to a different level of representation between stems and bound morphemes, speech errors provide evidence that morphemes are represented according to their morphological category (Cairns, 1999). For example, a speaker may erroneously say “We roasted a cook,” when he wants to say “We cooked a roast.” This provides evidence that a past-tense marker was associated with the verb phrase, and that morphophonological rules apply after the exchange. Note that this error does not violate the generalization that exchanges involve words of the same grammatical category. “Roast” and “cook” can both be either a noun or a verb. These types of errors and the constraints associated with the errors leads psycholinguistics to believe that sentence planning involves the formulation of a grammatical structure (Cairns, 1999). These type of word substitutions and exchanges implicate a breakdown in grammatical encoding.

Bock and Levelt (1994) sketch a broad outline of the language production processes that every normal speaker follows. These processes have been developed after careful analyses of speech errors, and after recent experimental data. The series of steps are as follows:

1. MESSAGE
2. GRAMMATICAL ENCODING
   2.1. Functional Processing
      2.1.1.1.Lexical Selection
      2.1.1.2.Function Assignment
   2.2. Positional Processing
      2.2.1.1.Constituent Assembly
      2.2.1.2.Inflection
3. PHONOLOGICAL ENCODING
4. ARTICULATION

Bock and Levelt (1994) review all of the steps, but the focus of the current review will center on grammatical encoding.

<u>Functional Processing</u>

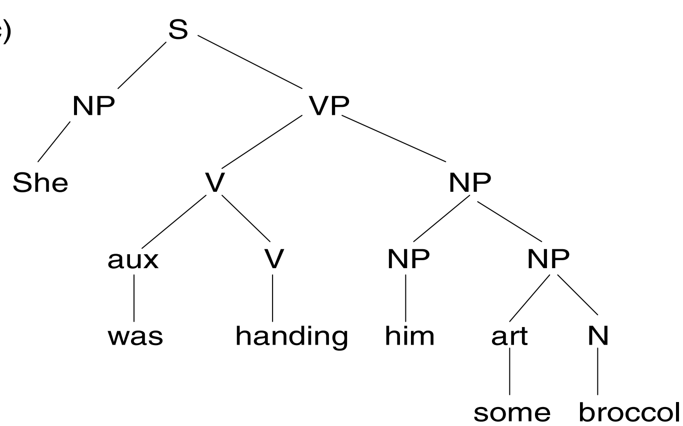
Grammatical encoding can be divided into functional processing and positional processing (Bock & Levelt, 1994; Garrett, 1988). Functional processing involves two subcomponents: lexical selection and function assignment. Computations that govern lexical selection involve conceptual and syntactic factors (Garrett, 1988; Bock & Levelt, 1994). The goal of lexical selection is to choose lemmas suitable for conveying the message. In a lexical item such as “sheep”, conceptual properties include domestic animal, wool pelt, milk, four legs, etc. It also has the syntactic property of a noun. Lemmas contain important grammatical information such as form class (noun, verb, etc.). For example, the lemma “listen” has a category link to a verb node whereas the lemma “cat” has a link to a noun node. It is important to note that all words do not correspond to lexical concepts, and the lemma for the transitive verb “listen” in the utterance “listen to the radio” requires the selection of the lemma “to”. For conveying the utterance “She was handing him some broccoli,” appropriate lemmas include masculine and feminine pronouns, a noun, and a verb that relates to the agent, recipient, and theme (Bock & Levelt, 1994).

After the selection of appropriate lemmas, functional assignment calls for assigning syntactic relations or grammatical functions (e.g., subject-nominative, object-dative) to the words (Bock & Levelt, 1994). In other words, the speaker’s sentence production mechanism must specify the words that will serve as the subject of the utterance and which, if any, will serve as objects of various kinds. It is thought that verbs play an important role in function assignment (Bock & Levelt, 1994), and may serve to organize clauses. For example, in the sentence such as “She was handing him some broccoli”, the verb “hand” requires three arguments; an agent, a recipient, and a theme. A link between the agent, feminine pronoun lemma and the nominative (subject) function is established. Also linked are the recipient, the masculine pronoun lemma, and the indirect object. Finally, the theme creates a link between “broccoli” and the accusative function.

<u>Positional Processing</u>

Additional processing is required after the selection of lemmas, and a set of syntactic functions are linked together via argument structures of the lemmas (Bock & Levelt, 1994; Garrett, 1988). For example, in the sentence "She was handing him some broccoli", indefiniteness of the argument indicated by "some" and the past progressive nature of the action is required. Also, the elements of an utterance need to be fixed to a position. This is theorized to occur in a subcomponent of positional processing, called constituent assembly. The elements are fixed as the language mechanism formulates a hierarchy for phrasal constituents that manages the order of word production and links the syntactic functions. The hierarchy for the example "She was handing him some broccoli" can be predicted from the syntactic features of the selected lemmas and the syntactic functions. The hierarchy for the example can be depicted in sketch (c) as follows:

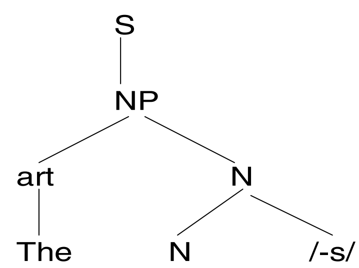
(c)



Another aspect of positional processing is the placement of inflectional affixes and function words, which carry information about number, tense, and aspect. Garrett

(1982) argues that these elements are intrinsic features of the grammatical frame and do not need to be linked by being assigned a grammatical function or a position. For example, if the subject is specified as definite and plural, the generation of the subject noun phrase should automatically include a definite determiner branch and a branch for the plural inflection along the lines of

(d)



In other words, if the plural form of cat (e.g, cats) is selected during lexical selection, the lemma should require the construction of a noun phrase in which the head noun is affixed with the plural /-s/.

Effects of Sentence-Structure Priming on Sentence Production

In the early years of psycholinguistic research, analyses of spontaneous speech errors have allowed researchers to sketch the underpinnings of sentence production (Butterworth, 1980; Fromkin, 1971; Garrett, 1975, 1988; MacKay, 1970; Shattuck-Hufnagel, 1979). In the last two decades, systematic and controlled empirical testing has become an important tool in the study of language production (Bock, 1986; Bock &

Griffin, 2000; Chang, Dell, Bock, & Griffin, 2000; Smith & Wheeldon, 2001). The sentence-structure priming paradigm has been established as a reliable method of experimentally assessing the syntactic processing and production abilities of speakers. Speakers tend to repeat the structures of previously uttered sentences even when the sentences differ in prosodic, lexical, and conceptual content (Bock & Loebell, 1990). For example, speakers are more likely to use a passive sentence if they just heard or produced a sentence that was passive rather than active.

One version of the sentence-structure priming paradigm assesses changes in speech initiation times for a target sentence following the presentation of a priming sentence. The priming sentence affects the speed at which a subject is able to initiate a target sentence. If the target sentence shares related syntactic sentence structures with the priming sentence, the initiation time is shorter. For example, the hierarchy of phrasal constituents or sentence structure of a previously spoken sentence will make generation of the sentence that follows easier if a similar hierarchy can be used. The explanation for this effect is that grammatical encoding is facilitated by the activation of the syntactic structures prior to the presentation of the target sentence (Bock, 1986; Smith & Wheeldon, 2001). However, if the priming sentence is unrelated to the target sentence, response latency increases as unrelated components become activated and the processing load is increased.

Smith and Wheeldon (2001) hypothesized that syntactic priming reduces the time dedicated to syntactic planning. In order to test their hypothesis, they designed an experiment in which participants described an array of moving pictures on both an initial prime trial and a subsequent target trial. The prime was either related or unrelated to the syntactic structure of the target sentence. In the related condition, the prime and target trial sentences were matched both in terms of the grammatical role of a noun phrase (i.e., a subject phrase) and in terms of the complexity of the internal structure of the phrase (i.e., a conjoined noun phrase). In contrast, in the unrelated condition, the prime trials matched the target trials in terms of the grammatical role of the noun phrases but not in terms of the complexity of their internal structure (i.e., a simple noun phrase rather than a conjoined noun phrase). Target trials were measured for production latencies to determine whether there was a significant difference between target trials that were preceded by related and unrelated primes. Results showed a significantly faster (by 55 ms) speech initiation latency when target trials were preceded by a related sentence-structure condition than by an unrelated sentence-structure condition. These results clearly support the view that syntactic priming reduces the time spent generating syntactic structures.

The idea that syntactic priming increases the availability of a syntactic structure has been supported by a number of studies (Bock, 1986, 1989; Bock & Loebell, 1990; Hartsuiker & Kolk, 1998). Some of the sentence structures that show priming include double-object datives, prepositional datives (Bock, 1986, 1989; Bock & Loebell, 1990), active transitives, and passive transitives (Bock, 1986). This phenomenon cannot be ascribed to thematic, lexical, or prosodic factors (Bock & Loebell, 1990). The logic behind this phenomenon is that speakers construct a mental representation of a sentence's phrase structure hierarchy, and the availability of a particular type of phrase structure is increased through syntactic priming. Therefore, the production cost for the speaker to construct the subsequent sentence structure is reduced.

Within the sentence-structure priming literature, there is a growing debate regarding the mechanism that leads to priming (Bock & Griffin, 2000). The issue is whether priming is due to transient activation of syntactic structures or implicit learning. Some studies (Levelt & Kelter, 1982; Branigan, Stewart, & Pickering, 1998) show that priming is related to transient activation, and priming beyond a single intervening clause or sentence occurs only when participants are told to remember the priming sentences. However, other studies (Bock & Kroch, 1989; Bock & Griffin, 2000) show that priming persists over intervals that are fairly long, which point to mechanisms of implicit learning rather than transient activation. Identifying the mechanism that leads to priming is beyond the scope of this study, but the important point to remember is that priming reduces the costs associated with constituent assembly and generating the structure of a sentence.

Effects of Syntactic Complexity on Sentence Production

The generation of a sentence requires a speaker to formulate an idea, select lexical items, create a syntactic structure, phonologically encode the intended utterance, and generate a motor program that will drive approximately one hundred speech muscles needed to articulate the appropriate speech sounds (Garrett, 1975; Seikel, King, & Drumright, 2005). All of these integrated components work efficiently in the typical speaker. This is an amazing feat if one thinks about all of the required steps that unfold during the production of a sentence. A logical line of reasoning would predict that the length or complexity associated with an utterance should influence the speech initiation times of articulation in speakers. If more steps are needed to produce an utterance, then planning should take longer, thereby increasing the speech initiation times.

One of the first studies (Johnson, 1966) to investigate the effects of syntactic complexity on speech initiation time involved sentences that differed according to the branching structure or hierarchical tree of the utterance. Some sentences had a more right branching structure or fewer syntactic nodes, and other sentences had more nodes and a more complex branching structure. For example, a sentence such as “The person who jumped over there is good” is less complex than “The person over there who jumped is good.” This early study (Johnson, 1966) found that syntactic complexity affects speech initiation time, thereby supporting the notion that there are processing costs associated with the generation of syntax.

In addition to syntactic complexity, utterance length or the number of stressed syllables in a sentence appear to influence the speech initiation time of speakers. In an experimental study (Stemberg, Monsell, Knoll, & Wright, 1978) that required speakers to memorize and articulate lists of words, speech initiation time increased when a list had more words. The rationale behind the finding that the number of words in an utterance influences speech initiation times is that a short-term memory buffer holds the motor program for an utterance prior to its articulation (Stemberg et al., 1978). However, an interesting follow-up experiment revealed that it’s not the actual words that increase initiation time, but the number of stressed syllables. For example, a list that contains six words but only 3 stressed words has similar speech initiation times as a list of 3 stressed words. Thus, the implication is that an increase in the number of stressed words will result in an increase in the time required to retrieve the units from the short-term memory buffer.

A more recent study (Ferreira, 1991) supported earlier findings (Johnson, 1966) that syntactic characteristics (e.g., complexity) of an utterance affect the processing speed that takes place prior to its articulation. These findings were not attributed to semantic plausibility or propositional complexity. More specifically, this particular study (Ferreira, 1991) found that the more syntactic nodes in a sentence, the longer it would take subjects to initiate it. The reason behind this finding is the processing cost involved in constructing syntactic constituents of a sentence. If there are more syntactic constituents that need to be constructed, then this would increase the processing cost. An increase in the speech initiation time is a reflection of the increase in syntactic processing associated with the sentence.

Syntactic complexity also appears to have an effect on the speech motor stability of adults who stutter. A spatiotemporal index used to quantify the stability of the lower lip found that a target phrase produced in isolation and embedded in utterances of increased syntactic complexity affects normally fluent adults and adults who stutter in a different way (Kleinow & Smith, 2000). Syntactic complexity did not seem to affect the speech motor stability of normally fluent adults, whereas the speech motor stability of adults who stutter decreased when the stimuli were more complex. At the very least, these results are indicative that the production processes of adults who stutter are more vulnerable to the linguistic demands required to produce more syntactically complex sentences. Moreover, this provides some support for the idea that syntactic complexity may contribute to the speech disruptions of individuals who stutter (Kleinow & Smith, 2000).

In summary, these findings appear to support the hypothesis that linguistic complexity is one factor that contributes to speech initiation time and speech motor stability.

Statement of the Problem and Research Questions for the Study

Some studies (Logan, 2003; Silverman & Bernstein-Ratner, 1997; Klouda & Cooper, 1987) do not show a link between syntactic processing and stuttering, whereas other studies (Anderson & Conture, 2004; Cuadrado & Weber-Fox, 2003; Wall, Starkweather, & Cairns, 1981; Bernstein-Ratner & Sih, 1987; Logan & Conture, 1995; Logan & Lasalle, 1999; Weiss & Zebrowski, 1992) identify some type of connection. Despite the lack of clear and overwhelming evidence that connects syntactic processing and stuttering, there is speculation that individuals who stutter have inefficient (e.g., delayed or impaired) linguistic or grammatical encoding, and this subtle delay or impairment taxes speech fluency extraordinarily, thereby creating more opportunities for breakdowns. It seems clear that additional research in examining the syntactic processes of individuals who stutter is greatly needed in an attempt to confirm, clarify and identify any subtle delays or impairments.

A good way to begin to understand the syntactic processes of individuals who stutter is to expose them to experimental paradigms that employ on-line sentence production tasks that manipulate syntactic variables in a systematic fashion and allow for the measurement of syntactic processing time (via speech initiation time) and speech accuracy (e.g., speech errors, disfluencies, etc). A review of the literature revealed a significant void of this type of research with adults who stutter. These types of investigations should provide a glimpse into the underpinnings of grammatical encoding abilities in individuals who stutter.

The focus of such an investigation should center on adults who stutter. The difficulty with studying children who stutter is that there are sub-groups that have not yet been identified, with the most important being the 20% who continue to stutter into adulthood. Adults, on the other hand, have more stable and mature linguistic systems. If we can determine what contributes to their stuttering, it should provide us with some hypothesis about the characteristics of children who do not recover. Also, if the investigation confirms that individuals who stutter generate grammatical information too slowly or lose it too rapidly, it may be possible to counteract this limitation by temporarily increasing the availability of the relevant syntactic structures. This would have significant implications for treatment. Within the framework of current psycholinguistic theories of sentence production, speaking more slowly allows more time for the psycholinguistic system to create the syntactic framework of sentences, thereby leading to fewer fluency disruptions. Interestingly, this is one of the most common therapy recommendations when a speech-language pathologist treats a person who stutters (Guitar, 2006).

The logic of the first experiment was based on language production research that demonstrates the processing cost associated with syntactic structures in sentence production (Bock, 1986; Ferreira, 1991; Garrett, 1982; Levelt, 1989). The claim is that the generation of syntactic structures during sentence production entails processing costs and affects fluency and rapidity of utterance generation (Smith & Wheeldon, 2001; Ferreira, 1991). The greater the syntactic complexity of an utterance, the longer it takes a speaker to initiate it (Ferreira, 1991) and the greater likelihood of speech disfluency (Bernstein-Ratner, 1997).

One of the aims of Experiment 1 was to replicate Ferreira's (1991) finding that more complex syntax increases speech initiation time. Another aim was to investigate whether the latency effect is similar or different when comparing two different groups of speakers: typical speakers and adults who stutter. As discussed previously, the generation of more complex syntactic structures has been hypothesized to have a more negative influence on the sentence production abilities of children and adults who stutter than of those who do not. A logical prediction was that speech initiation latency during more complex utterances will be longer in individuals who stutter when compared to typical adult speakers.

The specific aims of Experiment 1 were achieved by using similar methods to the Ferreira (1991) study, which measured the effects of length and syntactic complexity on speech initiation latency for prepared utterances. Speakers read, memorized, and produced sentences of varying length and complexity. Sentences appeared in one of four experimental conditions: 1) Short condition, 2) Long, low syntactic complexity condition 3) Long, medium syntactic complexity condition, 4) Long, high syntactic complexity condition.

Speech initiation latencies for the sentences were measured to determine any significant differences between groups and conditions. According to the results reported by Ferreira (1991), typical adults have average speech initiation latencies of 550 milliseconds during long sentences with low syntactic complexity, whereas long sentences with high syntactic complexity sentences have an average initiation latency of 656 milliseconds. This is a significant difference. A point of interest in the current study is to compare speech initiation latencies of adults who stutter to the speech initiation latencies of normal speakers. If adults who stutter have some sort of deficit in grammatical encoding, and syntactic production processes are different from those of typical speakers, then speech initiation latencies of longer and more complex sentences should be greater, due to increased processing costs associated with generating syntactic structures.

One of the aims of Experiment 2 was to replicate Smith and Wheeldon's finding that syntactic priming reduces the time dedicated to the generation of syntactic structure, thereby reducing the processing costs of the speaker and promoting fluency and rapidity of sentence production (Smith & Wheeldon, 2001). In other words, a reduction in the sentence processing costs should lead to a facilitatory effect in constructing a sentence and a decrease in speech initiation latency. Another aim was to investigate whether the facilitatory effect is the same or different when comparing two different groups of speakers: typical speakers and adults who stutter. As discussed previously, the generation of syntactic structures has been hypothesized to have a more negative influence on the sentence production abilities of children and adults who stutter than on those who do not.

The specific aims of Experiment 2 were achieved by using methods similar to the Smith and Wheeldon (2001) study of syntactic priming in spoken sentence production (Experiment 1 in Smith and Wheeldon, 2001). The results of Smith and Wheeldon's (2001) study provide evidence that the generation of the structure of an utterance is not an entirely automatic and non-costly process, and priming by a sentence with related syntactic structure reduces the cost of sentence production. The only major difference in the current study was the inclusion of an experimental group of adults who stutter.

The current study required speakers to produce a sentence that describes moving pictures on a computer screen on both an initial prime trial and a subsequent target trial. The two conditions consisted of a syntactically related prime trial and a syntactically unrelated prime trial. In the related condition, the prime and target trials are matched in terms of the complexity of the internal structure of the subject phrase with a conjoined noun phrase (e.g., Syntactically Related Prime Trial = "The eye and the fish move apart"; Target Trial = "The spoon and the car move up."). In contrast, the complexity of the internal structure of the subject phrase is a simple noun phrase rather a conjoined noun phrase in the unrelated condition (e.g., Syntactically Unrelated Prime Trial = "The eye moves up and the fish moves down"; Target Trial = "The spoon and the car move up").

Speech initiation latencies for the target trials that come after related and unrelated primes were measured to determine any significant differences. According to the results of Smith and Wheeldon (2001), target trials that come after a related condition are produced significantly faster than target trials that come after an unrelated condition. A point of interest is to compare facilitation effects of adults who stutter to the facilitation effects of normal speakers. If adults who stutter have some sort of delay or impairment in subtle syntactic production processes, then facilitatory effects of syntactic priming should differ when compared to typical speakers. If the Anderson and Conture (2004) syntactic priming study with children who stutter is an indication of the syntactic processes in adults who stutter, the logical prediction for the current study is greater facilitation for adults who stutter when compared to typical adult speakers. This outcome could lead researchers and clinicians toward more fruitful ways of evaluating the psycholinguistic weaknesses and strengths of adults who stutter, which may lead to better assessment and treatment methods. Another interesting comparison is to compare effects of syntactic complexity and syntactic priming with the same group of adults who stutter. If longer and more syntactically complex sentences take significantly more time to produce for adults who stutter than for typical adults, does syntactic priming compensate and facilitate the generation of the structure of a sentence in the same group of adults who stutter? The use of the same subjects in Experiments 1 and 2 may demonstrate that the same adults who stutter who are inhibited by complexity are facilitated by syntactic priming.

The research questions are as follows:

1) Is there a significant difference in speech initiation time of sentences with varying syntactic complexity when adults who stutter are compared to fluent adults?

2) Is there a significant difference in the speech initiation time in related and unrelated sentence-structure priming conditions when adults who stutter are compared to fluent adults?

3) Is there a significant difference in the number of speech disfluencies in the sentences of varying complexity when adults who stutter are compared to fluent adults?

4) Is there a significant difference in the number of disfluencies in the related and unrelated sentence-structure priming conditions when adults who stutter are compared to fluent adults?

METHOD

Experiment 1

<u>Participants</u>

Participants were fifteen adults (M = 29.13 years; SD = 6.42 years) who exhibited stuttering and fifteen adults (M = 28.86 years; SD = 6.19 years) who did not stutter or exhibit any other speech or language problem. Monolingual English-speaking adults were recruited from advertisements posted in the speech, language, and hearing departments of Eastern Washington University, Lehman College of the City University of New York, and The Graduate Center of the City University of New York. All participants were native speakers of American English with no history of neurological, psychological, or intellectual problems per participant report and examiner observation. They were required to pass a bilateral pure-tone screening test at 25 dB for 500, 1000, 2000, and 4000 kHz. Another requirement was the absence of oral-facial abnormalities (e.g., cleft palate) and speech-motor difficulties (e.g., oral apraxia) as determined by an informal oral-facial examination and speech-motor examination. Adults in neither group had significant sensory deficits or current use of psychoactive medications.

Participants in the experimental group were required to exhibit the presence of three or more disfluencies (sound/syllable repetitions, sound prolongations, or atypical blocks in the forward flow of speech) per 100 words of conversational speech (Bloodstein, 1995), based on a 300-word speech sample. In addition, experimental participants were required to score at least a “mild” (i.e., total overall score = 11 or above) on the Stuttering Severity Instrument-3 (Riley, 1994).

Every participant in the experimental group was age- ($\pm$ 3 years) and sex-matched with an adult in the control group who did not stutter. Control group participants were required to score below "mild" (i.e., total overall score = 10 or below) on the Stuttering Severity Instrument-3 (Riley, 1994). In addition, each control participant was required to exhibit two or fewer speech disfluencies per 100 words of conversational speech. Appendix A contains a list of each participant's gender, age, and stuttering severity scores.

A licensed (New York and New Jersey) and certified (American Speech, Language, Hearing Association) speech-language pathologist examined a spontaneous conversational language sample, a reading sample, and a case history form that gathered information about each participant's historical and current speech-language functioning. None of the participants reported any listening comprehension or language difficulties. Moreover, the language sample was examined and revealed vocabulary and sentence structures that were within normal limits for native adult speakers of American English. In sum, all of the participants (fluent adults and adults who stutter) passed the language screening and additional testing or exclusion from the current study was not deemed necessary.

Materials

A set of 24 basic sentences were taken from the Ferreira (1991) study. All of the sentences had been tested in a pilot study by the current investigator and a prior study (Ferreira, 1991), which required participants to memorize and repeat the sentences upon a cue. Each of the 24 basic sentences appeared in four different conditions. In the conditions, the sentences varied in terms of sentence length and/or syntactic complexity.

Apparatus

Participants were tested individually while they faced the screen of a computer monitor positioned 15 inches away from them. Each person wore a microphone attachment that was used to trigger the speech initiation relay connected to the experiment. Experiments were run with E-Prime software. This software controlled the display of the sentences, and speech initiation times were gathered with a voice-activated relay interfaced with the computer.

Design

Twenty-four base sentences with differing variations of the subject noun phrase appeared in one of four conditions. The first condition, which was labeled short, had a subject that contained only an article and a noun (e.g., “The river empties into the bay that borders the little town”). The first condition constituted the base sentence upon which the other conditions were built. For example, in the second, third, and fourth conditions, the sentences consisted of the base sentence but had subjects with three more words. Sentences with three more words in the subject noun phrase were labeled as long. The long conditions consisted of subjects that had the same number of words, but differed in syntactic complexity. For example, in the second condition, labeled as long and low syntactic complexity, the subject noun phrase had an article, two conjoined adjectives, and the head noun (e.g., “The large and raging river empties into the bay that borders the little town”). In the third condition labeled as long and medium syntactic complexity, the subject consisted of an article and a head noun, followed by an embedded prepositional phrase (e.g., “The river near their city empties into the bay that borders the little town”). The fourth and final condition, known as long and high syntactic complexity, the subject had an article, head noun, and an embedded relative clause (e.g., “The river that stopped flooding empties into the bay that borders the little town”). The differing conditions of low, medium, and high syntactic complexity were attributable to the increase in the number of syntactic nodes in the structural representation of each phrase type. There were eight syntactic nodes in the long and low syntactic complexity condition, whereas the long and medium syntactic complexity and long and high syntactic complexity conditions contained nine and twelve nodes, respectively. A complete set of the sentences in the four conditions appears in Appendix B.

The 24 experimental sentences in each condition were intermixed with 24 filler sentences. The presentation of sentences was randomized with a Latin square design. Appendix C contains the list of experimental sentences of varying syntactic complexity that were randomized with a Latin square design for four subject groups. Each group was presented with six sentences of each type, plus 24 fillers, for a total of 48 sentences.

<u>Procedure</u>

Participants sat in front of a computer screen, and each trial consisted of the following steps. A message appeared on the screen and prompted the participant to push a button to indicate that he or she was ready for a sentence. A sentence appeared after the push of a button. The participant memorized the sentence and pushed a button after (s)he felt confident enough to repeat the sentence accurately. Upon the push of a button, the sentence disappeared from the computer screen. After a random delay varying from 500 to 1000 milliseconds, the question "What happened?" appeared on the screen. The appearance of the question on the screen was the participant's cue to begin saying the sentence as quickly and as accurately as possible. However, before the experiment began, every participant needed to accurately complete a set of practice trials. If a participant made an error during a practice trial, (s)he was corrected and asked to repeat the trial. Appendix C contains a list of the practice sentences.

The experimenter listened to the participants' productions. If a participant did not say the sentence exactly as it appeared on the screen, an error was noted so that the trial could be eliminated from the data analysis of reaction times. Participants were free to take as long as necessary between trials.

Experiment 2

Participants

The participants that completed the tasks of Experiment 1 also completed the tasks of Experiment 2. Thus, selection criteria for Experiment 2 remained the same as in Experiment 1.

Materials

A set of 84 simple pictures (black and white line drawings) of everyday concrete objects was taken mostly from the Snodgrass and Vanderwart (1980) list. All of the pictures had been pre-tested in a simple picture naming paradigm (Wheeldon & Monsell,

1992) and a syntactic priming paradigm (Smith & Wheeldon, 2001). These pictures were identified and named quickly and easily, with a mean naming latency of 530 milliseconds (Smith & Wheeldon, 2001). The set of 84 pictures consisted of 32 experimental target pictures, 32 experimental prime pictures, and 20 filler pictures.

Apparatus

Participants were tested individually while they faced the screen of a computer monitor positioned 15 inches away from them. Each person wore a microphone attachment that was used to trigger the speech initiation relay that was connected to the E-Prime computer software that controlled the experiment. This software controlled the display of the sentences and gathered speech initiation times via a voice-activated relay interfaced with the computer.

Design

The general design was modeled after Smith and Wheeldon's study (2001) of sentence-structure priming. The 32 pictures allocated to the experimental target trials were divided into two sets of 16 pictures. Both sets of 16 pictures were matched in terms of mean naming latency (Set 1 = 529ms vs. Set 2 = 531ms), number of syllables (Set 1 = 1 syllable vs. Set 2 = 1 syllable), and number of phonemes (Set 1 = 3 phonemes vs. Set 2 = 3 phonemes). Experimental target pictures from Set 1 (16 pictures) were paired with pictures from Set 2 (16 pictures), thereby creating 16 target picture pairs. The first picture in each target pair was assigned to the leftmost position of the viewing area, whereas the second picture of the target pair was assigned to the rightmost position. An additional 16 target picture pairs were created by moving the pictures occupying the leftmost position in the first set of picture pairs to the rightmost position in the second set. Moreover, the pictures in the rightmost position in the first set were moved to the leftmost position in the second set. This ensured that individual pictures made a balanced contribution to production latencies for words at both of the two screen positions. In addition, phonological or conceptual similarities between two pictures in a pair did not exist. Overall, the pairings resulted in a total of 32 target picture pairs.

The same constraints were applied to the 32 pictures allocated to the experimental prime trials. The 32 pictures were divided into 2 sets of 16 pictures. Naming latencies, number of syllables, and number of phonemes were matched. Then, pictures from Set 1 were paired to pictures in Set 2, thereby creating 1 set of 16 picture prime pairs. Another set of 16 prime picture pairs was created by moving the pictures occupying the leftmost position in the first set of picture pairs to the rightmost position in the second set. The pictures in the rightmost position in the first set were moved to the leftmost position in the second set. Moreover, phonological or conceptual similarities between two pictures in a pair did not exist. This resulted in a total of 32 prime picture pairs.

The 32 target picture pairs were assigned to the related and unrelated prime conditions. Over the course of the experiment, the 32 target picture pairs were rotated so that each target picture pair occurred an equal number of times in both conditions. Likewise, the 32 prime picture pairs assigned to the related and unrelated condition were rotated so that each prime pair occurred an equal number of times with both sets of target picture pairs.

The experiment consisted of eight blocks of trials. The first block demonstrated typical experimental and filler trials to participants. Verbal and written directives were given at this time. Basically, participants were told to describe the picture from a left to right fashion by using a single clause sentence when pictures moved in the same vertical directions or opposing vertical directions (e.g., “The spoon and the car move up/apart”). In contrast, participants were instructed to describe opposing vertical movements from left to right via a double clause sentence (e.g., “The eye moves up and the fish moves down”). The second, third, and fourth blocks were practice blocks of 16 trials each. The sentence types of the practice blocks resembled those of the experimental blocks: experimental and filler trials. During the practice blocks, participants encountered each of the 32 experimental target pictures once. In the fifth, sixth, seventh, and eight blocks, participants were presented with 16 experimental trials and 24 filler trials in each block. Appendix D contains the list of experimental sentences and block layout for Experiment 2. An experimental trial was defined as the presentation of a prime trial followed by a presentation of the target trial. Eight of these 16 experimental trials were assigned to the primed and unprimed trials, whereas the other eight were assigned to the target trials. The eight primed trials in each block were divided into four primed trials and four unprimed trials. The same picture never occurred in two consecutive trials. The 24 filler trials across a block were randomized. Finally, the ordering of the blocks was rotated across participants to ensure that each block occurred an equal number of times in each position in the experiment.

<u>Procedure</u>

Each picture began to move upon appearing on the screen. The picture movements consisted of four possible directions: up, down, right, and left. In the primed condition, a target trial was preceded by a prime trial. In the prime trials and target trials, movements were combined to form two possible movement categories: 1) The pictures moved in the *same vertical direction* (i.e., up and up or down and down); 2) The pictures moved in *opposing horizontal directions* (i.e., left and right or right and left). In trials featuring these movements, participants were instructed to describe objects depicted in the display from left to right using single clause sentences (i.e., "The spoon and car move up down" or "The spoon and car move apart") as soon as they could. In contrast, the unprimed trials featured pictures moving in *opposing vertical directions* (i.e., up and down or down and up). In trials with these movements, participants were instructed to describe the objects depicted in the display from left to right via a double clause sentence (i.e., "The spoon moves up and the fish moves down"). In the unprimed condition, an unprimed trial that required a double clause sentence came before a target trial that required a single clause sentence. Each experimental block contained an equal number of trials that featured each movement category. Pictures were removed from the screen after appearing for 3 seconds. After a 2 second interval, the next trial was initiated.

Each condition had filler trials to camouflage the purpose of the experiment. Filler trials consisted of sentences that were syntactically different and similar to the experimental sentences. The purpose of the filler trials was to increase the variety of syntactic structures and minimize inter-trial priming. In the filler trials, there were picture movements designed to stimulate the following kinds of descriptions: 1) The picture moved up, down, right, or left (one picture moves); 2) The pictures moved up, down, right, or left (three pictures move together), in which case the participant was instructed to say "They all move ____." A third unrelated filler trial contained no pictures. Filler trials also included sentence types that were syntactically similar to those in the experimental trials. However, these trials were always preceded and followed by filler trials that featured sentence types syntactically dissimilar to those used in experimental trials. Each filler trial had a set of directives that were given to each participant during practice trials.

Data Collection of Dependent Measures

Speech Initiation Time

During each of the four experimental conditions (short, long-low, long-medium, & long-high) in Experiment 1 and each of the two conditions (unrelated & related) in Experiment 2, the E-prime computer program controlled the presentation of the stimuli and recorded, in milliseconds, the speech initiation times. Speech initiation time was defined as the time that elapsed between the onset of the cue (i.e., "What happened" in Experiment 1; appearance of pictures in Experiment 2) and the onset of speech initiation. This was measured by the triggering of the voice key by the subject's verbal response.

Speech Disfluency

During each experimental condition in Experiments 1 and 2, each target sentence was analyzed for the occurrence of an instance of stuttering. An instance of stuttering was defined as a sound/syllable repetition, sound prolongation, or atypical block or pause in the forward flow of speech.

Data Analyses

The dependent variables in both experiments consisted of speech initiation time and speech disfluency. Individual trials were categorized as errors and excluded from the analyses of speech initiation time if any of the following occurred: 1) responses that contained incorrect words; 2) responses that contained incorrect syntax; 3) responses that did not use the required sentence structure (in Experiment 2); 4) responses that contained disfluency; 4) responses that were greater than two standard deviations from the participant's mean speech initiation time; 5) responses that did not trigger the voice-activated microphone.

Between- and Within-Group Comparisons

Mean speech initiation times for subjects and items were submitted to an analysis of variance, with *group* as a between-subjects factor and *condition* as a within-subjects variable. These analyses assessed main effects and interactions. Filler sentences and error responses were eliminated from data analyses. Post hoc comparisons of means were conducted as appropriate. Main effects of group, complexity, and priming were predicted to be significant. Moreover, a significant interaction was predicted to reflect that adults who stutter are more affected by complexity than are fluent adults, and adults who stutter benefit more from sentence-structure priming than do fluent adults.

Intra- and Inter-judge Measurement Reliability

Intra- and inter-judge reliability measures were obtained for the speech disfluency measure. Seven participants were randomly selected from the fluent group and seven participants were randomly selected from the adults who stutter group. Intra-judge reliability was assessed by requiring the primary investigator to re-analyze each 300-word speech sample for the mean frequency of stuttering. This represented approximately 50% of the total data used for the Stuttering Severity Instrument (Riley, 1994).

Inter-judge reliability of speech disfluency was determined by having an ASHA certified Speech-Language Pathologist judge each speech sample that the primary investigator used for intra-judge reliability. Reliability scores for intra- and inter-judge assessment of speech disfluency was obtained via Sander's (1961) Agreement Index (Agreements/[Agreements + Disagreements]). Intrajudge reliability for the mean frequency of total speech disfluencies was .96, whereas interjudge reliability was .90.

RESULTS

Experiment 1

Speech Initiation Time Analyses

Responses that contained incorrect words, incorrect syntax, speech disfluencies, or a speech initiation time greater than two standard deviations above the mean of all that subject's responses were excluded from analyses of speech initiation time. This resulted in the loss of 4.2% responses for the fluent group and 13.6% for the adults who stutter. This was a significant difference [$t(1, 28) = 4.076$, $p = .0003$]. The greater data loss in adults who stutter was an expected outcome due to speech disfluencies.

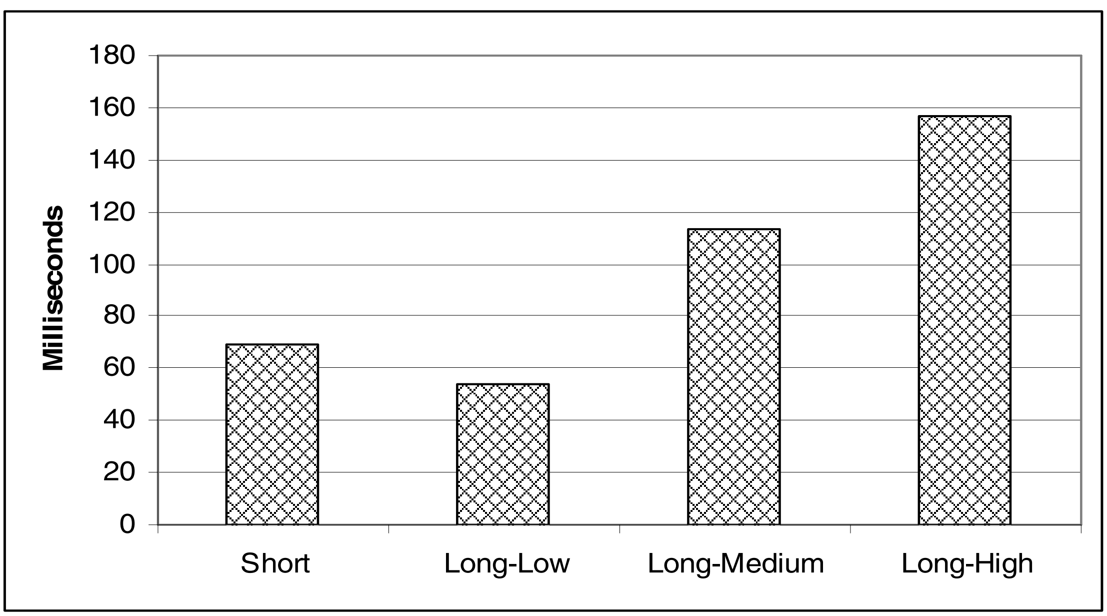
Mean speech initiation times for all the individuals (fluent adults and adults who stutter) across the four conditions (short, long-low, long-medium, and long-high) are shown in Appendix E. Table 1 shows mean speech initiation times for the two groups across four sentence types. The results were analyzed with a mixed analysis of variance by subjects and by items. Fluency was a between groups variable with two levels (fluent and disfluent) and complexity was a repeated measures variable with four levels (short, long-low, long-medium, long-high). An alpha level of 0.05 was used. These analyses revealed a significant main effect of fluency [F_1 (1, 28) = 9.719, $p = .004$, partial $\eta^2 = .258$; F_2 (1, 46) = 50.321, $p < .0001$, partial $\eta^2 = .522$] and a significant main effect of complexity [F_1 (1, 28) = 75.961, $p < .0001$, partial $\eta^2 = .731$; F_2 (1, 46) = 200.595, $p < .0001$, partial $\eta^2 = .813$]. The interaction between fluency and complexity was also significant [F_1 (1, 28) = 6.460, $p = .017$, partial $\eta^2 = .187$; F_2 (1, 46) = 16.985, $p < .0001$, partial $\eta^2 = .270$]. Figure 1 represents the mean speech initiation times plotted on a bar graph, and Figure 2 shows the mean speech initiation time differences between the two

Table 1. Mean speech initiation times (msec) for the two groups across sentence types in Experiment 1.

	Short Condition	Long-Low Condition	Long-Medium Condition	Long-High Condition	All Conditions
Fluent Adults (N=15)					
M	534	566	622	662	596
SD	83	65	71	55	83
Adults Who Stutter (N=15)					
M	603	620	735	819	694
SD	106	126	115	120	144
All Adults (N=30)					
M	568	593	679	741	645
SD	100	103	110	121	128

Figure 1. Mean speech initiation times (msec) for the two groups across sentence types in Experiment 1.

Figure 2. Mean speech initiation time difference (msec) for the two groups across sentence types in Experiment 1.



groups across the four conditions.

In order to analyze the significant effects of condition on speech initiation times, a number of sequential bonferroni corrected t-tests were performed. Within the group of adults who stutter, analyses revealed a significant difference between the long-low and long-medium conditions [$t(1, 14) = 5.116$, $p < .0001$, $d = .953$, critical p-value = .0083] and the long-medium and long-high conditions [$t(1, 14) = 4.906$, $p < .0001$, $d = .714$, critical p-value = .007]. Within the fluent group, analyses also showed a significant difference between the long-low and long-medium conditions [$t(1, 14) = 3.971$, $p = .001$, $d = .822$, critical p-value = .01]. However, the difference between the long-medium and long-high conditions [$t(1, 14) = 2.337$, $p = .035$, $d = .629$, critical p-value = .0167] was not significant. This indicates that the speech initiation times of both groups increase as syntactic complexity increases.

Speech initiation time differences between the two groups were assessed at each level of the complexity variable. It is important to note that Levene's test for equality of variances showed no significant difference in variance between the two groups for the short and long-medium complexity conditions; however, the long-low ($p = .027$) and long-high ($p = .017$) conditions reached significance, so analyses assumed unequal variances for these conditions. The first comparison focused on the short condition, comparing a mean of 534 ms for the fluent group and 603 ms for the adults who stutter. The sequential bonferroni t-test revealed that the means were not significant [$t(1, 28) = 1.962$, $p = .06$, $d = .725$, critical p-value = .025]. The second comparison involved the long-low (566 ms vs. 620 ms) complexity condition, and results indicated no significant difference [$t(1, 28) = 1.474$, $p = .152$, $d = .538$, critical p-value = .05]. In the long-medium (622 ms vs. 735 ms) complexity condition, a t-test revealed highly significant effects [$t(1, 28) = 3.244$, $p = .003$, $d = 1.182$, critical p-value = .0125]. Moreover, significant effects were detected in the long-high (662 ms vs. 819 ms) complexity condition [$t(1, 28) = 4.582$, $p < .0001$, $d = 1.682$, critical p-value = .00625]. These comparisons indicate that the speech initiation times of adults who stutter are significantly longer than those of fluent adults only for sentences of greater syntactic complexity.

The experimental group consisted of individuals that were placed in either a mild, moderate, or severe stuttering severity category. Interestingly, the mean speech initiation times of fluent utterances for the three different levels of stuttering severity was lowest for the mild group and highest for the severe stutterer in both the long-low and long-high complexity conditions. The long-medium complexity condition did not show a notable trend. Figures 3, 4, and 5 show the speech initiation time differences among the three different levels of stuttering severity. Evident from these figures is the trend that shows slower speech initiation times for moderate and severe adults who stutter. However, these comparisons should be interpreted with caution. The number of subjects within each severity level was unequal, as nine subjects were classified as mild, five as moderate, and only one as severe.

Figure 3. Mean speech initiation times (msec) for the mild (N = 9), moderate (N = 5), and severe (N = 1) adults who stutter in the long-low complexity condition in Experiment 1.

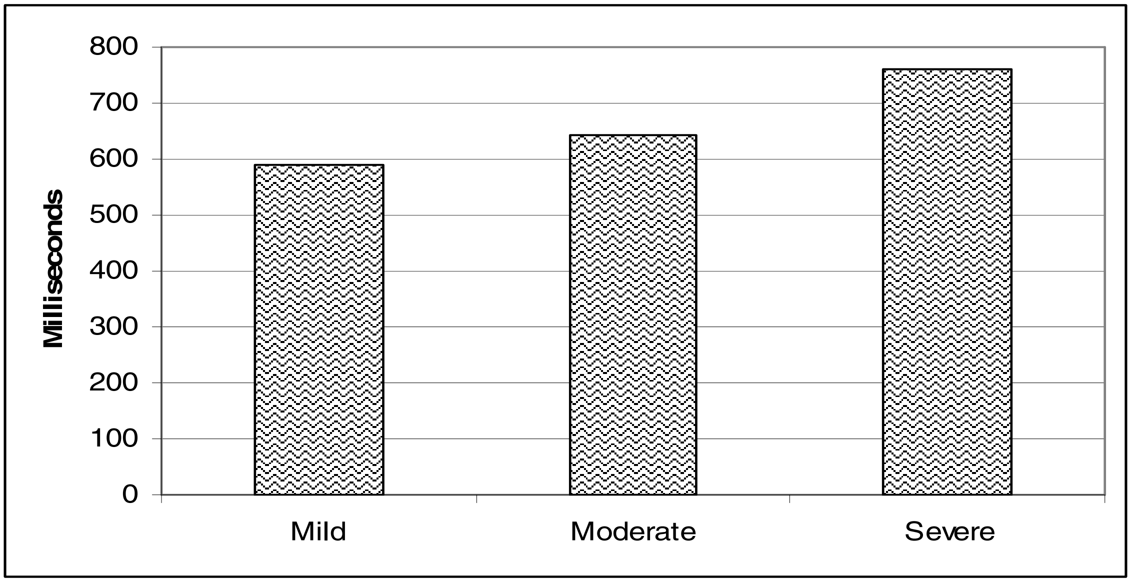


Figure 4. Mean speech initiation times (msec) for the mild (N = 9), moderate (N = 5), and severe (N = 1) adults who stutter in the long-medium complexity condition in Experiment 1.

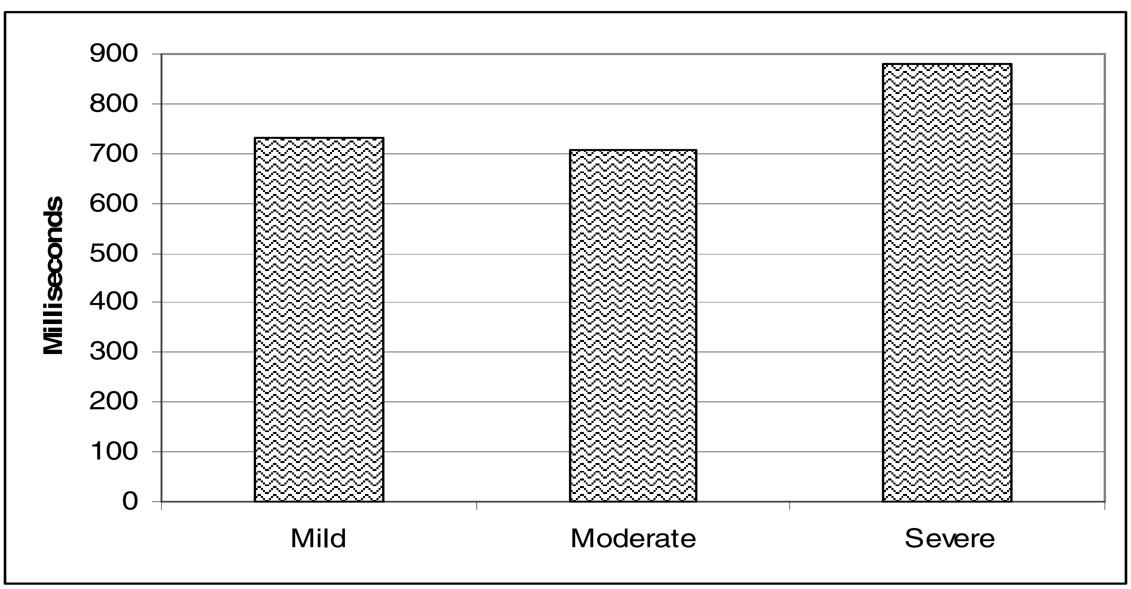
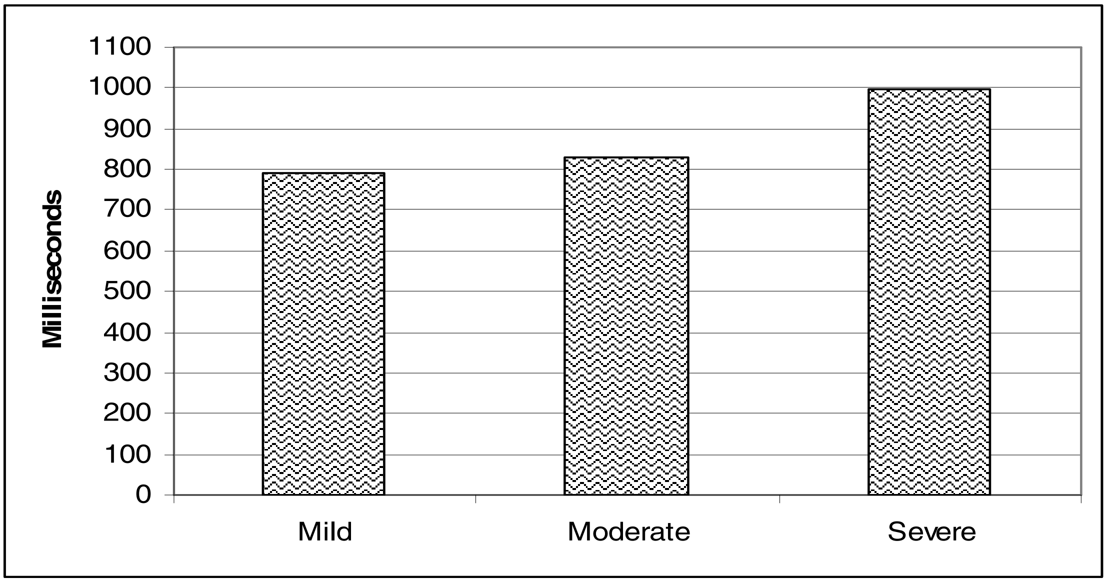


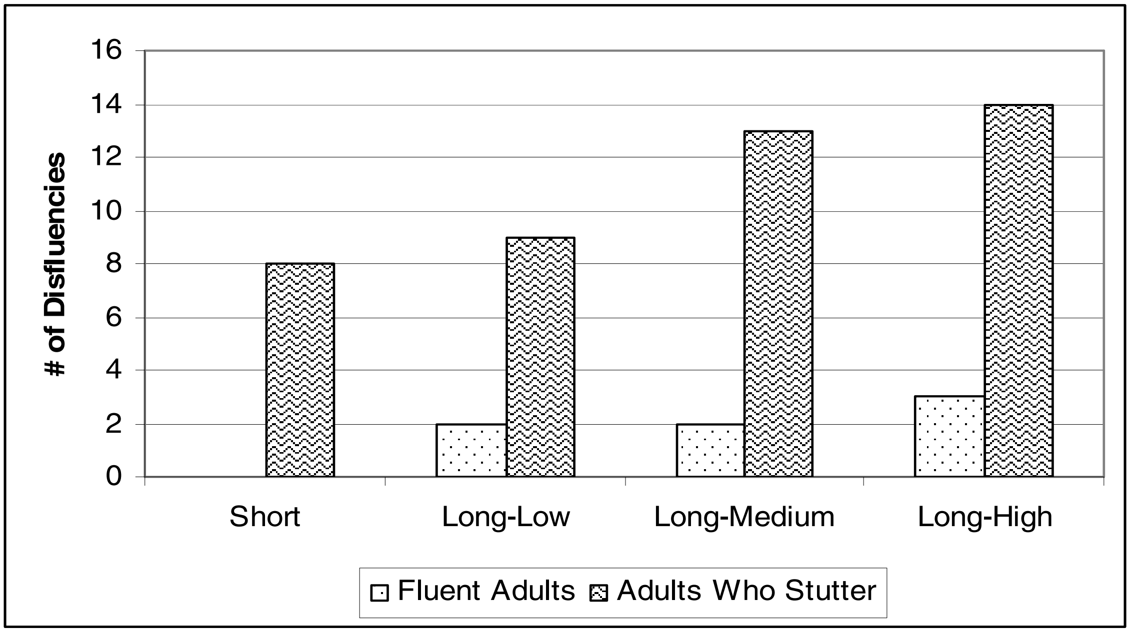
Figure 5. Mean speech initiation times (msec) for the mild (N = 9), moderate (N = 5), and severe (N = 1) adults who stutter in the long-high complexity condition in Experiment 1.



Speech Disfluency Analyses

Speech disfluencies were an area of interest in this study, so these were collected in an attempt to detect any differences or notable trends between groups and conditions. Speech disfluencies were defined as sound/syllable repetitions, sound prolongations, and atypical pauses in speech. The total number and percentage of target sentences that contained speech disfluencies for all the individuals (fluent adults vs. adults who stutter) across the four conditions (short, long-low, long-medium, & long-high) are shown in Appendix F. Figure 6 shows the total number of target sentences that contained speech disfluencies for the two groups across four conditions. A visual analysis shows a trend of increasing disfluencies in relation to syntactic complexity, especially for adults who

Figure 6. Total number of target sentences with speech disfluencies across conditions in Experiment 1 in fluent adults (N = 15) and adults who stutter (N = 15).



stutter. As a result of the low number of target sentences that contained disfluencies, analyses were conducted with the total number of fluent sentences as a way to gauge the influence of syntactic complexity on disfluency. These sentences were analyzed with a 2 x 4 Chi Square test and results revealed no significant difference ($x^2 = 0.091$) at the alpha level of 0.05. A 1 x 3 Chi Square was used to assess any significant differences within the group of adults who stutter across the three (long-low vs. long-medium, long-medium vs. long-high, long-low vs. long-high) levels of syntactic complexity. This was not significant ($x^2 = 4.94$) at the 0.05 alpha level. Overall, results do not support the prediction that disfluencies increase significantly in adults who stutter in relation to increases in syntactic complexity.

Memorization Time

Experiment 1 was designed to reflect the time required to syntactically plan and initiate an utterance. However, every subject was required to memorize the sentence before verbally producing it. As a result, an investigation into the memorization times was warranted in an attempt to rule out any memorization effects that may have influenced the speech initiation times in the various conditions.

The mean time to memorize the four different types of sentences is found in Table 2 and Appendix G. A mixed analysis of variance was performed with fluency as a between-groups variable (fluent and disfluent) and complexity as a repeated measures variable with three levels (long-low, long-medium, long-high). The short condition was not included in this analysis because the comparison is only legitimate among sentences of equal length. The mixed ANOVA for memorization showed no significant difference in complexity [$F(1, 28) = 1.496$, $p = .233$] or fluency [$F < 1$], and no significant interaction [$F < 1$]. This result signifies that memorization did not vary according to syntactic complexity and, therefore, did not affect the speech initiation times of Experiment 1.

Table 2. Mean memorization times (msec) for the two groups across four sentence types in Experiment 1.

	Short	Long-Low	Long-Medium	Long-High	All Conditions
Fluent Adults (N=15)					
M	7445	13223	13336	13773	11944
SD	1679	1560	1408	1628	3042
Adults Who Stutter (N=15)					
M	8146	13099	13487	13461	12049
SD	1936	1478	1478	1639	2784
All Adults (N=30)					
M	7796	13161	13412	13618	11996
SD	1816	1495	1421	1613	2904

Experiment 2

Speech Initiation Time Analyses

Responses that contained incorrect words, incorrect syntax, speech disfluencies, or a speech initiation time greater than two standard deviations above the mean of all that subject's responses were excluded from all analyses of speech initiation time. This resulted in the loss of 3.75% for the fluent group and 11.25% for the adults who stutter. A t-test analysis revealed a significant difference [$t(1, 28) = 3.286$, $p = .003$]. The greater data loss in adults who stutter was an expected outcome due to speech disfluencies.

The mean speech initiation times for the two groups across the two priming conditions are shown in Table 3. Appendix H shows the mean speech initiation times for all the individuals (fluent adults and adults who stutter) across the two conditions (unprimed and primed). Figure 7 represents the mean speech initiation times plotted on a bar graph and figure 8 shows the mean difference between the two groups across the two priming conditions. As shown in figure 7, the mean speech initiation time of adults who stutter moves closer to that of fluent adults in the related priming condition. Data were submitted to a mixed analysis of variance with repeated measures for subjects and a univariate analysis of variance for items. Fluency was a between groups variable with two levels (fluent and disfluent) and prime was a repeated measures variable with two levels (unprimed and primed). The main effect of prime was significant [F_1 (1, 28) = 45.126, $p < .0001$, partial $\eta^2 = .617$; F_2 (1, 63) = 15.114, $p < .0001$] whereas the main effect of fluency was not significant [F_1 (1, 28) = 1.065, $p = .311$, partial $\eta^2 = .037$; F_2 (1, 63) = 8.239, $p = .006$]. In addition, the interaction between fluency and prime was significant

Table 3. Mean speech initiation times (msec) for the two groups across two condition types in Experiment 2.

	Unprimed Condition	Primed Condition	Unprimed and Primed Conditions
Fluent Adults (N=15)			
M	948	900	924
SD	192	186	187
Adults Who Stutter (N=15)			
M	1066	923	995
SD	202	188	205
All Adults (N=30)			
M	1007	912	960
SD	202	184	198

Figure 7. Mean speech initiation times (msec) for the unprimed and primed conditions for each group in Experiment 2.

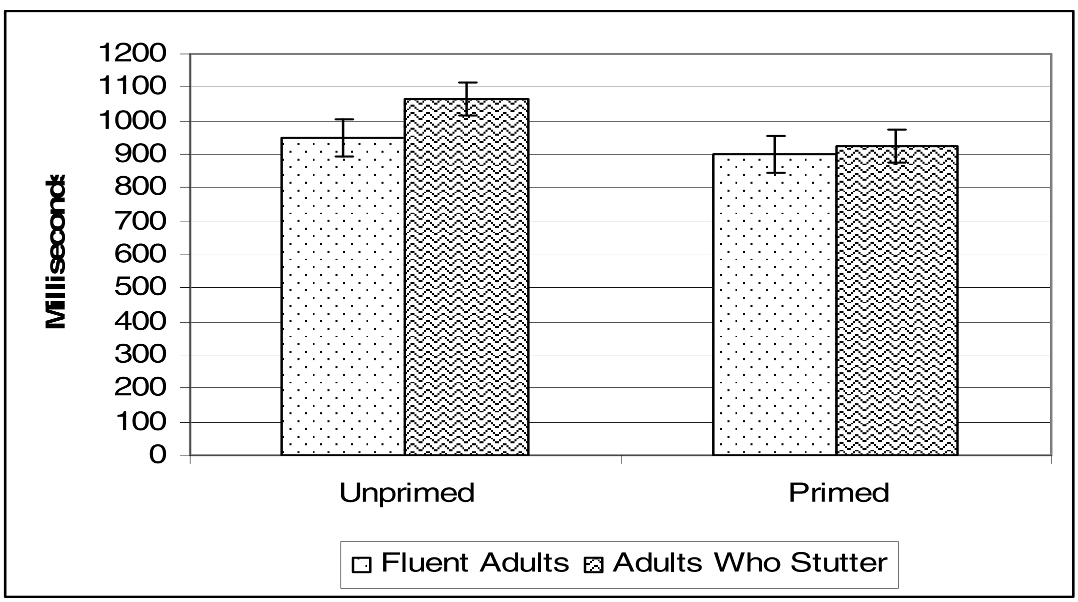
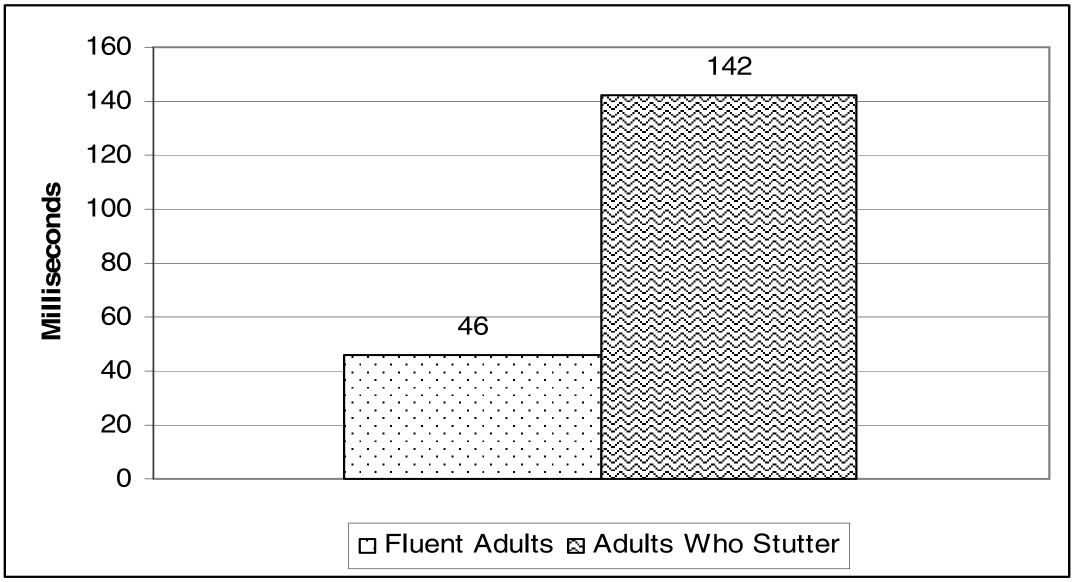


Figure 8. Mean speech initiation time differences (msec) between the unprimed and primed conditions for each group in Experiment 2.



[F_1 (1, 28) = 11.147, $p < .002$, partial $\eta^2 = .285$] by subjects but only approached significance by items [F_2 (1, 63) = 3.722, p = .058].

A number of t-tests were performed to investigate the significant differences between the two groups and the two different priming conditions. Within the fluent group, t-test analyses revealed a significant difference [t(1,14) = 3.697, p = .002, d = 0.253] between the primed and unprimed conditions. The group of adults who stutter also showed a significant difference between the priming conditions [t(1, 14) = 5.653, p < .0001, d = 0.732]. Within the unprimed condition, the fluent speakers and adults who stutter exhibited no significant difference [t(1, 28) = 1.644, p = .111, d = 0.598]. Moreover, the primed condition showed no significant difference between groups [t(1, 28) = 0.346, p = .732, d = 0.123].

Another analysis was a correlation between priming and syntactic complexity. A priming facilitation score was created for each subject by subtracting the primed speech initiation times from the unprimed speech initiation times. Subjects' facilitation scores were correlated with their mean speech initiation times for the long-high syntactic complexity sentences. For the fluent group, the correlation was not significant ($r = .307$, $p = .265$), but the adults who stutter showed a significant correlation between high syntactic complexity and priming facilitation ($r = .678$, $p = .005$). This indicates that the disfluent adults who had the greatest difficulty with syntactic complexity also showed the greatest facilitation with sentence structure priming.

Subjects' facilitation scores and mean speech initiation times for the long-high syntactic complexity condition are depicted in a scatter plot in Figure 9. The scatter plot of all the subjects that participated in both studies depicts 10 adults who stutter who appear to form a subgroup within the experimental group. Their linguistic abilities appear to differ from the fifteen fluent speakers and the other five adults who stutter. Five of the adults who stutter appear to mirror the fluent speakers.

Figure 10 shows the mean speech initiation time for the long-high complexity condition for all of the fluent adults, the five adults who stutter that appear to mirror the fluent adults, and the ten adults who stutter that seem to stand apart. As can be seen from this bar graph, the subgroup of ten adults who stutter that had the slowest speech initiation times in the long-high complexity condition were, on average, 210 milliseconds slower than the fluent group. Moreover, the speech initiation times of the other subgroup of adults who stutter ($N = 5$) were closer to the fluent group. This subgroup differed by an average of 50 milliseconds from the fluent group.

Figure 9. Scatter plot of speech initiation times (msec) in the high complexity condition in the Experiment 1 and facilitation effects (msec) in Experiment 2.

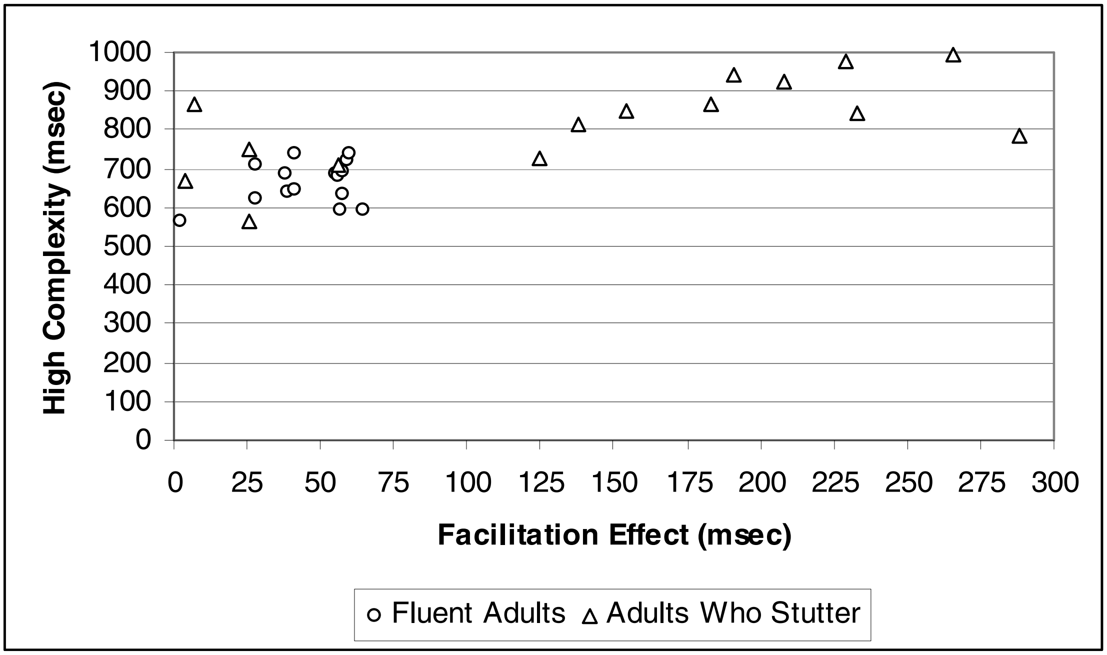
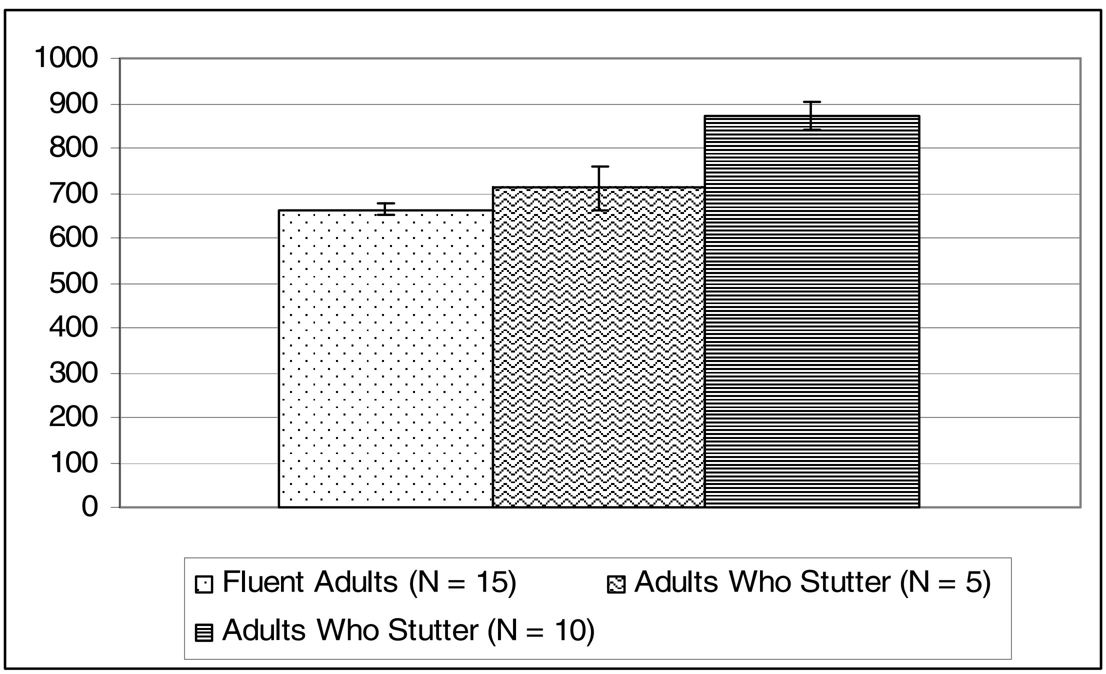


Figure 10. Mean speech initiation times of sentences in the long-high complexity condition of the fluent adults speakers and two subgroups of adults who stutter.



The subgroup of ten adults who stutter who showed greater complexity effects relative to other subjects also showed greater priming effects relative to others. Figure 11 depicts the mean speech initiation time difference for the fluent adults and the two subgroups of adults who stutter. Apparent from this visual analysis is the difference between the two subgroups of adults who stutter. The ten adults who stutter who had the slowest speech initiation time in the long-high complexity condition also showed the greatest mean facilitation effect (201 milliseconds). On the other hand, the remaining five adults who stutter had a mean facilitation effect of only 23 milliseconds, an effect that was less than the average of 45 milliseconds found in the fluent group.

Figure 12 shows the mean speech initiation time in the unprimed condition for the mild, moderate, and severe adults who stutter. As shown in figure 12, moderate and severe stuttering subjects had the slowest mean speech initiation times (compared to mild adults who stutter) in utterances that did not contain any disfluencies.

The speech initiation time differences between the unprimed and primed conditions were compiled for the three different severity levels of adults who stutter. This is shown in figure 13. The mild adults who stutter showed a mean difference of 151 milliseconds. The moderate and severe adults who stutter had mean differences of 101 and 266, respectively. It appears, then, that the severe stutterer was more facilitated by priming than were the mild and moderate stutterers. However, due to the very low number of subjects within each level of severity, these data should be interpreted with caution.

Figure 11. Mean speech initiation time difference (msec) between the unprimed and primed conditions for the fluent adults and two subgroups of adults who stutter in Experiment 2.

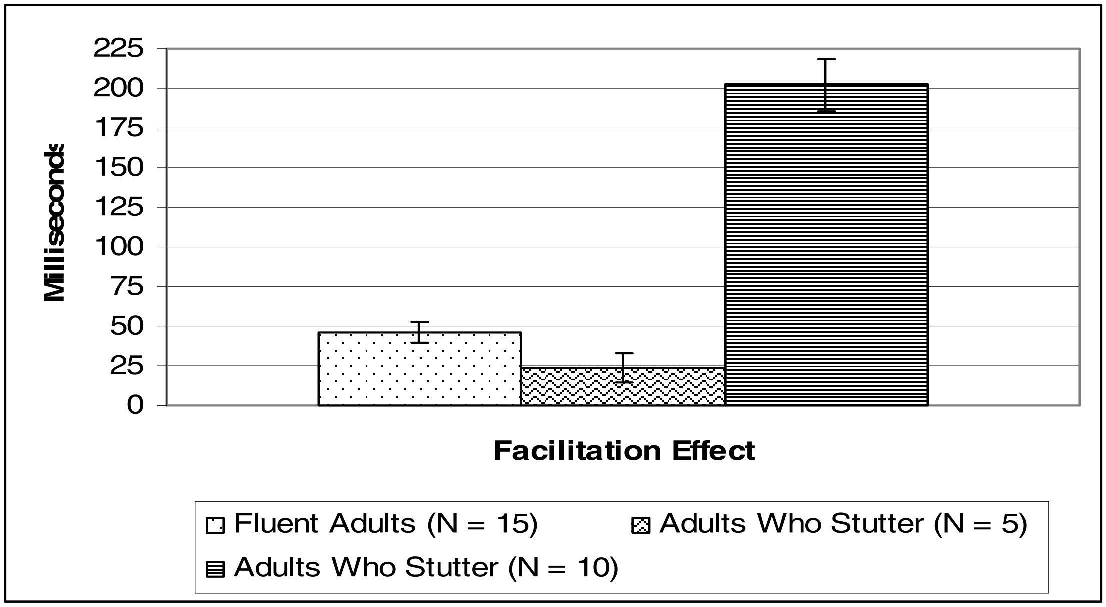


Figure 12. Mean speech initiation times (msec) for the three stuttering severity levels within the group of adults who stutter in the unprimed condition.

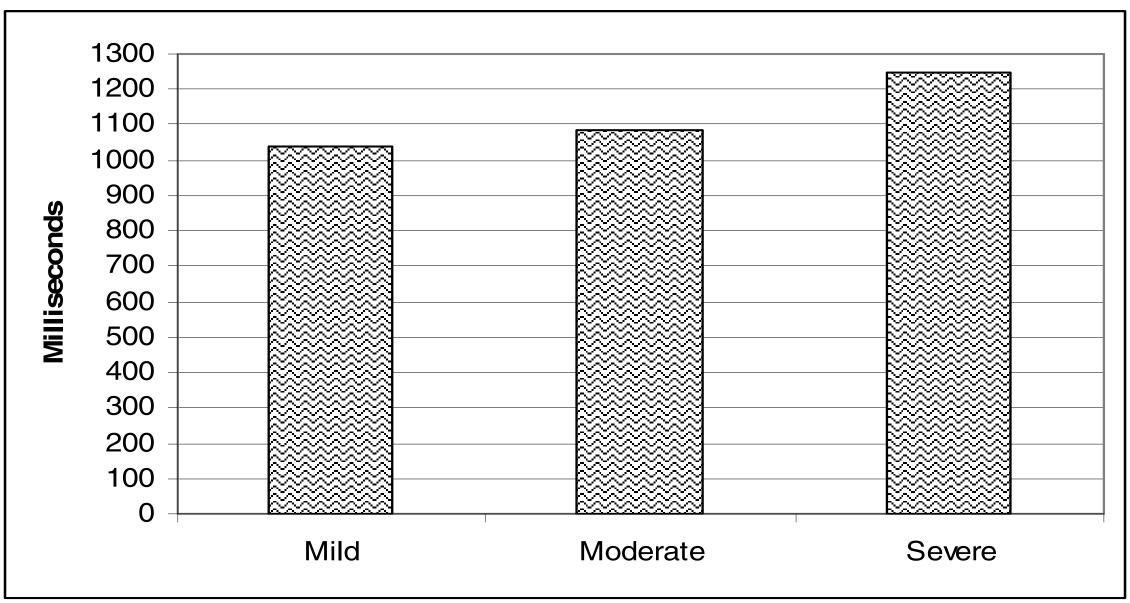
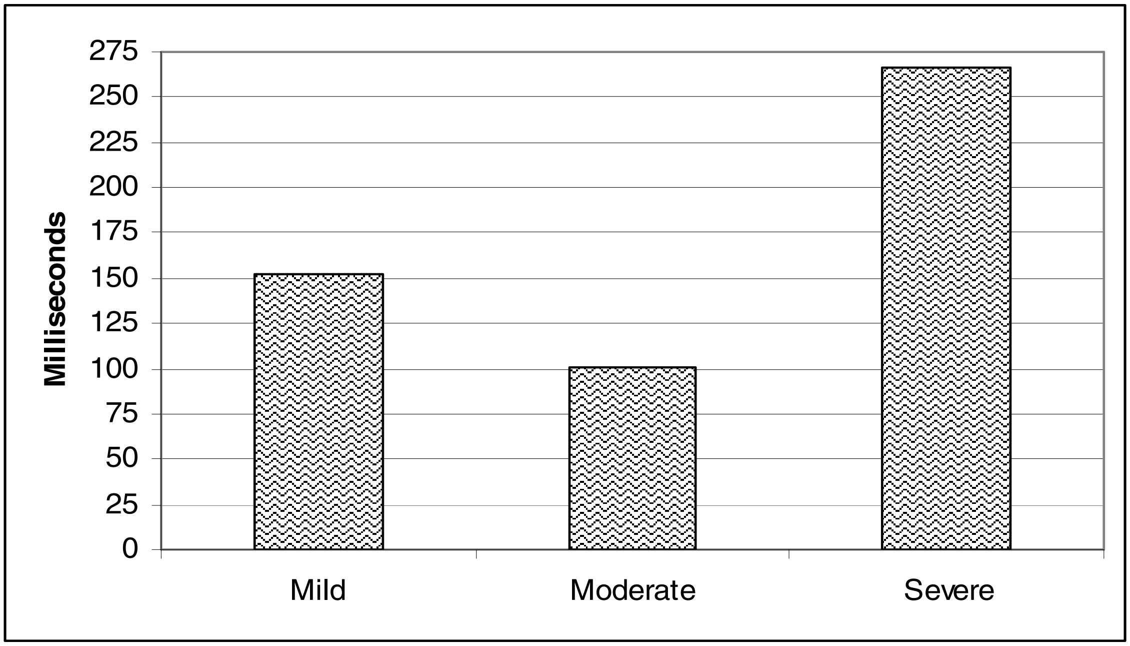


Figure 13. Mean speech initiation time difference (msec) between the unprimed and primed conditions for the three stuttering severity levels within the group of adults who stutter.



Speech Disfluency Analyses

Speech disfluencies, defined as sound/syllable repetitions, sound prolongations, and atypical pauses in speech, were collected in an attempt to analyze any differences between groups and conditions. The total number of target sentences that contained speech disfluencies for all the individuals (fluent adults and adults who stutter) across the two conditions (unprimed and primed conditions) are shown in Appendix I. Table 4 shows the total number of target sentences that contained speech disfluencies for the two groups across two conditions. Not surprisingly, the group of adults who stutter had more speech disfluencies in the unprimed and primed conditions than the fluent adults. Due to the low number of target utterances that contained speech disfluencies, a 2 x 2 Chi Square

Table 4. Total number and percentage of target sentences that contained speech disfluencies for the two groups across two condition types in Experiment 2.

	Unprimed	Primed
Fluent Adults (N=15)	4 (1.66%)	3 (1.25%)
Adults Who Stutter (N=15)	26 (10.80%)	18 (7.5%)

was used to analyze the total number of fluent sentences. The pattern of disfluencies did not differ significantly between the two groups ($x^2 = 0.059$).

DISCUSSION

The primary purpose of the present study was to assess the grammatical planning and formulation abilities of adults who stutter. This process in adults who stutter was hypothesized to be somewhat slower or less efficient than in adults who do not stutter. One prediction was that adults who stutter, when compared to adults who do not stutter, would exhibit significantly different speech initiation times in conditions that manipulated syntactic complexity or sentence structure primes. The first and second experiments manipulated syntactic complexity and structural priming of sentences, respectively, in an attempt to gain some insight into the time course of grammatical planning and formulation. In both experiments, speech initiation times and number of speech disfluencies were collected.

The overall study resulted in five main findings: (a) speech initiation times of adults who stutter were inhibited more by syntactic complexity than in fluent adults; (b) speech initiation times of adults who stutter were facilitated more by sentence structure priming than in fluent adults; (c) adults who stutter that had the greatest difficulty with syntactic complexity also showed the greatest facilitation with sentence structure priming; (d) adults who stutter are composed of at least two subgroups; (e) adults who stutter exhibited more speech disfluencies than did adults who do not stutter across all conditions, but those differences were not significant.

Main Findings of Speech Initiation Time and Syntactic Complexity

One goal of this study was to determine if syntactic complexity influences the time course of grammatical encoding and sentence production, as measured by speech initiation time. Materials for the first experiment were those used by Ferreira (1991). The long sentences had eight (low complexity), nine (medium complexity), or twelve (high complexity) syntactic nodes in the structural representation of each subject noun phrase, and this determined the syntactic complexity of each sentence. The length of these sentences, defined as the number of words and syllables, was kept constant in an attempt to limit any confounding influences related to lexical, phonological, or articulatory processes.

For all the subjects that participated in the first experiment, on average, speech initiation times increased in relation to syntactic complexity. For example, in the long-low syntactic complexity condition, average speech initiation time for all subjects was 593 milliseconds, whereas the speech initiation time increased to 679 and 741 milliseconds in the long-medium and long-high syntactic complexity conditions, respectively. Differences among the speech initiation times of the three long conditions were all statistically significant. These data replicate Ferreira's (1991) study and confirm the hypothesis that the generation of more complex syntactic structures during sentence production entails processing costs and affects rapidity of utterance generation.

As a group, the fluent adults had faster mean speech initiation times across the four conditions when compared to adults who stutter. The mean speech initiation time across all four conditions was 596 milliseconds for fluent adults, whereas the mean for adults who stutter was 694 milliseconds. The results of this study support the findings of other investigations (Adams & Hayden, 1976; Bakker & Brutten, 1989; Bishop, Williams, & Cooper, 1991; Cross & Luper, 1979; Dembowski & Watson, 1991; Logan, 2003; and Watson & Alfonso, 1987) that indicated significantly slower overall speech initiation times for the fluent utterances of adults who stutter relative to fluent speakers. For example, in a recent similar study (Logan, 2003), the overall mean speech initiation time for the stuttering group was 132 milliseconds longer than that of the fluent group. However, many of the previous studies did not attempt to control confounding variables such as sentence length, semantics, and phonology and did not use sufficiently complex sentences. The current study is one of the few that attempted to satisfy these conditions. In it, the overall mean difference of speech initiation time in fluent utterances between fluent adults and adults who stutter was 98 milliseconds. In a comparison of the means between long-low vs. long-medium and long-medium vs. long-high in the current study, fluent adults showed increases of 56 and 40 milliseconds, respectively, both of which were statistically significant. In contrast, adults who stutter showed an increase of 115 milliseconds when complexity increased from low to medium and 84 milliseconds when complexity changed from medium to high. These differences were significant and indicate that both groups needed additional time for syntactic planning as the sentences increased in syntactic complexity. However, adults who stutter were clearly more inhibited by increasing complexity than were fluent adults.

An interesting trend between the groups was the increasing speech initiation time difference. For example, in the long-low syntactic complexity condition, the fluent group was 54 milliseconds faster than the adults who stutter, and this difference was not statistically significant. The difference between groups increased to 113 and 157 milliseconds in the medium and high syntactic complexity conditions, respectively, differences that were significant. This trend seems to indicate that syntactic complexity affects the sentence production of adults who stutter to a greater degree than it affects fluent adults. In other words, the processing costs associated with syntactic complexity appear to be greater in adults who stutter than in fluent adults. It is reasonable to assume that this reflects the less efficient generation by stutterers of sentence structures required for sentence production. It is important to note that differences in speech initiation time cannot be attributed to speech disfluencies of the adults who stutter, as these were not included in the analyses. The significant differences in speech initiation time were found in fluent utterances only. Also, the differences in speech initiation time cannot be attributed to speech motor programming that is required for articulation of phonemes and syllables, as this variable was kept constant for all the sentences throughout the conditions.

Another interesting trend, which should be interpreted with caution (due to the very low number of subjects), is the analysis of speech initiation times in relation to each subject's stuttering severity classification. The adults who stutter were divided into three different categories according to stuttering severity (mild, moderate, and severe) levels as determined by the Stuttering Severity Instrument (Riley, 1994). The main reason for this analysis was to determine if a person's stuttering severity classification impacts the time required for the generation of fluent sentences, and if syntactic complexity affects one category of adults who stutter more than another category. Analyses of these data showed that the adults who stutter mildly had the fastest mean speech initiation time in the long-low and long-high syntactic complexity conditions. In the long-medium condition, the moderate adults who stutter had the fastest mean speech initiation time. Thus, the relationship between stuttering severity and speech initiation time is suggestive, but imperfect. In all the conditions, the one person who was categorized as severe had the slowest mean speech initiation time; this leaves open the possibility that severity may be related to syntactic planning and processing inefficiencies. This suggestive finding warrants additional research into the variables that may differentiate subgroups of adults who stutter.

Main Findings of Speech Initiation Time and Sentence Structure Priming

One purpose of this experiment was to determine if sentence structure priming reduces the time dedicated to the generation of sentence structure, thereby reducing the language processing costs to the speaker and promoting rapidity of sentence production. The sentence structure priming data revealed that all subjects exhibited shorter speech initiation times following a sentence that contained a related sentence structure (primed) than following one with an unrelated structure (unprimed). For example, the mean speech initiation time for all subjects in the unprimed condition was 1007 ms, whereas the mean speech initiation time was reduced to 912 milliseconds in the primed condition, a statistically significant difference. These data replicate Smith and Wheeldon's (2001) finding that syntactic priming facilitates the generation of sentence structure in the sentence that follows the priming sentence. In Smith and Wheeldon's (2001) study the speakers were facilitated by 55 milliseconds, whereas the speakers in the current study were facilitated by 95 milliseconds. The main reason for the large speech initiation time difference between Smith and Wheeldon's (2001) study and the current study was the inclusion of adults who stutter, which increased the overall mean.

Another purpose of this experiment was to analyze sentence structure priming and its facilitation effect in adults who stutter. A goal of the current study was to determine if facilitation effects in adults who stutter are the same or different relative to fluent adults. It was hypothesized that subtle deficits or inefficient generation of sentence structure in adults who stutter would result in a greater facilitation by priming in stutterers relative to non-stutterers. The results of Experiment 2 supported this speculation. Data showed that fluent speakers had faster speech initiation times across the two conditions when compared to adults who stutter. Fluent adults had mean speech initiation times of 948 and 900 milliseconds in the unprimed and primed conditions, respectively, whereas the adults who stutter had means of 1066 and 923 ms in the same conditions.

Within the fluent group, the difference between the unprimed and primed conditions was 48 milliseconds. In other words, fluent speakers that were primed with related sentence structures reduced their syntactic processing cost by an average of 48 milliseconds. In contrast, adults who stutter reduced their syntactic processing cost by an average of 143 milliseconds when primed with related sentence structures. This trend indicates that adults who stutter benefit more from sentence structure priming than do fluent adults, and the beneficial effect appears to "normalize" the mean speech initiation times of adults who stutter with that of fluent adults. Anderson and Conture (2004) found similar results with their sentence structure priming study of young children who do and do not stutter. Children who stutter were significantly faster by approximately 212 milliseconds in the sentence structure priming condition than in the unprimed condition; however, for children who do not stutter, the mean speech initiation time difference was only 51 milliseconds between the unprimed and sentence structure priming conditions.

An interesting trend to note between the groups is the decreasing speech initiation time difference. For example, in the unprimed condition, the fluent group is 118 milliseconds faster than the adults who stutter (948 ms vs. 1066 ms). The speech initiation time difference decreases to 23 milliseconds in the primed condition (900 ms vs. 923 ms). The differences across groups and conditions create a significant interaction.

Associations Between Syntactic Complexity and Sentence-Structure Priming

One of the most interesting outcomes of the study was the finding that adults who stutter who had the greatest difficulty with syntactic complexity also showed the greatest facilitation with sentence structure priming. Figure 9 clearly showed ten adults who stutter who appeared to stand out from the rest of the speakers. Their speech initiation times and facilitation effects were obviously different from the fifteen fluent speakers and the other five adults who stutter. Interestingly, these five had mean speech initiation times and priming effects that seemed to mirror those of fluent adults. For example, as depicted in figure 10, the mean speech initiation time for the long-high complexity condition was 712 milliseconds for the five and 662 milliseconds for all of the fluent adults. In contrast, the ten adults who stutter that stood apart from the overall group had a mean speech initiation time of 872 milliseconds in the same condition. A similar trend was seen in the priming effect. The ten adults who stutter that were affected most by syntactic complexity also showed the most syntactic priming. These ten individuals showed a mean priming effect of 201 milliseconds, whereas the five adults who stutter that mirrored the fluent adults showed a mean priming effect of 24 milliseconds. This demonstrates that the significant differences found between the fifteen fluent adults and fifteen adults who stutter in both studies can be attributed to a subgroup of only ten adults who stutter. The identification of a subgroup within the current study is an important finding and warrants additional discussion.

Subgroups

The idea of subgroups (Conture, 2001; Schwartz & Conture, 1986) is not new to the field of stuttering, and the present findings support the idea that the psycholinguistic abilities of adults who stutter are heterogeneous and not homogeneous. A number of researchers and experts in stuttering have theorized that different causes can lead to speech disfluency (Conture, 2001; Guitar, 2006; Shapiro, 1999; Smith & Kelly, 1997), and the current study appears to support a grammatical encoding deficit in some adults who stutter, but not all. Conture (2001) wrote that a number of psycholinguistic factors are involved in stuttering, and the level of involvement of each factor may be dissimilar in different speakers who stutter. In Conture's (2001) view, inefficient psycholinguistic factors can center on any of the following components: lexical retrieval, syntactic encoding, phonological encoding, or motor execution. The processing efficiency of these language production mechanisms interact within each speaker to produce fluent speech, and individual abilities can differ among speakers (Conture, 2001). In support of Conture's hypothesis regarding inefficient psycholinguistic processing, a recent lexical priming experiment (Pellowski & Conture, 2005) demonstrated that speakers who stutter were significantly slower in response to semantically related primes, whereas speakers who do not stutter were significantly faster. According to spreading activation theory (Collins & Loftus, 1975), word nodes that are stored in the mental lexical of speakers who stutter may be interconnected weakly or inefficiently. Another study (Anderson &

Conture, 2004) found that speakers who stutter exhibited a greater syntactic priming effect than speakers who do not stutter. According to Anderson and Conture (2004), these findings may indicate that speakers who stutter are less skilled at generating sentence structures, and syntactic priming boosts the computational resources available for syntactic processing. This hypothesis is confirmed by the adults in the current study.

Similar to Conture (2001), Shapiro (1999) speculated that speech fluency can be influenced by many factors, such as speech and language processing, speech motor coordination, cognitive and learning potential, and social and emotional maturity. In terms of speech and language processing, several different models of stuttering that focus on an impaired or inefficient language mechanism have been developed by various writers (Kolk & Postma, 1997; Perkins, Kent, & Curlee, 1991; Wingate, 1988), and each model leads to the same result: stuttering. One model attributes stuttering to a breakdown in the ability of the person who stutters to quickly and efficiently attach the nucleus of the syllable with the onset of the syllable (Wingate, 1988). This breakdown leads to disfluencies due to an attempt by the speaker to buy time until the appropriate onset is attached to the appropriate syllable nucleus. A similar but somewhat broader model (Perkins et al., 1991) suggests that stuttering occurs when integration of the syllable frame and segment content becomes impaired. In other words, the creation of the syllable slot and retrieval of the segments that must go into the slot are operating inefficiently and not properly timed.

Perhaps the most well-known psycholinguistic model of stuttering is the covert repair hypothesis (Kolk & Postma, 1997). According to this hypothesis, the impairment is thought to center on phonological encoding. An increase in speaking rate and a slower rate of activation of phonological segments increases the chances for misselection of target segments, and this forces the speaker to repair the speech plan. When the speaker is able to repair the breakdown covertly, speech disfluency does not occur. At other times, when breakdown in phonological planning occurs and cannot be repaired covertly, a speaker produces overt speech disfluency.

All of the above psycholinguistic models of stuttering pinpoint a different linguistic deficit. The current study pinpoints the generation of syntactic structures in spoken sentence production. The important point to understand from all of the various psycholinguistic models of stuttering is that there are a number of linguistic deficits that can lead to stuttering, and it is highly unlikely that the same deficit is responsible for stuttering in the entire population of individuals who stutter. The most likely scenario is that the psycholinguistic deficits in adults who stutter vary, and rather than having a single cause, there are different causes for various subgroups of adults who stutter. In the current study, the subgroup that showed significant complexity and priming effects demonstrated an inefficient ability to construct or generate sentences, whereas the other subgroup that did not show such an effect may have a deficit in some other psycholinguistic domain, such as lexical retrieval, phonological encoding, or something within the speech motor system.

Unfortunately, very little research has been conducted on identifying subgroups of adults who stutter. However, the lack of research does not imply that this is not an area worthy of research. The opposite is true. Knowledge about the different subgroups that most likely exist within the population of adults who stutter should be useful to researchers in terms of subject selection and maximizing the ability to detect differences between adults who do and do not stutter. Perhaps unknowingly including different subgroups of adults who stutter in a small scale study, as are most published studies of adults who stutter, results in an inability to detect subtle differences in psycholinguistic and speech motor processes. In addition to its usefulness to researchers, the knowledge that a person belongs to a particular type of subgroup may aid clinicians in diagnosing stuttering and planning therapy accordingly (Conture, 2001). In sum, identifying subgroups by psycholinguistic deficit is an area that deserves additional research.

Speech Disfluencies, Syntactic Complexity, and Sentence-Structure Priming

Two of the research questions in the current study pertained to speech disfluencies. The prediction was that syntactic complexity or sentence structure priming would have some effect on speech disfluencies. This prediction assumed increased processing costs associated with higher syntactic complexity and the reduction in processing costs associated with sentence structure priming. Unfortunately, the fluent adults did not have many speech disfluencies, and this made statistical analyses difficult. Thus, observation of the data for speech disfluencies does not show any clear positive or negative trend. For example, out of 360 total target sentences across the four different conditions in Experiment 1, only 7 sentences were produced by fluent adults with speech disfluencies. In contrast, adults who stutter had a total of 44 target sentences that contained disfluencies out of a possible 360 sentences. The fact that adults who stutter had more speech disfluencies was an expected outcome, as these were individuals who were diagnosed with a fluency disorder. The interesting part of this outcome was the trend, as seen in figure 12, that disfluent target sentences tended to increase in relation to syntactic complexity. Even though this was not a statistically significant outcome, the trend is apparent and may signify that an increased processing cost associated with syntactic complexity may lead to increased speech disfluencies. Perhaps the differences would have reached significance if there were additional target sentences or adults who stutter, thereby allowing additional opportunities for target sentences to be produced disfluently. Another interesting finding was that, on average, the ten adults who stutter that were affected most by syntactic complexity and showed the most sentence structure priming also had fewer disfluent target sentences than did the five adults who stutter who seemed to mirror the fluent adults. For example, in the long-high syntactic complexity condition, the relevant five adults who stutter had eight disfluent target sentences (26.6%) out of thirty target sentences. In contrast, the ten adults who stutter had six disfluent target sentences (10.0%) out of sixty target sentences. This finding may indicate that the five adults who stutter who had faster speech initiation times relative to the other ten adults who stutter experienced a speed-accuracy trade-off. The five adults who stutter may have generated and produced sentences faster, but this led to a higher likelihood of speech breakdowns such as disfluency. This is an area that warrants additional research.

Theoretical Implications

Previous research has found that syntactic complexity is often associated with the frequency of stuttering (Bernstein Ratner & Sih, 1987; Gaines, Runyan, & Meyers, 1991; Logan & Lasalle, 1999). In addition, researchers found that stuttering often coincided with utterance-initial and clause-initial words when compared to other areas within a sentence (Wall, Starkweather, & Cairns, 1981). The majority of these studies demonstrate a relationship between syntactic factors and stuttering, but most stop short of attempting to identify the distinct grammatical operational deficits that may exist in individuals who stutter. The theoretical implication of the current study is that it supports the notion that adults who stutter have a specific weakness in grammatical processing, which inhibits their ability to rapidly construct a syntactic structure for sentence production.

We know that pre-production planning of an utterance must involve a number of psycholinguistic operations that must work efficiently on various levels. One psycholinguistic model of speech-language production (Levelt, 1989; Levelt, Roelofs, & Meyer, 1999) is a multistage, serial processing model that proposes several autonomous levels of language processing. The stages of this model include conceptual preparation, grammatical encoding, phonological encoding, and articulation. In terms of grammatical encoding in sentence production, we know that at least three kinds of operations exist: 1) determination of the sentence's meaning; 2) construction of an appropriate syntactic structure; and 3) the selection of the required lexical items (Garrett, 1975). Within Bock and Levelt's (1994) broad outline of the language production processes that every normal speaker follows, the current study seems to point toward inefficient grammatical encoding abilities in adults who stutter, and, more specifically, a subcomponent of positional processing called constituent assembly. Both positional processing and constituent assembly are subcomponents of grammatical encoding. In the constituent assembly stage of sentence production, the elements of a sentence are fixed as the language mechanism formulates a hierarchy for phrasal constituents that manage the order of word production and link the syntactic functions. It is very likely that a weakness in one area of language such as grammatical encoding will impact the timing of other language areas (e.g., phonological encoding, articulation, etc.), thereby increasing the potential for delayed speech initiation times or fluency breakdowns such as stuttering.

In the first experiment, the syntactic complexity of a sentence, as measured by the number of syntactic nodes, resulted in speech initiation times that became slower as the number of syntactic nodes increased. This outcome indicated that the generation of syntactic nodes or phrasal constituents taxed the language production processes, and this burden was exacerbated in adults who stutter. The increased burden associated with generating syntactic nodes or phrasal constituents led to delays in the overall sentence production process. This idea was supported by the significantly slower speech initiation times and the trend that showed an increase in speech disfluency as syntactic complexity and phrasal constituents were systematically manipulated under experimental conditions.

The second experiment provided additional support for the hypothesis that adults who stutter are inefficient in generating a syntactic structure prior to sentence production. This was evident because adults who stutter were much slower in the condition that did not contain a related sentence structure prime when compared to fluent adults. Then, when adults who stutter were primed with a related sentence-structure, which assisted the language production process of constructing an appropriate syntactic structure, the net result was a greater facilitation effect in adults who stutter than in fluent adults. By hypothesis, this outcome is due to the fact that fluent adults have normal abilities in generating sentence structure, and the reduction in processing cost is, therefore, limited. However, in speakers who have a deficient ability to generate sentence structure, the facilitation effect of related sentence structure primes will be enhanced because of the benefits that the primes provide for the inefficient system. This was exactly what occurred in the current study. Fluent adults exhibited facilitation effects of 46 milliseconds, whereas adults who stutter had facilitation effects of 142 milliseconds. In sum, these findings suggest that adults who stutter produced slower speech initiation times because their grammatical encoding systems were not as efficient as those of fluent adults, and related syntactic priming strengthened the ability to construct an appropriate sentence structure to a greater degree. In fact, the related sentence structure prime reduced the cost associated with sentence generation to a point that approached "normal" levels.

The finding that adults who stutter produced fewer target sentences with speech disfluencies during the primed condition than in the unprimed condition and in sentences with low syntactic complexity when compared to high syntactic complexity provided additional evidence for an inefficient ability to construct sentence-structures in a timely manner. In other words, the number of sentences with fluency breakdowns increased in conditions that stressed (e.g., increased syntactic complexity or absence of a related sentence-structure prime) the speaker's grammatical encoding skills.

It should be noted that time constraints were placed on the trials of the second experiment, as subjects were given only a few seconds to formulate appropriate sentence structure for the target sentences. If subjects were not able to formulate a sentence within the allowed time constraints, the trial would end and the following trial would begin. Perhaps the time constraints placed additional stress on the available resources for syntactic processing, and the significant facilitation effect caused by the sentence structure primes was a result of an easing the pressure on the already taxed syntactic processing system. Cuadrado and Weber-Fox (2003) found that on-line syntactic processing with time constraints became weaker in adults who stutter, as their study revealed that time-constrained grammatical processing led to an increase in errors in more syntactically complex sentences.

The theoretical implications of the current study leave many questions unanswered. One important yet unanswered question is as follows. If adults who stutter have an inefficient grammatical encoding ability, what triggers disfluency? Why are some sentences produced with disfluencies and others produced fluently? Perhaps the occurrence of disfluency is influenced by an interplay of concomitant factors such as time constraints (self-imposed or externally imposed), the syntactic complexity of the utterance, the speaker's ability to integrate an inefficient grammatical encoder with other linguistic processes (e.g., phonological encoding, articulation, etc), and the speaker's history with speech and language therapy. For example, if the computational resource of a speaker with an inefficient syntactic processing system is taxed via time constraints or syntactic complexity, thereby leading to a delay in generating the structure of an utterance, this will have consequences in overt articulation of the utterance. Consequences may include delayed speech initiation times or speech disfluencies. However, a variable that has not been examined in the current study is the influence of speech and language therapy and how this may influence psycholinguistic ability or whether an utterance is produced disfluently. All of the participants in the study had had various forms of speech and language therapy over time, and the effect on syntactic processing is unknown at this point.

Clinical Implications

The current study was not designed with the specific purpose of drawing clinical implications. However, the outcomes of the experiments provide the opportunity to speculate about how they can be applied to the clinical realm. Perhaps the most important finding is the demonstration that subtle syntactic and psycholinguistic inefficiencies are present in the linguistic system of individuals who stutter. If these subtle psycholinguistic processing deficits lead to or exacerbate disfluencies, then the development of tests that measure subtle psycholinguistic (e.g., grammatical encoding) strengths and weaknesses may allow a clinician to predict which children have a greater likelihood of stuttering into adulthood. Psycholinguistic tasks that measure subtle differences in children's linguistic processing, as opposed to standardized language tests that collect very general information, may enhance clinicians' ability to predict which children are at risk for stuttering in adulthood. Such tests would allow us to predict with greater accuracy which children who begin to stutter have a decreased likelihood of recovering from stuttering. In addition to predicting which children have deficits in their linguistic system, these psycholinguistic tests can indicate which methods may alleviate speech fluency breakdowns.

Another clinical implication is support for one of the most popular fluency enhancing techniques advocated by many speech-language pathologists. A reduced speech rate has been known to eliminate or significantly reduce stuttering (Guitar, 2006). Researchers have speculated that the beneficial effect of slow speech on fluency may be due to a number of factors. Slower speech may allow the speech motor system time to integrate and coordinate all of the muscles and articulators required for fluent speech.

However, slow speech may also provide more time for the speaker to encode grammatical structures. In other words, if an inefficient grammatical encoder is given enough time to successfully plan and generate the structure of an utterance, then the chances for a fluency breakdown should be reduced.

An additional therapy technique that may be supported by psycholinguistic research is the use of priming in establishing or increasing fluency. In a study (Andrews, Howie, Dozsa, & Guitar, 1982) that investigated stuttering in different fluency-inducing conditions, shadowing another speaker or repeating what they say immediately afterwards was found to reduce stuttering. The reason for the increased fluency was unclear. However, in the psycholinguistic arena, listening to a sentence and repeating the sentence immediately afterward most likely primes the psycholinguistic system of a speaker, thereby reducing the processing cost. In theory, a reduction in psycholinguistic processing cost should reduce the likelihood of a breakdown (i.e., speech disfluency) in a speaker with an inefficient psycholinguistic system. This is another area that deserves additional research.

Future Research

A number of potential areas for future research are warranted. The first and foremost aim should be to replicate the findings of this particular study with additional tasks and a greater number of adults who stutter. This would serve two general purposes. First, a replication would confirm that adults who stutter have subtle grammatical encoding deficits and results can be generalized to the adult stuttering population with more confidence. The second purpose would allow researchers to determine if subgroups exist within the population of adults who stutter. This study revealed that subgroups may exist, but any future research should make subgroups one of the focal points from the onset of the study. A way to examine subgroups in future studies is by analyzing stuttering severity levels and language processing in a number of different speaking tasks that manipulate lexical retrieval, grammatical encoding, and phonological encoding.

Conclusion

This study found that the speech initiation time of fluent adults and adults who stutter was influenced by the complexity of a sentence. A speaker required more time to initiate a more complex sentence than a less complex one, and this finding was magnified in adults who stutter. Another finding was that priming with related sentence structures created a facilitation effect, thereby reducing the cost involved with generating a sentence. Again, this was magnified in adults who stutter. These results were indicative of a subtle deficit or inefficiency in the grammatical encoding system of adults who stutter when compared to typical adults. Finally, there was an indication that subgroups may exist within the population of adults who stutter.

APPENDICES

Appendix A. Subjects' group affiliation, gender, age, and stuttering severity.

Group	Gender	Age	Stuttering Severity
FA 1	Male	31	-
FA 2	Male	25	-
FA 3	Male	40	-
FA 4	Female	22	-
FA 5	Male	24	-
FA 6	Male	26	-
FA 7	Male	35	-
FA 8	Male	36	-
FA 9	Male	20	-
FA 10	Male	21	-
FA 11	Male	28	-
FA 12	Male	34	-
FA 13	Male	28	-
FA 14	Female	25	-
FA 15	Male	38	-
AWS 1	Male	32	Moderate
AWS 2	Male	27	Mild
AWS 3	Male	38	Mild
AWS 4	Female	21	Mild
AWS 5	Male	25	Moderate
AWS 6	Male	24	Mild
AWS 7	Male	33	Moderate
AWS 8	Male	37	Mild
AWS 9	Male	22	Moderate
AWS 10	Male	21	Mild
AWS 11	Male	28	Mild
AWS 12	Male	35	Mild
AWS 13	Male	29	Severe
AWS 14	Female	26	Moderate
AWS 15	Male	39	Mild

Appendix B. Experimental Sentences of Varying Syntactic Complexity in Experiment 1.

Short Condition

1. The dog went to the pond that's next to the museum.
2. The customer asked for change from his ten dollar bill.
3. The rope was in the garage we just finished painting.
4. The student wanted a vacation in the Swiss Alps.
5. The girls played with the toys they got for Christmas.
6. The boxes were in the bedroom next to the stairs.
7. The movie had a sad ending that made everyone cry.
8. The doorknob sticks in the cold weather that we get in Edmonton.
9. The coyotes hunt in the hills that are next to the lake.
10. The player left the team that was threatening to trade him.
11. The lawyer won the case that had been covered in the newspapers.
12. The car belongs to the girl who we met at the dance club.
13. The river empties into the bay that borders the little town.
14. The doctor fired the nurse who was stealing drugs.
15. The torches burned in the city that won the Stanley Cup.
16. The hotel was near the train station everyone wants to restore.
17. The martians needed some fuel that contained unusual compounds.
18. The cake was served at the dinner that preceded the mayor's speech.
19. The birds flew into the forest that the company wants to chop down.
20. The troops marched through the woods that are full of bears.
21. The plane climbed higher into the sky that was clear and blue.
22. The horse bit the young child who was wearing a pink shirt.
23. The instructor taught the introductory course that's now a requirement.
24. The thief escaped from the police who were trying to catch him.

Long, Low Syntactic Complexity Condition

1. The big and hairy dog went to the pond that's next to the museum.
2. The tall and handsome customer asked for change from his ten dollar bill.
3. The small but heavy rope was in the garage we just finished painting.
4. The vain yet clever student wanted a vacation in the Swiss Alps.
5. The small and giggling girls played with the toys they got for Christmas.
6. The small yet awkward boxes were in the bedroom next to the stairs.
7. The short but tedious movie had a sad ending that made everyone cry.
8. The round and shiny doorknob sticks in the cold weather that we get in Edmonton.
9. The strong and agile coyotes hunt in the hills that are next to the lake.
10. The proud but gifted player left the team that was threatening to trade him.
11. The tough and angry lawyer won the case that had been covered in the newspapers.
12. The large but foreign car belongs to the girl who we met at the dance club.
13. The large and raging river empties into the bay that borders the little town.
14. The old and friendly doctor fired the nurse who was stealing drugs.
15. The dim but flaming torches burned in the city that won the Stanley Cup.

16. The old yet fancy hotel was near the train station everyone wants to restore.
17. The green yet friendly martians needed some fuel that contained unusual compounds.
18. The rich and tasty cake was served at the dinner that preceded the mayor’s speech.
19. The large yet fragile birds flew into the forest that the company wants to chop down.
20. The young and fearless troops marched through the woods that are full of bears.
21. The small but mighty plane climbed higher into the sky that was clear and blue.
22. The young but tired horse bit the young child who was wearing a pink shirt.
23. The friendly and kind instructor taught the introductory course that’s now a requirement.
24. The smart but crafty thief escaped from the police who were trying to catch him.

Long, Medium Syntactic Complexity Condition

1. The dog in Dad’s garden went to the pond that’s next to the museum.
2. The customer at Sam’s market asked for change from his ten dollar bill.
3. The rope behind my shed was in the garage we just finished painting.
4. The student at Bonn’s metro wanted a vacation in the Swiss Alps.
5. The girls in Jane’s sandbox played with the toys they got for Christmas.
6. The boxes on his workbench were in the bedroom next to the stairs.
7. The movie in our theatre had a sad ending that made everyone cry.
8. The doorknob on our entrance sticks in the cold weather that we get in Edmonton.
9. The coyotes of those mountains hunt in the hills that are next to the lake.
10. The player in the outfield left the team that was threatening to trade him.
11. The lawyer in Steve’s courtroom won the case that had been covered in the newspapers.
12. The car on York’s highway belongs to the girl who we met at the dance club.
13. The river near their city empties into the bay that borders the little town.
14. The doctor at her clinic fired the nurse who was stealing drugs.
15. The torches on their building burned in the city that won the Stanley Cup.
16. The hotel on our ravine was near the train station everyone wants to restore.
17. The martians from this spacecraft needed some fuel that contained unusual compounds.
18. The cake in Bill’s oven was served at the dinner that preceded the mayor’s speech.
19. The birds in your bushes flew into the forest that the company wants to chop down.
20. The troops from their barracks marched through the woods that are full of bears.
21. The plane under thick clouds climbed higher into the sky that was clear and blue.
22. The horse in Sue’s pasture bit the young child who was wearing a pink shirt.
23. The instructor from King’s college taught the introductory course that’s now a requirement.
24. The thief on Pat’s rooftop escaped from the police who were trying to catch him.

Long, High Syntactic Complexity Condition

1. The dog that bites children went to the pond that's next to the museum.
2. The customer who was shopping asked for change from his ten dollar bill.
3. The rope that came apart was in the garage we just finished painting.
4. The student who was reading wanted a vacation in the Swiss Alps.
5. The girls who were laughing played with the toys they got for Christmas.
6. The boxes that were empty were in the bedroom next to the stairs.
7. The movie that was premiering had a sad ending that made everyone cry.
8. The doorknob that is broken sticks in the cold weather that we get in Edmonton.
9. The coyotes that are hungry hunt in the hills that are next to the lake.
10. The player who missed practice left the team that was threatening to trade him.
11. The lawyer who was speaking won the case that had been covered in the newspapers.
12. The car that was rented belongs to the girl who we met at the dance club.
13. The river that stopped flooding empties into the bay that borders the little town.
14. The doctor who was quitting fired the nurse who was stealing drugs.
15. The torches that were costly burned in the city that won the Stanley Cup.
16. The hotel that just opened was near the train station everyone wants to restore.
17. The martians who had landed needed some fuel that contained unusual compounds.
18. The cake that was tasty was served at the dinner that preceded the mayor's speech.
19. The birds that are frightened flew into the forest that the company wants to chop down.
20. The troops that are training marched through the woods that are full of bears.
21. The plane that was leaving climbed higher into the sky that was clear and blue.
22. The horse that was training bit the young child who was wearing a pink shirt.
23. The instructor who was useless taught the introductory course that's now a requirement.
24. The thief who was cornered escaped from the police who were trying to catch him.

Appendix C. Randomized Latin square design for experimental sentences of varying syntactic complexity in Experiment 1.

Group 1

1. Many people over twenty-five years of age are deciding to get college degrees. F
2. Some journalists have been accused of misquoting their sources. F
3. The boxes were in the bedroom next to the stairs. Sh
4. The plane that was leaving climbed higher into the sky that was clear and blue. LH
5. The strong and agile coyotes hunt in the hills that are next to the lake. LL
6. Although the storm brought high winds, it did no damage. F
7. Because most people are living longer, employees in the twenty-first century will retire later. F
8. Students were subjected to numerous tests during the month of June. F
9. The river near their city empties into the bay that borders the little town. LM
10. The thief who was cornered escaped from the police who were trying to catch him. LH
11. Clams are considered a delicacy by many people. F
12. After the collapse of Ancient Greece, the Olympics were discontinued until modern times. F
13. The round and shiny doorknob sticks in the cold weather that we get in Edmonton. LL
14. Seven burglars were arrested by the police on Saturday night. F
15. Two police officers stopped the car during a routine traffic violation. F
16. Introduced by his assistant, the mayor began with an opening statement. F
17. The troops that are training marched through the woods that are full of bears. LH
18. A car hit the shoulder, turned over, and skidded to a stop. F
19. The martians from this spacecraft needed some fuel that contained unusual compounds. LM
20. The rope was in the garage we just finished painting. Sh
21. Tulips are flowers that grow from bulbs. F
22. The short but tedious movie had a sad ending that made everyone cry. LL
23. Many athletes are worried about drug testing. F
24. The girls played with the toys they got for Christmas. Sh
25. The student wanted a vacation in the Swiss Alps. Sh
26. All the children wanted to play a computer game. F
27. Comets usually fly by the earth at very high speeds. F
28. The tough and angry lawyer won the case that had been covered in the newspapers. LL
29. Insurance companies classify younger drivers as a risk category. F
30. Television news shows get some of their highest ratings during a disaster. F
31. While they were eating dinner, the young couple had a terrible argument. F
32. The birds that are frightened flew into the forest that the company wants to chop down. LH

33. The proud but gifted player left the team that was threatening to trade him. LL
34. The customer asked for change from his ten dollar bill. Sh
35. Winners of the state contest go to the national finals. F
36. The horse that was training bit the young child who was wearing a pink shirt. LH
37. Before the dog ate the food, the girl filled his water bowl. F
38. The torches on their building burned in the city that won the Stanley Cup. LM
39. The dog went to the pond that's next to the museum. Sh
40. The hotel on our ravine was near the train station everyone wants to restore. LM
41. African tribal masks are often imitated by Western sculptors. F
42. The doctor at her clinic fired the nurse who was stealing drugs. LM
43. The instructor who was useless taught the introductory course that's now a requirement. LH
44. The large but foreign car belongs to the girl who we met at the dance club. LL
45. Although the story was well-written, it was too unbelievable. F
46. Flying kites is a great thing to do on a summer afternoon. F
47. The cake in Bill's oven was served at the dinner that preceded the mayor's speech. LM
48. After several months of treatment, the young soldier was much improved. F

Group 2

1. All the children wanted to play a computer game. F
2. Two police officers stopped the car during a routine traffic violation. F
3. The thief escaped from the police who were trying to catch him. Sh
4. The torches that were costly burned in the city that won the Stanley Cup. LH
5. The birds flew into the forest that the company wants to chop down. Sh
6. Seven burglars were arrested by the police on Saturday night. F
7. The big and hairy dog went to the pond that's next to the museum. LL
8. The doorknob on our entrance sticks in the cold weather that we get in Edmonton. LM
9. The tall and handsome customer asked for change from his ten dollar bill. LL
10. Because most people are living longer, employees in the twenty-first century will retire later. F
11. Flying kites is a great thing to do on a summer afternoon. F
12. The player in the outfield left the team that was threatening to trade him. LM
13. Although the storm brought high winds, it did no damage. F
14. After several months of treatment, the young soldier was much improved. F
15. The martians who had landed needed some fuel that contained unusual compounds. LH
16. Insurance companies classify younger drivers as a risk category. F
17. The plane climbed higher into the sky that was clear and blue. Sh
18. The horse bit the young child who was wearing a pink shirt. Sh
19. Many athletes are worried about drug testing. F
20. The hotel that just opened was near the train station everyone wants to restore. LH
21. Although the story was well-written, it was too unbelievable. F
22. Winners of the state contest go to the national finals. F
23. The small but heavy rope was in the garage we just finished painting. LL

24. Tulips are flowers that grow from bulbs. F
25. The small and giggling girls played with the toys they got for Christmas. LL
26. Many people over twenty-five years of age are deciding to get college degrees. F
27. The movie in our theatre had a sad ending that made everyone cry. LM
28. The small yet awkward boxes were in the bedroom next to the stairs. LL
29. After the collapse of Ancient Greece, the Olympics were discontinued until modern times. F
30. Students were subjected to numerous tests during the month of June. F
31. The vain yet clever student wanted a vacation in the Swiss Alps. LL
32. African tribal masks are often imitated by Western sculptors. F
33. Introduced by his assistant, the mayor began with an opening statement. F
34. Before the dog ate the food, the girl filled his water bowl. F
35. The coyotes of those mountains hunt in the hills that are next to the lake. LM
36. The instructor taught the introductory course that's now a requirement. Sh
37. Clams are considered a delicacy by many people. F
38. Television news shows get some of their highest ratings during a disaster. F
39. The lawyer in Steve's courtroom won the case that had been covered in the newspapers. LM
40. The doctor who was quitting fired the nurse who was stealing drugs. LH
41. Comets usually fly by the earth at very high speeds. F
42. The car on York's highway belongs to the girl who we met at the dance club. LM
43. A car hit the shoulder, turned over, and skidded to a stop. F
44. The troops marched through the woods that are full of bears. Sh
45. The river that stopped flooding empties into the bay that borders the little town. LH
46. The cake that was tasty was served at the dinner that preceded the mayor's speech. LH
47. While they were eating dinner, the young couple had a terrible argument. F
48. Some journalists have been accused of misquoting their sources. F

Group 3

1. African tribal masks are often imitated by Western sculptors. F
2. Tulips are flowers that grow from bulbs. F
3. The river empties into the bay that borders the little town. Sh
4. The student at Bonn's metro wanted a vacation in the Swiss Alps. LM
5. Comets usually fly by the earth at very high speeds. F
6. Although the story was well-written, it was too unbelievable. F
7. The friendly and kind instructor taught the introductory course that's now a requirement. LL
8. Introduced by his assistant, the mayor began with an opening statement. F
9. The smart but crafty thief escaped from the police who were trying to catch him. LL
10. The young but tired horse bit the young child who was wearing a pink shirt. LL
11. Two police officers stopped the car during a routine traffic violation. F
12. A car hit the shoulder, turned over, and skidded to a stop. F
13. The coyotes that are hungry hunt in the hills that are next to the lake. LH
14. Television news shows get some of their highest ratings during a disaster. F

15. The rope behind my shed was in the garage we just finished painting. LM
16. Seven burglars were arrested by the police on Saturday night. F
17. Insurance companies classify younger drivers as a risk category. F
18. Many people over twenty-five years of age are deciding to get college degrees. F
19. The girls in Jane's sandbox played with the toys they got for Christmas. LM
20. The martians needed some fuel that contained unusual compounds. Sh
21. The car that was rented belongs to the girl who we met at the dance club. LH
22. While they were eating dinner, the young couple had a terrible argument. F
23. Winners of the state contest go to the national finals. F
24. The young and fearless troops marched through the woods that are full of bears. LL
25. The doctor fired the nurse who was stealing drugs. Sh
26. Many athletes are worried about drug testing. F
27. The dog in Dad's garden went to the pond that's next to the museum. LM
28. After several months of treatment, the young soldier was much improved. F
29. The torches burned in the city that won the Stanley Cup. Sh
30. Students were subjected to numerous tests during the month of June. F
31. Because most people are living longer, employees in the twenty-first century will retire later. F
32. The cake was served at the dinner that preceded the mayor's speech. Sh
33. After the collapse of Ancient Greece, the Olympics were discontinued until modern times. F
34. The doorknob that is broken sticks in the cold weather that we get in Edmonton. LH
35. Flying kites is a great thing to do on a summer afternoon. F
36. The boxes on his workbench were in the bedroom next to the stairs. LM
37. The large yet fragile birds flew into the forest that the company wants to chop down. LL
38. The customer at Sam's market asked for change from his ten dollar bill. LM
39. Although the storm brought high winds, it did no damage. F
40. Clams are considered a delicacy by many people. F
41. The player who missed practice left the team that was threatening to trade him. LH
42. The small but mighty plane climbed higher into the sky that was clear and blue. LL
43. The lawyer who was speaking won the case that had been covered in the newspapers. LH
44. The hotel was near the train station everyone wants to restore. Sh
45. All the children wanted to play a computer game. F
46. The movie that was premiering had a sad ending that made everyone cry. LH
47. Some journalists have been accused of misquoting their sources. F
48. Before the dog ate the food, the girl filled his water bowl. F

Group 4

1. Because most people are living longer, employees in the twenty-first century will retire later. F
2. Winners of the state contest go to the national finals. F

3. The lawyer won the case that had been covered in the newspapers. Sh
4. The birds in your bushes flew into the forest that the company wants to chop down. LM
5. Many athletes are worried about drug testing. F
6. The troops from their barracks marched through the woods that are full of bears. LM
7. Although the story was well-written, it was too unbelievable. F
8. The rich and tasty cake was served at the dinner that preceded the mayor’s speech. LL
9. Clams are considered a delicacy by many people. F
10. The car belongs to the girl who we met at the dance club. Sh
11. The plane under thick clouds climbed higher into the sky that was clear and blue. LM
12. The girls who were laughing played with the toys they got for Christmas. LH
13. Two police officers stopped the car during a routine traffic violation. F
14. The old yet fancy hotel was near the train station everyone wants to restore. LL
15. The rope that came apart was in the garage we just finished painting. LH
16. African tribal masks are often imitated by Western sculptors. F
17. The large and raging river empties into the bay that borders the little town. LL
18. Introduced by his assistant, the mayor began with an opening statement. F
19. After the collapse of Ancient Greece, the Olympics were discontinued until modern times. F
20. The customer who was shopping asked for change from his ten dollar bill. LH
21. Although the storm brought high winds, it did no damage. F
22. Flying kites is a great thing to do on a summer afternoon. F
23. Before the dog ate the food, the girl filled his water bowl. F
24. The horse in Sue’s pasture bit the young child who was wearing a pink shirt. LM
25. Tulips are flowers that grow from bulbs. F
26. The doorknob sticks in the cold weather that we get in Edmonton. Sh
27. Insurance companies classify younger drivers as a risk category. F
28. The dog that bites children went to the pond that’s next to the museum. LH
29. The coyotes hunt in the hills that are next to the lake. Sh
30. The boxes that were empty were in the bedroom next to the stairs. LH
31. A car hit the shoulder, turned over, and skidded to a stop. F
32. While they were eating dinner, the young couple had a terrible argument. F
33. The student who was reading wanted a vacation in the Swiss Alps. LH
34. The movie had a sad ending that made everyone cry. Sh
35. The dim but flaming torches burned in the city that won the Stanley Cup. LL
36. All the children wanted to play a computer game. F
37. The instructor from King’s college taught the introductory course that’s now a requirement. LM
38. Many people over twenty-five years of age are deciding to get college degrees. F
39. The old and friendly doctor fired the nurse who was stealing drugs. LL
40. Some journalists have been accused of misquoting their sources. F
41. After several months of treatment, the young soldier was much improved. F
42. Comets usually fly by the earth at very high speeds. F

43. The player left the team that was threatening to trade him. Sh
44. The thief on Pat's rooftop escaped from the police who were trying to catch him. LM
45. Students were subjected to numerous tests during the month of June. F
46. The green yet friendly martians needed some fuel that contained unusual compounds. LL
47. Television news shows get some of their highest ratings during a disaster. F
48. Seven burglars were arrested by the police on Saturday night. F

Group Practice

1. The young and friendly executive left the company that was undergoing budget cuts.
2. The old but swift man played tennis with younger individuals who belonged to the tennis club.
3. The large parrot that was hungry ate the sunflower seeds that were next to his cage.
4. The black car that was driven by the thief sped onto the highway that leads away from the town.
5. The letter that was written by the student was placed in the mailbox that is next to the school.
6. The inactive volcano near their town is a popular tourist attraction during the summer months.
7. The rattlesnake in John's yard bit the fearless dog who was protecting the children in the backyard.
8. The fresh and tasty cookie that was baked this afternoon was served for dessert.
9. The president of the university wants to diversify the student population.
10. The most popular poker event of the year is the Las Vegas World Series of Poker Tournament.

Appendix D. Syntactic priming experimental sentences and block layout for Experiment 2.

Block 1 (Demonstration: The experimenter demonstrates the experiment by completing the sentences)

1. The horse moves up.
2. The fish and the car move up.
3. The spoon and the book move apart.
4. The tie and the fork move together.
5. The pig moves up and the candle moves down.
6. The knife moves down and the rose moves up.
7. They all move down. (duck, ear, key)
8. No picture appears.

Block 2 (Practice: The subject completes a practice block. There is a brief pause for feedback after each trial.)

1. The shoe moves up.
2. The fish and the cup move up.
3. They all move down. (mouse, bottle, pants)
4. The cat and the book move down.
5. No picture appears.
6. The hat and the duck move together.
7. The foot and the house move apart.
8. The car moves up.
9. They all move down. (nose, snowman, phone)
10. The table moves up and the clock moves down.
11. The leaf moves up.
12. The dice move down and the tie moves up.
13. No picture appears.
14. The fork and the stool move apart.
15. The snake and the ear move up.
16. The saw moves down.

Block 3 (Practice: The subject completes a second practice block. There is no pause between trials. Feedback is given at the end of the block.)

1. No picture appears.
2. The brush moves up.
3. The hand and the dog move together.
4. The sock and the frog move down.
5. The eye moves down and the horse moves up.
6. They all move down. (elephant, candle, pig)
7. The spoon and the key move down.
8. The church and the kite move together.
9. The swan moves down.
10. No picture appears.

11. The watch moves down and the candle moves up.
12. The rabbit and the arm move apart.
13. The mushroom moves down.
14. The rose moves down and the mouse moves up.
15. The gate moves up.
16. The carrot and the pig move together.

Block 4 (Practice: The subject completes a third practice block. There is no pause between trials. Feedback is given at the end of the block.)

1. The wall moves up.
2. No picture appears.
3. The rabbit and the arm move up.
4. The pig moves down and the finger moves up.
5. The scissors and the flag move together.
6. The stamp moves up.
7. The table and the door move down.
8. The candle and the pants move apart.
9. The mouse moves up and the bottle moves down.
10. The bridge moves down.
11. They all move up. (stamp, knife, door)
12. No picture appears.
13. The camel and the carrot move apart.
14. The knife moves up.
15. The rose and the umbrella move up.
16. The bottle moves down and the axe moves up.

Block 5 (Experimental: There is no break between trials during Block 5. There is a brief break at the end of Block 5.)

1. No picture appears.
2. The rose and the camel move up.
3. They all move up. (scissors, tent, flag)
4. The scissors and the tent move apart. (RELATED PRIME)
5. The snake and the eye move up. (TARGET)
6. The scissors move up.
7. The pig moves down and the finger moves up.
8. They all move down. (ladder, gate, bridge)
9. The flag and the carrot move together. (RELATED PRIME)
10. The ear and the spoon move down. (TARGET)
11. The candle moves up and the knife moves down. (UNRELATED PRIME)
12. The cat and the shoe move down. (TARGET)
13. No picture appears.
14. The mouse and the bottle move up.
15. The flag moves down.
16. They all move down. (ladder, gate, bridge)
17. The finger and the rabbit move down. (RELATED PRIME)
18. The saw and the horse move together. (TARGET)

19. They all move up. (scissors, tent, flag)
20. The mouse moves down and the anchor moves up.
21. The phone moves up and the snowman moves down.
22. The nose moves up and the umbrella moves down.
23. The table moves down and the pants move up. (UNRELATED PRIME)
24. The cup and the fish move apart. (TARGET)
25. The carrot moves up.
26. No picture appears.
27. The bottle and the door move together.
28. The rocket moves up and the elephant moves down.
29. No picture appears.
30. The anchor and the door move down.
31. No picture appears.
32. The elephant and the mushroom move up. (RELATED PRIME)
33. The brush and the swan move apart. (TARGET)
34. The finger moves down.
35. The table and the candle move apart.
36. The elephant moves up.
37. The door moves down and the hammer moves up. (UNRELATED PRIME)
38. The car and the hat move up. (TARGET)
39. The bottle moves up and the camel moves down. (UNRELATED PRIME)
40. The tie and the foot move together. (TARGET)

Block 6 (Experimental: There is no break between trials during Block 6. There is a brief break at the end of Block 6.)

1. The ladder moves down.
2. The pig and the rocket move apart.
3. They all move up. (scissors, tent, flag)
4. The arm moves up.
5. The rabbit and the mushroom move up.
6. They all move down. (ladder, gate, bridge)
7. The carrot moves down and the tent moves up.
8. The umbrella moves up and the rose moves down. (UNRELATED PRIME)
9. The stool and the duck move together. (TARGET)
10. The ladder and the gate move up. (RELATED PRIME)
11. The hand and the key move apart. (TARGET)
12. The pig moves down.
13. The wall moves up and the flag moves down.
14. No pictures appear.
15. The arm and the axe move down.
16. They all move down. (ladder, gate, bridge)
17. The bridge and the wall move apart. (RELATED PRIME)
18. The dog and the kite move up. (TARGET)
19. No pictures appear.
20. They all move up. (scissors, tent flag)
21. The nose moves up and the stamp moves down. (UNRELATED PRIME)

22. The book and the leaf move down. (TARGET)
23. The candle moves up.
24. The rose moves down and the candle moves up.
25. The ladder moves down and the bridge moves up.
26. No pictures appear.
27. The gate and the scissors move up.
28. No pictures appear.
29. The snowman moves down and the anchor moves up. (UNRELATED PRIME)
30. The fork and the dice move up. (TARGET)
31. The table moves down.
32. The elephant moves up and the finger moves down.
33. The door moves up.
34. The axe and the rocket move together. (RELATED PRIME)
35. The sock and the watch move down. (TARGET)
36. No pictures appear.
37. The arm and the pig move down. (RELATED PRIME)
38. The frog and the church move together. (TARGET)
39. The phone moves down and the mouse moves up. (UNRELATED PRIME)
40. The clock and the house move apart. (TARGET)

Block 7 (Experimental: There is no break between trials during Block 7. There is a brief break at the end of Block 7.)

1. The nose moves down.
2. The wall and the pig move up.
3. No pictures appear.
4. The phone and the door move down.
5. The snowman moves up.
6. The flag and the scissors move together.
7. They all move down. (ladder, gate, bridge)
8. The camel moves up and the hammer moves down.
9. The knife moves up and the umbrella moves down. (UNRELATED PRIME)
10. The shoe and the book move apart. (TARGET)
11. The pants move down and the nose moves up. (UNRELATED PRIME)
12. The fish and the stool move up. (TARGET)
13. The rose moves down.
14. The tent and the ladder move up. (RELATED PRIME)
15. The eye and the dog move together. (TARGET)
16. The phone moves up.
17. The carrot moves down and the candle moves up.
18. No pictures appear.
19. The camel moves down and the phone moves up.
20. They all move up. (scissors, tent, flag)
21. The hammer and the snowman move down.
22. They all move down. (ladder, gate, bridge)
23. The carrot and the bridge move apart. (RELATED PRIME)
24. The spoon and the hand move down. (TARGET)

25. The hammer moves up and the snowman moves down. (UNRELATED PRIME)
26. The hat and the fork move down. (TARGET)
27. The mouse moves down.
28. No pictures appear.
29. The stamp moves up and the arm moves down.
30. The rabbit moves up and the table moves down.
31. No pictures appear.
32. The mushroom and the axe move together. (RELATED PRIME)
33. The horse and the sock move up. (TARGET)
34. The anchor moves up.
35. The rabbit and the arm move down. (RELATED PRIME)
36. The swan and the frog move apart. (TARGET)
37. The umbrella moves down.
38. They all move up. (scissors, tent, flag)
39. The camel moves down and the phone moves up. (UNRELATED PRIME)
40. The foot and the clock move together. (TARGET)

Block 8 (Experimental: There is no break between trials during Block 8. There is a brief break at the end of Block 8.)

1. The table moves up and the nose moves down.
2. The pants move down.
3. The mouse and the rose move together.
4. They all move down. (ladder, gate, bridge)
5. The gate and the scissors move apart. (RELATED PRIME)
6. The key and the snake move down. (TARGET)
7. The rabbit moves up.
8. The wall and the flag move down. (RELATED PRIME)
9. The kite and the ear move apart. (TARGET)
10. The rose moves down and the candle moves up. (UNRELATED PRIME)
11. The duck and the cat move up. (TARGET)
12. No pictures appear.
13. The pants move down and the nose moves up.
14. The rocket moves down.
15. The tent moves down and the flag moves up.
16. The stamp moves up and the table moves down. (UNRELATED PRIME)
17. The leaf and the cup move down. (TARGET)
18. The arm moves up.
19. No pictures appear.
20. They all move up. (scissors, tent, flag)
21. The rocket and the elephant move together. (RELATED PRIME)
22. The watch and the saw move up. (TARGET)
23. The knife moves down.
24. The snowman moves down and the mushroom moves up.
25. They all move down. (ladder, gate, bridge)
26. The mushroom moves up and the axe moves down.
27. No pictures appear.

28. The ladder and the elephant move down.
29. They all move up. (scissors, tent, flag)
30. The mouse moves up and the door moves down. (UNRELATED PRIME)
31. The dice and the car move together. (TARGET)
32. The pig and the finger move up. (RELATED PRIME)
33. The church and the brush move together. (TARGET)
34. The camel moves up.
35. The camel and the pants move together.
36. No picture appears.
37. The carrot and the bridge move up.
38. The door moves down.
39. The anchor moves down and the bottle moves up. (UNRELATED PRIME)
40. The house and the tie move apart. (TARGET)

Appendix E. Speech initiation times (msec) in fluent adults (FA) and adults who stutter (AWS) in Experiment 1.

Subject	Short	Long-Low	Long-Medium	Long-High
FA 1	518	487	608	688
FA 2	416	600	665	639
FA 3	535	568	619	685
FA 4	416	493	565	593
FA 5	594	586	691	721
FA 6	581	493	520	681
FA 7	592	608	581	736
FA 8	654	668	673	689
FA 9	591	674	698	738
FA 10	492	551	633	592
FA 11	503	560	610	634
FA 12	625	647	697	710
FA 13	612	548	736	647
FA 14	378	473	513	563
FA 15	510	536	522	625
AWS 1	674	731	687	711
AWS 2	499	498	790	751
AWS 3	570	685	786	785
AWS 4	528	560	787	847
AWS 5	694	641	735	926
AWS 6	437	355	418	564
AWS 7	626	616	732	865
AWS 8	578	603	776	868
AWS 9	702	724	821	976
AWS 10	631	668	792	813
AWS11	435	449	660	727
AWS 12	781	811	791	939
AWS 13	717	762	880	997
AWS 14	500	507	572	669
AWS 15	671	692	801	842
Mean	568	593	679	741

Appendix F. Total number and percentage of target sentences that contained speech disfluencies in fluent adults (FA) and adults who stutter (AWS) in Experiment 1.

Subject	Short	Long-Low	Long-Medium	Long-High
FA 1	0	0	0	0
FA 2	0	0	1 (16.6%)	1 (16.6%)
FA 3	0	0	0	0
FA 4	0	0	0	0
FA 5	0	0	0	1 (16.6%)
FA 6	0	1 (16.6%)	1 (16.6%)	0
FA 7	0	0	0	0
FA 8	0	1 (16.6%)	0	1 (16.6%)
FA 9	0	0	0	0
FA 10	0	0	0	0
FA 11	0	0	0	0
FA 12	0	0	0	0
FA 13	0	0	0	0
FA 14	0	0	0	0
FA 15	0	0	0	0
AWS 1	1 (16.6%)	1 (16.6%)	0	2 (33.3%)
AWS 2	0	1 (16.6%)	2 (33.3%)	1 (16.6%)
AWS 3	0	0	1 (16.6%)	1 (16.6%)
AWS 4	0	0	0	0
AWS 5	3 (50.0%)	1 (16.6%)	2 (33.3%)	1 (16.6%)
AWS 6	0	0	0	0
AWS 7	0	0	2 (33.3%)	3 (50.0%)
AWS 8	0	0	0	0
AWS 9	2 (33.3%)	2 (33.3%)	0	1 (16.6%)
AWS 10	0	2 (33.3%)	1 (16.6%)	0
AWS11	1 (16.6%)	1 (16.6%)	2 (33.3%)	3 (50.0%)
AWS 12	0	0	0	0
AWS 13	1 (16.6%)	1 (16.6%)	2 (33.3%)	0
AWS 14	0	0	1 (16.6%)	2 (33.3%)
AWS 15	0	0	0	0
Total	8 (4.4%)	11 (6.1%)	15 (8.3%)	17 (9.4%)

Appendix G. Mean memorization times of target sentences for fluent adults (FA) and adults who stutter (AWS) in Experiment 1.

Subject	Short	Long-Low	Long-Medium	Long-High
FA 1	6233	9441	12422	10314
FA 2	5352	14587	14112	15213
FA 3	8021	11940	10382	12365
FA 4	7170	13653	13447	14236
FA 5	9641	14823	12089	13274
FA 6	5469	12341	14631	13889
FA 7	6424	13725	13234	13991
FA 8	10620	15284	15122	16239
FA 9	9043	14589	13887	16010
FA 10	9479	11625	13873	12213
FA 11	8146	14589	12810	13253
FA 12	6347	13785	15676	15811
FA 13	6610	13248	11567	13774
FA 14	5391	12643	12478	12147
FA 15	7732	12080	14321	13878
AWS 1	10036	15472	12894	14785
AWS 2	5921	13211	14557	12561
AWS 3	8133	12870	13125	12463
AWS 4	6784	15296	15238	14299
AWS 5	10347	15211	14330	15452
AWS 6	7449	11498	12063	10238
AWS 7	6232	11262	11286	13514
AWS 8	9641	12365	12154	14159
AWS 9	9587	13493	15963	15489
AWS 10	11248	14821	13658	14231
AWS11	5432	12002	11159	13272
AWS 12	8481	12734	13221	14056
AWS 13	10012	13011	15552	14220
AWS 14	7562	11237	12988	9881
AWS 15	5334	12004	14122	13307
Mean	7796	13161	13412	13618

Appendix H. Speech initiation data (msec) in fluent adults (FA) and adults who stutter (AWS) in Experiment 2.

Subject	Unprimed	Primed	Difference
FA 1	779	741	38
FA 2	903	864	39
FA 3	853	798	55
FA 4	866	801	65
FA 5	622	563	59
FA 6	671	615	56
FA 7	1146	957	41
FA 8	871	929	58
FA 9	1108	1048	60
FA 10	1024	967	57
FA 11	1237	1179	58
FA 12	889	861	28
FA 13	1291	1250	41
FA 14	953	951	2
FA 15	1008	980	28
AWS 1	822	766	56
AWS 2	767	741	26
AWS 3	892	604	288
AWS 4	1210	1056	154
AWS 5	906	698	208
AWS 6	739	713	26
AWS 7	1236	1229	7
AWS 8	1063	880	183
AWS 9	1327	1098	229
AWS 10	1192	1054	138
AWS 11	986	861	125
AWS 12	1138	947	191
AWS 13	1248	982	266
AWS 14	1125	1121	4
AWS 15	1341	1108	233
Mean	1007	912	94

Appendix I. Total number and percentage of target sentences that contained speech disfluencies in fluent adults (FA) and adults who stutter (AWS) in Experiment 2.

Subject	Unprimed	Primed
FA 1	0	0
FA 2	0	0
FA 3	1	0
FA 4	1	0
FA 5	0	0
FA 6	1	1
FA 7	0	0
FA 8	0	0
FA 9	0	0
FA 10	0	1
FA 11	1	1
FA 12	0	0
FA 13	0	0
FA 14	0	0
FA 15	0	0
AWS 1	4	3
AWS 2	3	1
AWS 3	0	0
AWS 4	0	3
AWS 5	5	0
AWS 6	0	1
AWS 7	0	1
AWS 8	2	0
AWS 9	3	2
AWS 10	1	0
AWS 11	2	0
AWS 12	2	2
AWS 13	4	5
AWS 14	0	0
AWS 15	0	0
Total	30 (6.25%)	21 (4.40%)

REFERENCES

Adams, M. & Hayden, P. (1976). The ability of stutterers and nonstutterers to initiate and terminate phonation during production of an isolated vowel. *Journal of Speech and Hearing Research*, 19, 290-296.

Anderson, J., & Conture, E. (2004). Sentence-structure priming in young children who do and do not stutter. *Journal of Speech, Language, and Hearing Research*, 47, 552-571.

Andrews, G., Howie, P., Dozsa, M., & Guitar, B. (1982). Stuttering: Speech pattern characteristics under fluency-inducing conditions. *Journal of Speech and Hearing Research*, 25, 208-216.

Au-Yeung, J. & Howell, P. (1998). Lexical and syntactic context and stuttering. *Clinical Linguistics & Phonetics*, 12, 67-78.

Bakker, K., & Brutten, G. (1989). A comparative investigation of the laryngeal premotor, adjustment, and reaction times of stutterers and nonstutterers. *Journal of Speech and Hearing Research*, 32, 239-244.

Bernstein, N. (1981). Are there constraints on childhood disfluency? *Journal of Fluency Disorders*, 6, 341-350.

Bernstein-Ratner, N. (1997). Stuttering: A psycholinguistic perspective. In R.F. Curlee & G. Siegel (Eds.), *The Nature and Treatment of Stuttering: New Directions* (2nd ed. Pp. 99-128). Boston: Allyn and Bacon.

Bernstein-Ratner, N., & Sih, C. (1987). Effects of gradual increases in sentence length and complexity on children's disfluency. *Journal of Speech and Hearing Research*, 52, 278-287.

Bishop, J., Williams, H., & Cooper, W. (1991). Age and task complexity variables in motor performance of stuttering and nonstuttering children. *Journal of Fluency Disorders*, 16, 207-217.

Bloodstein, O. (1995). *A handbook on stuttering* (5th ed.). San Diego, CA: Singular.

Bock, K. (1982). Toward a cognitive psychology of syntax: Information processing contributions to sentence formulation. *Psychological Review*, 89, 1-47.

Bock, K. (1986). Syntactic persistence in language production. *Cognitive Psychology*, 18, 355-387.

Bock, K. (1989). Closed-class immanence in sentence production. *Cognition*, 31, 163-186.

Bock, K. (1995). Sentence production: From mind to mouth. In J. L. Miller & P. D. Eimas (Eds.), *Handbook of perception and cognition: Vol. 11. Speech, language, and communication* (2nd ed., pp.181-216). San Diego, CA: Academic Press.

Bock, K. & Griffin, Z. (2000). The persistence of structural priming: Transient activation or implicit learning? *Journal of Experimental Psychology: General*, 129, 177-192.

Bock,K. & Kroch, A. (1989). The isolability of syntactic processing. In G. Carlson & M. Tanenhaus (Eds.), *Linguistic Structure in Language Processing*. Dordrecht: Kluwer Academic.

Bock, K. & Levelt, W. (1994). Language production: Grammatical encoding. In M. Gernsbacher (Ed.), *Handbook of Psycholinguistics*. San Diego: Academic Press.

Bock, K. & Loebell, H. (1990). Framing sentences. *Cognition*, 35, 1-39.

Bosshardt, H. (1993). Differences between stutterers' and nonstutterers' short-term recall and recognition performance. *Journal of Speech and Hearing Research*, 36, 286-

293.

Bosshardt, H. (1994). Temporal coordination between pre-motor and motor processes in speech production. In C.W. Starkweather & H. Peters (Eds.), *Stuttering: Proceedings of the First World Congress on Fluency Disorders* (Volume 1). Nijmegen, Netherlands: University Press.

Branigan, H., Stewart, A., Pickering, M. (1998). Is syntactic priming a two-way effect? *Proceedings of the Twentieth Annual Conference of the Cognitive Science Society*. Hillsdale, NJ: Erlbaum.

Brundage, S., & Bernstein-Ratner, N. (1989). The measurement of stuttering frequency in children's speech. *Journal of Fluency Disorders*, 14, 351-358.

Butterworth, B. (1980). Some constraints on models of language production. In B. Butterworth (ed.), *Language Production: Volume 1, Speech and Talk*. London: Academic Press.

Cairns, H. (1999). *Psycholinguistics: An Introduction*. Austin: Pro-Ed.

Chang, F., Dell, G., Bock, K., Griffin, Z. (2000). Structural priming as implicit learning: A comparison of models of sentence production. *Journal of Psycholinguistic Research*, 29, 217-229.

Collins, A. & Loftus, E. (1975). A spreading-activation theory of semantic processing. *Psychological Review*, 82, 407-428.

Conture, E. (2001). *Stuttering: Its Nature, Diagnosis, and Treatment*. Boston: Allyn & Bacon.

Cross, D., & Luper, H. (1979). Voice reaction time of stuttering and nonstuttering children and adults. *Journal of Fluency Disorders*, 4, 59-77.

Cuadrado, E., & Weber-Fox, C. (2003). Atypical syntactic processing in individuals who stutter: Evidence from event-related brain potentials and behavioral measures. *Journal of Speech, Language, and Hearing Research*, 46, 960-976.

Dembowski, J., & Watson, B. (1991). Preparation time and response complexity effects on stutterers' and nonstutterers' acoustic LRT. *Journal of Speech and Hearing Research*, 34, 49-59.

Dell, G. (1986). A spreading-activation theory of retrieval in sentence production. *Psychological Review*, 93, 283-321.

Ferreira, F. (1991). Effects of length and syntactic complexity on initiation times for prepared utterances. *Journal of Memory and Language*, 30, 210-233.

Fromkin, V. (1971). The non-anomalous nature of anomalous utterances. *Language*, 47, 27-52.

Gaines, N., Runyan, C., & Meyers, S. (1991). A comparison of stutterers' fluent versus stuttered utterances on measures of length and complexity. *Journal of Speech and Hearing Research*, 34, 37-42.

Garrett, M. (1975). The analysis of sentence production. In G. Bower (ed.) *The Psychology of Learning and Motivation: Advances in Research and Theory*. New York: Academic Press.

Garrett, M. (1982). Production of speech: Observations from normal and pathological language use. In A.W. Ellis (Ed.), *Normality and pathology in cognitive functions* (pp.19-76). London: Academic Press.

Garrett, M. (1988). Processes in language production. In F.J. Newmeyer (Ed.), *Linguistics: The Cambridge Survey: Volume III. Language: Psychological and*

Biological Aspects. Cambridge, England: Cambridge University Press.

Gordon, P., & Luper, H. (1989). Speech disfluencies in nonstutterers: Syntactic complexity and production task effects. *Journal of Fluency Disorders*, 14, 429-445.

Gordon, P., Luper, H., & Peterson, H. (1986). The effects of syntactic complexity on the occurrence of disfluencies in 5-year-old nonstutterers. *Journal of Fluency Disorders*, 11, 151-164.

Guitar, B. (2006). Stuttering: An Integrated Approach to its Nature and Treatment. Baltimore, MD: Lippincott Williams & Wilkins.

Hartsuiker, R., & Kolk, H. (1998). Syntactic facilitation in agrammatic sentence production. *Brain and Language*, 62, 221-254.

Howell, P., & Au-Yeung, J. (1995). Syntactic determinants of stuttering in spontaneous speech of normally fluent and stuttering children. *Journal of Fluency Disorders*, 20, 317-330.

Howell, P., Au-Yeung, J., & Sackin, S. (1999). Exchange of stuttering from function words to content words with age. *Journal of Speech, Language, and Hearing Research*, 42, 345-354.

Hubbard, C. & Prins, D. (1994). Word familiarity, syllabic stress pattern, and stuttering. *Journal of Speech and Hearing Research*, 37, 564-571.

Johnson, N. (1966). On the relationship between sentence structure and the latency in generating a sentence. *Journal of Verbal Learning and Verbal Behavior*, 5, 375, 380.

Johnson, W. (1961). *Stuttering and What You Can Do About It*. Danville, IL: Interstate.

Kadi-Hanifi, K., & Howell, P. (1992). Syntactic analysis of the spontaneous speech of normally fluent and stuttering children. *Journal of Fluency Disorders*, 17, 151-170.

Kleinow, J. & Smith, A. (2000). Influences of length and syntactic complexity on the speech motor stability of the fluent speech of adults who stutter. *Journal of Speech, Language, and Hearing Research*, 43, 548-559.

Klouda, G., & Cooper, W. (1987). Syntactic clause boundaries, speech timing, and stuttering frequency in adult stutterers. *Language and Speech*, 30, 263-276.

Kolk, H. & Postma, A. (1997). Stuttering as a covert repair phenomenon. In R. Curlee & Siegel (Eds.), *Nature and Treatment of Stuttering: New Directions* (2nd ed., pp. 182-203). Boston: Allyn & Bacon.

Levelt, W. (1989). Speaking: *From intention to articulation*. Cambridge, MA: MIT Press.

Levelt, W., & Kelter, S. (1982). Surface form and memory in question answering. *Cognitive Psychology*, 14, 78-106.

Levelt, W., Roelofs, A., & Meyer, A. (1999). *A theory of lexical access in speech production. Behavioral and Brain Sciences*, 22, 1-75.

Logan, K. (2001). The effect of syntactic complexity upon the speech fluency of adolescents and adults who stutter. *Journal of Fluency Disorders*, 26, 85-106.

Logan, K. (2003). The effect of syntactic structure upon speech initiation times of stuttering and nonstuttering speakers. *Journal of Fluency Disorders*, 28, 17-35.

Logan, K., & Conture, E. (1995). Length, grammatical complexity, and rate differences in stuttered and fluent conversational utterances of children who stutter. *Journal of Fluency Disorders*, 20, 35-62.

Logan, K., & Conture, E. (1997). Temporal, grammatical, and phonological characteristics of conversational utterances produced by children who stutter. *Journal of Speech and Hearing Research*, 40, 107-210.

Logan, K. & Lasalle, L. (1999). Grammatical characteristics of children's conversational utterances that contain disfluency clusters. *Journal of Speech, Language, and Hearing Research*, 42, 80-91.

MacKay, D. (1970). Spoonerisms: The structure of errors in the serial order of speech. *Neuropsychologia*, 8, 323-350.

MacKay, D. (1982). The problem of flexibility, fluency, and speed-accuracy trade-off in skill behavior. *Psychological Review*, 89, 483-506.

Melnick, K., & Conture, E. (2000). Relationship of length and grammatical complexity to the systemic speech errors and stuttering of children who stutter. *Journal of Fluency Disorders*, 25, 21-45.

Melnick, K., Conture, E., & Ohde, R. (2003). Phonological priming in picture naming of young children who stutter. *Journal of Speech, Language, and Hearing Research*, 46, 1428-1443.

Owens, R. (2005). *Language Development: An Introduction*. Boston: Pearson.

Pellowski, M. & Conture, E. (2002). Characteristics of speech disfluency and stuttering behaviors in 3- and 4-year-old children. *Journal of Speech, Language, and Hearing Research*, 45, 20-34.

Pellowski, M. & Conture, E. (2005). Lexical priming in picture naming of young children. *Journal of Speech, Language, and Hearing Research*, 48, 278-294.

Perkins, W., Kent, R., Curlee, R. (1991). A theory of neuropsycholinguistic function in stuttering. *Journal of Speech and Hearing Research*, 34, 734-752.

Riley, G. (1994). *Stuttering Severity Instrument for Children and Adults—3*. Austin, TX: Pro-Ed.

Rispoli, M. (2003). Changes in the nature of sentence production during the period of grammatical development. *Journal of Speech, Language, and Hearing Research*, 46, 818-830.

Rispoli, M. & Hadley, P. (2001). The leading edge: The significance of sentence disruptions in the development of grammar. *Journal of Speech, Language, and Hearing Research*, 44, 1131-1143.

Sander, E. (1961). Reliability of the Iowa Speech Disfluency Test. *Journal of Speech and Hearing Disorders*, 7, 21-30.

Schwartz, H., & Conture, E. (1986). Subgrouping young stutterers: Preliminary behavioral perspectives. *Journal of Speech and Hearing Research*, 31, 62-71.

Seikel, J., King, D., & Drumright, D. (2005). *Anatomy and Physiology for Speech, Language, and Hearing*. New York: Delmar Learning.

Shapiro, D. (1999). *Stuttering Intervention: A Collaborative Journey to Fluency Freedom*. Austin, TX: Pro-Ed.

Shattuck-Hufnagel, S. (1979). Speech errors as evidence for a serial order mechanism in sentence production. In W. Cooper & E. Walker (Eds.), *Sentence Processing: Psycholinguistic Studies Presented to Merrill Garrett*. Hillsdale, NJ: Lawrence Erlbaum.

Silverman, S., & Bernstein-Ratner, N. (1997). Syntactic complexity, fluency, and accuracy of sentence imitation in adolescents. *Journal of Speech, Language, and Hearing Research*, 40, 95-106.

Smith, A. & Kelly, E. (1997). Stuttering: A dynamic, multifactorial model. In R. Curlee & G. Siegel (Eds.), *Nature and Treatment of Stuttering: New Directions* (2nd ed). Boston: Allyn & Bacon.

Smith, M., & Wheeldon, L. (2001). Syntactic priming in spoken sentence production—An online study. *Cognition*, 78, 123-164.

Snodgrass, J., & Vanderwart, M. (1980). A standardized set of 260 pictures: norms for name agreement, image agreement, familiarity and visual complexity. *Journal of experimental Psychology: Human Learning and Memory*, 6, 174-215.

Starkweather, W. (1987). *Fluency and stuttering*. Englewood Cliffs, NJ: Prentice Hall.

Sternberg, S., Monsell, S., Knoll, R., & Wright, C. (1978). The latency and duration of rapid movement sequences: Comparisons of speech and typewriting. In G. Stelmach (Ed.), *Information Processing in Motor Control and Learning*. New York: Academic Press.

Wall, M., Starkweather, C., & Cairns, H. (1981). Syntactic influences on stuttering in young child stutterers. *Journal of Fluency Disorders*, 6, 283-298.

Watson, B., & Alfonso, P. (1987). Physiological bases of acoustic LRT in nonstutterers, mild stutterers, and severe stutterers. *Journal of Speech and Hearing Research*, 30, 434-447.

Weiss, A., & Zebrowski, P. (1992). Disfluencies in the conversations of young children who stutter: Some answers about questions. *Journal of Speech and Hearing Research*, 35, 120-128.

Wheeldon, L., & Monsell, S. (1992). The locus of repetition priming of spoken word production. *Quarterly Journal of Experimental Psychology*, 44A, 723-761.

Wingate, M. (1976). *Stuttering theory and treatment*. New York: Irvington-Wiley.

Wingate, M. (1988). *The Structure of Stuttering: A Psycholinguistic Approach*. New York: Springer-Verlag.

Yaruss, J. (1997). Clinical implications of situational variability in preschool children who stutter. *Journal of Fluency Disorders*, 22, 187-203.

Yaruss, S. (1999). Utterance length, syntactic complexity, and childhood stuttering. *Journal of Speech and Hearing Research*, 42, 329-344.

Zackheim, C., & Conture, E. (2003). Childhood stuttering and speech disfluencies in relation to children's mean length of utterance: A preliminary study. *Journal of Fluency Disorders*, 28, 115-142.