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Recent advances in the treatment of stuttering: A theoretical perspective

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Abstract

Prolonged speech and its variants are widely used in the behavioral treatment of stuttering. Unlike these approaches, which depend on clinician-prescribed speech pattern changes, two behavioral treatment regimens, one for children and another for adults, recently developed at the Australian Stuttering Research Center, promote self-monitoring of speech as a means of controlling stuttering. In these programs, the clients themselves modify their speech in subtle and variable ways to gain control over stuttering and, in that, they appear to be similar to a well-known experimental technique for suppressing stutters known as response contingent stimulation. The present paper provides an integrated explanation for the effectiveness of both clinician-directed as well as client-initiated speech pattern modifications and, in the process, develops a new model of stuttering. It also shows why client-generated speech patterns changes potentially produce faster and more lasting improvement than those changes prescribed by a clinician.

Learning outcomes: The reader will learn about: (1) two hypothesized methods of preparing utterance motor plans—speech concatenation and speech construction; (2) how behavioral treatment programs make use of speech construction to promote fluency in persons who stutter; (3) why therapy procedures based on cognitively driven speech construction produce faster and superior results than those based on motorically driven speech construction; and (4) the empirical evidence that suggests that speech concatenation is the source of stuttering.

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1. Introduction

For over half a century, primarily influenced by Johnson's (1942) diagnosogenic theory, speech–language pathologists had shown great trepidations about offering direct treatment for stuttering in young children. Recently, however, work carried out at the Australian Stuttering Research Center, which is based on a path-breaking study reported by Martin, Kuhl, and Harlodson (1972), has shown that stuttering in children can be treated safely (Woods, Shearsby, Onslow, & Burnham, 2002), efficaciously (Harris, Onslow, Packman, Harrison, & Menzies, 2002; Onslow, Menzies, & Packman, 2001), and economically (Jones, Onslow, Harrison, & Packman, 2000) with a home-based operant treatment regimen called the Lidcombe program. In the Lidcombe program, parents are trained to: (1) administer verbal praise and occasionally tangible rewards contingent on fluent utterances; (2) request in a nonthreatening manner that stuttered utterances be replaced with fluent utterances; and (3) rate stuttering severity on a daily basis on a 10-point scale (Onslow, Menzies, et al., 2001; Onslow, Ratner, & Packman, 2001). The most striking feature of the Lidcombe program is that neither the clinicians who work with the child while training the parents in the clinic nor parents who, for the most part, administer the treatment outside of the clinic attempt to modify the child's speech either through instructions (e.g., "speak slowly" or "draw out words," etc.) or by way of modeling. Onslow, Stocker, Packman, and McLeod (2002), after failing to find consistent acoustic timing differences between pre- and post-treatment speech of a group of children who successfully completed the Lidcombe program, concluded that no satisfactory explanation exists for the success of the program.

In another study, O'Brian, Onslow, Cream, and Packman (2003) described a treatment regimen for adults called the Camperdown program that initially and briefly required participants to adopt a slow (70 syllables/min), prolonged speech pattern modeled in a videotape. In later stages of treatment, participants were only required to produce speech that was rated 1–2 on a 9-point stuttering severity scale and 1–3 on a 9-point speech naturalness scale without having to meet any specific targets for speech modification such as speech rate, gentle voice onset, continuous vocalization, etc. Sixteen participants, out of the original group of 30, who completed the program met and maintained the stuttering severity and speech naturalness criteria and achieved a satisfactory rating on a lay listener based social validation measure 12 months post-treatment. Prolonged speech based stuttering treatment typically involves "shaping" speech systematically by requiring participants to meet specific criteria for rate and an assortment of related speech modifications such as gentle voice onset, continuous vocalization, and soft articulatory contact in small, incremental steps (Ingham, 1984; Onslow, 1996). The Camperdown program demonstrated that people who stutter (PWS) could develop natural-sounding, nearly stutter-free speech without specific clinician instructions with regard to speech modifications although they do require consistent and reliable feedback concerning stuttering severity and speech naturalness.

The success of the Lidcombe and the Camperdown programs appear to suggest that many children and adults who stutter are able to produce nearly stutter-free and natural-sounding speech by: (1) developing a cognitive set to speak without stutters and (2) monitoring their speech, initially with the help of clinicians or family members, to verify that this goal is achieved. This inference has strong empirical foundation. Numerous studies have demonstrated that response contingent stimulation (RCS) – presenting almost any kind of ‘‘stimulus’’ (more descriptively, any kind of *signal* [Wingate, 1980]) immediately and consistently contingent on stutters – significantly reduces or eliminates stutters in most but not all PWS (see Bloodstein, 1995; Costello & Ingham, 1984; Ingham, 1984, and Prins & Hubbard, 1988 for reviews). Although initially this finding was interpreted as evidence that stutters were an operant response class, the failure to *increase* stutter frequency through positive or negative reinforcement (Bloodstein, 1995; Daly & Kimbarow, 1978; Young, 1985) has generally led to the abandonment of that view (Ingham, 1984).

The perplexing finding that almost any kind of signal – positive, negative, and seemingly neutral – when paired with stutters would produce measurable decreases in stutter frequency in many PWS has been attributed by some to a ‘‘highlighting’’ effect (Siegel, 1970; Wingate, 1980). Siegel maintained that ‘‘. . . virtually any event that highlights or brings (stutters) to the speaker’s attention . . .’’ (p. 689) will reduce the frequency of stutters. In fact, when some PWS highlight their own stutters by some means such as by pressing a handswitch every time they stutter, stutter frequency is reduced (Hanson, 1978). James, Ricciardelli, Rogers, and Hunter (1989) suggested that when stutters are highlighted systematically as in RCS studies, the PWS might become more fluent by tapping fluent speech capabilities that remained unused in ‘‘contingency-free’’ speaking conditions. However, James et al. did not identify the origin and nature of ‘‘fluent speech capabilities’’ that are underutilized by PWS.

If PWS, in RCS experiments as well as in stuttering treatment programs derived from operant learning principles, are accessing normally unexploited fluent speech capabilities, it is important to identify the source(s) of these hidden capabilities. Recently, a number of researchers have proposed that the ‘‘stage’’ of speech production that is of direct relevance to an explanation of stuttering is the speech motor plan assembly and its execution (Peters, Hulstijn, & Van Lieshout, 2000; Postma, Kolk, & Povel, 1990; Wijnen & Boers, 1994). The present paper offers a speech motor plan assembly explanation for the suppression of stutters under novel speech patterns (Andrews, Howie, Dozsa, & Guitar, 1982) including those associated with the behavioral treatment of stuttering that systematically promote self-monitoring of speech by PWS.

2. Speech motor plan assembly

There appear to be two distinct but complimentary methods available for assembling the speech motor plan. Savage, Bradley, and Forster (1990) reported that the mean production latencies for pronounceable nonwords in a group of (normal-speaking) participants were about 10–14% slower than for words. The difference in production latencies between words and nonwords decreased to a mean of 6% after three trials of practice in producing both words and nonwords. The authors inferred, relying on an analogy to computer programs, that the pronunciation of ‘‘. . . common words might be executed by a command to retrieve a precompiled program which has been ‘debugged’ through experience, and condensed to run efficiently . . .’’ (p. 227). The ‘‘. . . programs for nonwords might be seen as newly written, untested, and possibly riddled with bugs’’ (p. 227) requiring more time to produce. Crompton (1982) has also argued that slips of the tongue such as *hissing mystery classes* (for *missing history classes*) occur because the speech production system retrieves the wrong syllables from a store of syllable-sized motor plans. Similarly, Levelt and Wheeldon (1994) proposed that motor plans for frequently used syllables in a language are stored in a "mental syllabary." They argued that it is more efficient to access "overlearned" syllable motor plans when assembling an utterance motor plan. However, they pointed out that the production of novel (not sufficiently practiced) sound sequences would require construction of motor plans in real time.

In this paper, the method of assembling the utterance motor plan by retrieving and concatenating motor plans stored in memory is called "speech concatenation." Production of novel (i.e., not sufficiently practiced) sound sequences or speaking in an unaccustomed manner (e.g., whispering, deliberately speaking in a high pitch, etc.) require that motor plans be constructed or motor plans retrieved from memory be suitably modified in real time. In this paper, this method of assembling the utterance motor plan is designated as "speech construction." Although it is conceivable that an overlearned utterance may entirely consist of stored motor plans, portions of many novel utterances we produce everyday also involve construction of motor plans in real time.

Logan (1988), while outlining a theory of automatization of cognitive tasks, proposed that for a given task, the cognitive system has a general algorithm, which a novice (to the task) will use to solve a class of problems related to the task. Each time a problem is solved, the solution is stored in memory. After sufficient practice, when the same problem is encountered again, the solution is retrieved from memory rather than computed online. It is at this point that processing has become automatic. The general algorithm is capable of providing solutions to a class of problems whereas automatic processing can provide solutions to specific problems for which solutions have been worked out in the past. Although Logan's theory of automatization did not specifically address speech motor plan assembly, the distinction between general algorithm and specific stored solutions is similar to the distinction between speech construction and speech concatenation that was made in the previous paragraph. Speech construction is assumed to use a general algorithm to convert the phonological representation of an utterance into a speech motor plan. One popular account of the construction of speech motor plans, propelled perhaps by the central role audition plays in the development of speech articulation in children (Borden, 1980), assumes that it involves converting auditory-phonetic goals into an articulatory program for the utterance under preparation. Perkell et al. (1997) provide a hypothesized account of computations involved in transforming auditory-phonetic goals into a speech motor plan. Speech concatenation, in contrast, is a rapid, direct, and resource-efficient speaking process that retrieves the motor plan for a unit of speech from memory in a single step. Speech concatenation, being an automatic process, is the default method for assembling the utterance motor plans because as long as a suitable stored motor plan is available, it is *automatically* retrieved from memory.

It is proposed here that speech construction is the source of latent fluent speech capability tapped when speaking in novel speech patterns, in RCS experiments, and in operant learning based stuttering treatment programs. It is well known that almost any change in the habitual speech pattern immediately results in a significant reduction or total elimination of stutters (Andrews et al., 1982; Bloodstein, 1950; Packman, Onslow, & van

Doorn, 1994; Perkins, Rudas, Johnson, & Bell, 1976). One way to force the speech production system to use speech construction instead of the default speech concatenation is to adopt a nonhabitual speech pattern. Speaking in a nonhabitual speech pattern will require speech construction because nonhabitual speech patterns, by definition, are not sufficiently practiced and, therefore, stored motor plans are not likely to be available for their production.

Some recent neurophysiological findings appear to support the above hypothesis. In a PET study of two fluency-evoking conditions (paced speech and singing), Stager, Jeffries, and Braun (2003) concluded that the fluency-evoking conditions more effectively "couple" the auditory and motor systems resulting in "... more efficient self-monitoring, allowing motor areas to more effectively modify speech." (p. 319). In contrast, Hirano et al. (1996) showed that the auditory processing areas in the superior temporal gyri were "rarely" activated during "vocalization of familiar materials" in a group of normal-speaking participants.

2.1. *Two types of speech construction*

There is a group of speaking situations in which speakers consciously choose to alter selected articulatory and/or prosodic parameters of utterances in a specific manner due to certain pragmatic considerations. One may speak in a high pitch to imitate a woman's voice or in a whisper to prevent eavesdropping. In this paper, the conscious modification of specific vocal and articulatory parameters in the course of speaking is referred to as *motorically driven speech construction*. When a speaker engages in motorically driven speech construction, the vocal and articulatory modifications are used to achieve a communication goal. Here the speaker consciously sets out to speak in a high pitch or in a whisper as a means to an end. From the perspective of the speaker, the alterations in the motor aspects of articulation and prosody are the starting point for achieving a communication goal, and hence its characterization as motorically driven speech construction.

There is also a second group of situations in which speech motor planning and execution become a more conscious, foreground (nonautomatic) speech construction process due to a different set of pragmatic considerations. These speaking situations, which involve *cognitively driven speech construction*, are best represented by what is referred to as clear speech. We tend to produce clear speech in certain adverse communication conditions (e.g., talking under high ambient noise or over long distances) or when speaking to certain audiences (e. g., children, nonnative speakers, hearing-impaired people, etc.) (Bradlow & Bent, 2002; Payton, Uchanski, & Braida, 1994; Picheny, Durlach, & Braida, 1986). Speaking clearly involves complex vocal and articulatory changes. The speaker slows down the rate of speech not merely by inserting pauses or proportionately stretching the duration of all sounds (as might occur in motorically driven speech construction), but also by increasing the duration of selected classes of vowels and consonants in specific phonetic contexts. Vowel reduction in unstressed syllables is less pronounced and occurs less often, stop bursts and word final consonants are almost always released, and the intensity of obstruent consonants in general and the stops in particular is increased relative to the intensity of adjacent vowels (i.e., CV intensity ratio increases) (Picheny et al., 1986). The complex, subtle, and selective modifications to articulation and prosody during clear speech are obviously intended to enhance intelligibility.

When a speaker engages in cognitively driven speech construction, the communication goal (e.g., enhanced intelligibility in clear speech) drives the vocal and articulatory changes. This is the opposite of motorically driven speech construction. In clear speech, the speaker sets out to "speak clearly." This cognitive set may lead to certain changes in articulation and prosody, which largely lie outside the speaker's awareness. For example, it is unlikely that when speaking clearly, the speaker consciously plans to release word-final consonants or increase CV intensity ratio.

2.2. *Motorically driven speech construction and stuttering therapy*

In rate control therapies, the PWS are trained to speak at a slow rate by deliberately and consciously prolonging syllables (Onslow, 1996; Perkins, 1984). Rate control procedures may also include other "ingredients" such as continuous vocalization, soft articulatory contacts, and gentle voice onset (Onslow, 1996). Typically, in the initial stages of treatment, rate is slowed to less than half the normal rate of speech (and highly exaggerated continuous vocalization, soft articulatory contacts, and gentle voice onset are used if they are incorporated into therapy) to eliminate nearly all stutters. Such changes in articulation and prosody can be achieved without having to continuously and closely monitor one's speech because the changes are predictable, global, and quite large. Thus, the initial stages of rate control therapies utilize a robust form of motorically driven speech construction to reduce stutters and this is generally highly successful (see reviews of behavioral treatment of stuttering in Ingham, 1984 and Onslow, 1996).

In later stages of treatment, however, the rate is increased to the lower end of the normal range of rate (along with more subtle and variable use of continuous vocalization, soft articulatory contacts, and gentle voice onset if they are a part of therapy) to ensure that the speech does not sound severely abnormal (Onslow, 1996). In order to maintain rate within a narrow range of variability at the lower end of the normal range and use other treatment variables listed above in subtle and complex ways, the PWS need to pay more or less continuous attention to their speech. In the final stages of rate control therapies, the PWS are using a finely tuned form of motorically driven speech construction. They are still prolonging syllables but they have to be careful not to overdo it lest speech may sound more unnatural. Over a period of time, many PWS may partly or completely abandon this demanding form of speech construction in favor of the default mode of speech concatenation because the highly tenuous and attention-demanding nature of speech construction employed at the endpoint of rate control therapies is unsustainable over the long run, and especially so under the high sensory and cognitive processing demands of everyday communication and other concurrent nonspeech activities. This probably accounts for the high rate of relapse following treatment of stuttering in adults (Bloodstein, 1995) reported in the literature.

Recently, Ingham et al. (2001) have reported on a treatment procedure that requires PWS to reduce the number of very brief "phonation intervals" (PI; absence of vocal folds vibration) as a means of suppressing stutters. In a departure from the typical prolonged speech based treatment regimen (which also frequently incorporates "continuous vocalization" as part of the treatment), the procedure reported by Ingham et al. emphasizes natural-sounding speech from the start. Clearly, reducing PIs, which naturally occur in the speech of people who stutter as well as those who do not, requires speech construction. While the approach has shown promise in producing short- and medium-term fluency gains, it is not known whether speaking with fewer PIs is less attention-demanding than what is required at the end of a prolonged speech regimen.

A study by De Nil, Kroll, and Houle (2001) appear to offer neurophysiological evidence in support of the hypothesis that stuttering treatment based on motorically driven speech construction requires the PWS to closely monitor their speech to achieve and maintain fluency. The study showed that the cerebellar activity significantly increased during reading in a group of PWS at the completion of an intensive behavioral stuttering treatment program and the level of activity returned to ''near normal'' levels at 1 year follow-up. The treatment program was an adaptation of the Precision Fluency Shaping Program (Webster, 1974), which requires specific and incremental changes in articulation and prosody during the course of the treatment. The authors inferred that ''... the increased cerebellar activation in stutterers may reflect their attempts at exerting greater voluntary control over their speech, hence higher attention (effort), greater monitoring and less automatized movement execution.'' (p. 79). They attributed the decrease in cerebellar activity at 1 year post-treatment to greater automaticity of ''speech skills'' acquired during the treatment. The experimental task involved reading single words in a highly controlled laboratory condition. Given that disfluency rate in spontaneous speech even in the relatively sterile environment of the laboratory had gone up 57% at 1 year follow-up compared to immediately after the completion of the treatment, it is reasonable to assume that the PWS in this group needed to continue to monitor their speech closely to retain their fluency gains.

2.3. Cognitively driven speech construction and stuttering therapy

The Camperdown program (O'Brian et al., 2003), described previously, begins by requiring clients to adopt a slow, prolonged speech pattern similar to a traditional rate control therapy, which, as discussed above, uses motorically driven speech construction. However, quickly the emphasis shifts from specific speech pattern changes to maintaining a low rate of stutters and a natural-sounding speech, which is consistent with what has been described in this paper as cognitively driven speech construction. Similar to the clear speech register where the emphasis is on producing clear speech and not on any specific vocal or articulatory modifications, in the Camperdown program, the focus is on a relatively stutter-free, natural-sounding speech without regard to how this goal is achieved. In the Camperdown program, the goals are framed in broad, conceptual terms whereas in a traditional prolonged speech therapy program, the goals are set in terms of specific speech motor modifications. When speakers strive to speak differently whether to produce clear speech or to speak without stutters, they deviate from their habitual speech. In other words, they are using speech construction.

Clearly, the PWS who successfully completed the Camperdown program made changes in their habitual speech as evidenced by the lower naturalness ratings of their post-treatment speech compared to the speech of a group of control speakers and the report by 11 participants that they preferred to stutter rather than use an *unnatural* speech pattern some of the time. However, the vocal and articulatory changes that occurred in their speech were generated, for the most part, internally by the speech production system motivated by a cognitive set to speak without stutters rather than dictated externally by instructions from a clinician. Because there was a simultaneous emphasis on speech naturalness, the vocal and articulatory modifications were likely to be subtle and variable.

The Camperdown program initially used motorically driven speech construction to achieve a relatively stutter-free speech. The Lidcombe program, on the other hand, exclusively uses cognitively driven speech construction since, at no point in therapy, are the children participating in this program asked to alter their articulation or prosody in specific ways. The cognitively driven speech construction approach to stuttering treatment appears to be superior to methods based on motorically driven speech construction. In prolonged speech therapies (Onslow, 1996; Perkins, 1984), "fluency" is "instated" by initially requiring the PWS to make substantial and specific modifications to articulation and prosody. In later stages of treatment, the PWS need to partially unlearn what they had learned in the initial stages in order to achieve an acceptable level of speech naturalness. This is clearly inefficient because it impedes progress in therapy and, in fact, many PWS fail to sufficiently reverse what they had learned in the initial stages of therapy to achieve an acceptable degree of speech naturalness (Onslow, 1996). This may explain why the Camperdown program with a mean of 20 h of clinic visits per participant (O'Brian et al., 2003) and the Lidcombe program with a median of 11 clinic visits per child (Jones et al., 2000) required significantly fewer clinician contacts compared to the traditional behavior therapies used in the past.

The cognitively driven speech construction approach used in the Lidcombe program appears to have produced satisfactory outcome in most children who completed it (Jones et al., 2000). O'Brian et al. (2003) do not explain why they required their adult participants in the Camperdown program to initially imitate a videotaped model of prolonged speech only to abandon it quickly in favor of giving participants a free-hand at how they spoke as long as stutter frequency and speech naturalness ratings were within the prescribed range. Given that numerous studies in the past (Onslow, Packman, Stocker, van Doorn, & Siegel, 1997; Onslow, Ratner, et al., 2001; see also reviews by Bloodstein, 1995; Costello & Ingham, 1984; Ingham, 1984, and Prins & Hubbard, 1988) have demonstrated that stutter frequency may be significantly reduced or entirely eliminated by the application of response contingent time-out (RCTO) with no specific requirements to alter speech patterns, the need for the initial exposure to prolonged speech in the Camperdown program is not clear. James et al. (1989) distinguished between a group of high and a group of low responders to RCTO among adult PWS, which might have led O'Brian et al. to conclude that RCTO or any other type of RCS would not be universally effective with all PWS in their group. Indeed, a small number of adults and older children who stutter do not show large and consistent reduction in stutters under RCS (Ingham, 1984; Onslow et al., 1997; Onslow, Menzies, et al., 2001; Onslow, Ratner, et al., 2001). However, as demonstrated by the Lidcombe program and the numerous RCTO studies cited above, nearly all young children and a majority of older children and adults appear to be able to control stuttering under reliable and consistent speech monitoring conditions with subtle and variable changes (Andrews et al., 1982; Onslow et al., 1997; Onslow, Menzies, et al., 2001; Onslow, Ratner, et al., 2001; O'Brian et al., 2003) in articulation and prosody.

3. Alternative explanations for behavioral treatment of stuttering

In the past, investigators have searched for a common denominator in speech pattern changes that could explain reduction in stutter frequency under RCS and other stutter reduction conditions. Among the changes noted include lengthened mean phonation duration and slowed speech (Andrews et al., 1982), decrease in phonation intervals (very short pauses), increase in vowel duration, decrease in articulation rate, and increase or decrease in voice onset time in voiceless consonants (Packman et al., 1994), a reduction in the variability of vowel duration (Onslow et al., 1997), a reduction in the variability of syllabic stress (Packman, Onslow, & Menzies, 2000), and a reduction in verbal output and lexical diversity (Onslow, Menzies, et al., 2001; Onslow, Ratner, et al., 2001). However, none of these changes occur in all participants and the same participants may show different changes at different times. Thus, the search for a common set of speech pattern changes to account for the success of behavioral treatment of stuttering has not been fruitful. Although different speech pattern changes produce different amounts of reduction in stutter rate (Andrews et al., 1982), we are yet to encounter a speech pattern change that does not produce measurable reduction in stutter frequency in most PWS. It appears that nearly *any* change in speech pattern may reduce or eliminate stutters (Bloodstein, 1995).

Two metaexplanations (Andrews et al., 1982) have been offered to account for reduction in stutters that occur during novel speaking tasks, presumably including those associated with the behavioral treatment of stuttering. Perkins et al. (1976) hypothesized that an increase in effective planning time due to a simplification or slowing down of the speech production process may account for reduction in stutters in a range of speaking tasks. Andrews (1981), in a similar vein, proposed that the neurophysiological demands of speech motor control and/or language formulation are reduced in speaking conditions that reduce or eliminate stutters. However, any deviation from practiced performance such as talking in a whisper (Perkins et al., 1976), in a dialect different from one's own (Andrews et al., 1982), or with prolonged syllables, all of which significantly reduce stutters, would appear to add to the complexity of the task instead of simplifying it. It is a mistake to think that speaking in a whisper is a simplification of the act of speaking because of the absence of vocal folds vibration just as it is a mistake to suggest that typing with only one hand instead of both hands is a simplification of the motor action if the typist habitually typed with both hands. Similarly, speaking at a slower rate by prolonging syllables complicates speech production just as a musician would find it difficult to perform a previously learned piece of music at slower than the practiced tempo.

The hypothesis offered in the present paper is that when PWS speak in a nonhabitual speech pattern, they stutter less or not at all because nonhabitual speech patterns require speech construction. When the PWS speak using a demonstrably novel pattern of speech – e.g., speaking under delayed auditory feedback, using "syllable-timed" speech, or prolonged speech, etc. (Andrews et al., 1982) – it is reasonable to assume that they are using speech construction because no stored motor plans are likely to be available for their production. However, when the PWS are using cognitively driven speech construction – speaking in RCS experiments and in speech monitoring conditions of the Lidcombe and the Camperdown programs – the changes in speech pattern (Onslow et al., 1997; Onslow, Menzies, et al., 2001; Onslow, Ratner, et al., 2001; O'Brian et al., 2003; Packman et al., 1994) are likely to be subtle and highly variable within and across individuals. These subtle and variable speech modifications are difficult to detect through the analyses of acoustic or physiological signals or through listening especially since such changes may be masked by the noise of inherent variability that always exists in the speaking process.

A different research technique is necessary to unambiguously demonstrate that the PWS are using speech construction under speech monitoring conditions. As discussed earlier, speech construction is a resource-intensive, attention demanding process whereas speech concatenation is a resource-efficient, background process. Attention demanding processes are vulnerable to dual-task interference (Luck & Vecera, 2002). It is hypothesized here that when the PWS speak under RCS or following successful completion behavioral treatment programs, they exhibit more stutters if they are required to perform an attention demanding secondary task. The increase in stutter rate in tasks such as making presentations reported by the participants in the Camperdown program (O'Brian et al., 2003) may be due to the inability to reliably monitor one's speech for stutters when engaged in speaking tasks that require greater attention to conceptualization and linguistic encoding. This assumes that when one is not actively monitoring one's speech in an attempt to speak without stutters, the default method of speech concatenation is used for speech motor plan assembly.

The dual-task paradigm, however, may not be appropriate and is not needed when investigating speaking conditions that involve motorically driven speech construction because the large, predictable, and global changes in speech pattern may be sustained without having to continuously monitor the speech output. Once an initial strategic decision is made to speak, for example, in a whisper, with prolonged syllables, or in time to a rhythmic beat, the low level speech constructional processes may be expected to incorporate the changes into the speech until another executive decision is made to terminate the nonhabitual speech pattern. However, in later stages of traditional, motorically driven rate control therapies, the PWS are required to make relatively small and precise modifications to their speech so that the speech sounds less unnatural. This type of speech will require nearly continuous attention, probably much more so than cognitively driven speech construction where the speaker does not have to make any prescribed speech pattern changes, and is, therefore, highly susceptible to dual-task interference.

4. Speech concatenation and stuttering

If the distinction between speech construction and speech concatenation is valid and if speech construction is incompatible with stuttering as discussed in the previous sections, then the possibility exists that the source of the stuttered speech may lie in speech concatenative processes. However, there are two reasons to reject the possibility that the speech motor plans stored in memory are somehow defective in ways that would result in stutters. First, since a motor plan needs to be constructed many times before it is stored in long-term memory and since I have argued that speech construction is devoid of stutters, it is impossible for a motor plan to be defective in ways that would result in stutters. However, it may still be argued that although the motor plan itself may not be defective, it may become defective in the process of storing it in memory. This is also unlikely given that the PWS, even when appearing to be using casual, concatenated speech, produce nearly all words without stutters some of the time. A faulty motor plan should result in stutters every time it is accessed.

Evidence from several different lines of research converge to suggest that the speed of retrieval of motor plans from memory may be slightly slower in PWS. In this section, the findings from speech reaction time (SRT) studies are reinterpreted to show how a delay in retrieving motor plans from memory may produce stutters. Conversely, tasks that promote faster retrieval of motor plans – phonological priming and adaptation tasks – are shown to reduce stutter frequency.

4.1. Speech reaction time

Bloodstein (1995) lists over 30 studies that found PWS to be slower in speech reaction time (SRT) in a range of tasks that included producing syllables, words, and sentences. SRT is influenced by the frequency of occurrence of words in a language (Oldfield & Wingfield, 1964). If PWS are slower in retrieving stored motor plans, the difference in RT for high and low frequency words should be magnified for them compared to individuals who do not stutter. Prins, Main, and Wampler (1997) reported that the difference in picture naming latencies were significantly larger for low frequency words than for high frequency words in PWS compared to a control group. Hubbard and Prins (1994) reported that PWS produced more disfluencies on sentences with low frequency words than on sentences with high frequency words. Danzger and Halpern (1973) also found that there were more ‘‘nonfluencies’’ on low frequency words than on high frequency words in a group of PWS. Dayalu, Kalinowski, Stuart, Holbert, and Rastatter (2002) found that stutter frequency correlated significantly with content word frequency and function word frequency—low frequency words in both categories produced more stutters. Ronson (1976), in adult PWS, and Palen and Peterson (1982) in children who stutter (age: 8–12 years) also found the expected word frequency effect in stutter rate.

4.2. Phonological priming

Priming, in cognitive psychology, refers to the paradigm in which two stimulus items (the ‘‘prime’’ and the ‘‘target’’) are paired to determine whether the prime facilitates or impedes the processing of the target item. A number of studies (Brooks & MacWhinney, 2000; Collins & Ellis, 1992; Lupker & Williams, 1989; Meyer, 1990; Meyer, 1991; Meyer & Meulen, 2000; Schriefers, Meyer, & Levelt, 1990; Schriefers & Teruel, 1999) have shown that when the prime is phonologically identical or partly similar to the target, the RT for naming the target is faster than when the prime is phonologically unrelated to the target. If phonological priming contributes to faster retrieval of motor plans (as reflected in faster RT) and if, as I have argued above, the PWS are slower in retrieving stored motor plans, then facilitative phonological priming should result in less stuttering and interfering phonological priming should produce more stutters. In two studies Wijnen and Boers (1994) and Burger and Wijnen (1999) showed that when the initial consonant or the initial consonant–vowel portion of a word was displayed on a computer screen (which served as the prime), the adult PWS, who had previously learned to associate the prime with the response word, produced the response word faster than when the prime did not share the initial segment(s) of the response word. Likewise, Melnick, Conture, and Ohde (2003) reported that phonologically similar primes resulted in faster naming latency in 3–5-year old children who stuttered as well as in a matched group of children who did not stutter.

On the other hand, Bosshardt (2002), in a dual-task study, found that when PWS repeated words while concurrently silently reading or memorizing phonologically similar words, the stutter frequency increased significantly. Reading or memorizing phonologically dissimilar words did not significantly increase the rate of disfluencies. While the three studies cited in the previous paragraph show how subthreshold activation of the initial portions of a speech unit speeds up retrieval of its motor plan in PWS, the latter study appears to suggest that the simultaneous subthreshold activation of close phonological neighbors impedes efficient retrieval of motor plans resulting in an increase in stutter frequency.

The advantage of sight word priming obtained by Wijnen and Boers (1994) and Burger and Wijnen (1999) may explain, in part, why most PWS find reading to be an easier task than speaking. When reading, English readers typically have within their eyesight a stretch of text as long as 15 characters to the right of the fixation point (Raynar, 1998). It is, therefore, possible that while reading the current word, the word next to it is primed. It is also known that reciting the alphabet and other well-rehearsed serial speech produces considerably fewer stutters (Bloodstein, 1995). It is suggested here that this is, in part, because serial speech often consists of high frequency words and, in part, because production of each preceding word in the series serves to prime the following word due to learned sequential dependency.

4.3. *Repetition priming*

The clearest and simplest form of priming is repetition priming where, for example, a person hears or sees a word and then immediately repeats it. Auditory repetition primes produce one of the shortest SRTs in normal speakers (Brooks & MacWhinney, 2000). Clinical experience shows that the PWS are also likely to stutter less when they repeat words they hear. A task referred to as shadowing, in which a speaker repeats what he/she hears as quickly as possible, reduces stutter frequency significantly (Andrews et al., 1982; Cherry, Sayers, & Marland, 1956). A second, related condition that reduces stutters significantly is chorus reading (Andrews et al., 1982; Ingham & Packman, 1979). Andrews et al., reported 100% reduction in stutters in all three participants during chorus reading. Pattie and Knight (1944) identified hearing unison reading of the same passage as the critical element in the reduction of "speech blocks" in PWS. The timing relationship between the speech outputs of the two speakers involved in chorus reading does not appear to have been investigated. It is, however, unlikely that the onsets of syllables or words would be exactly synchronized between the two speakers. Chorus reading may represent mutual priming at subsyllabic or syllabic level—the speech output of each person intermittently and alternately priming the speech of the other. Since chorus reading involves visual priming of text to be read, the previously discussed sight word priming advantage reported by Wijnen and Boers (1994) and Burger and Wijnen (1999) may also aid in the amelioration of stuttering under this condition.

4.4. *Adaptation*

Adaptation effect in stuttering refers to the fact that when PWS read a passage repeatedly, there is a progressive reduction in stutter frequency although stutter frequency levels off after four or five readings (Johnson & Inness, 1939). Bloodstein (1995, pp. 334–335) has identified oral reading as the critical element in stuttering adaptation since repeated silent or lipped readings do not produce large reduction in stutters in a subsequent oral reading. It is proposed here that adaptation effect is due to priming—the previous oral readings keep the motor plans for certain words (or other units of speech such as syllables) contained in the reading passage in a partially activated state making them more readily available in a subsequent reading. The adaptation effect reaches an asymptote after four or five readings probably because there is an upper limit to the number of speech units that may be reliably kept at subthreshold activation levels. Brutten and Dancer (1980) asked a group of PWS to read each of a series of 100 words individually (“massed practice”) and as a list (“distributed practice”) five times. The reduction in stutter frequency was greater and did not plateau in massed practice as compared to the distributed practice. The massed practice would require keeping the motor plan for a single word primed whereas the distributed practice would require simultaneous priming of the motor plans for 100 words.

5. A hypothesized account of how stutters are produced

Levelt and Wheeldon (1994) propose that the motor plans of syllables stored in memory consist of a set of gestural scores (cf., Browman & Goldstein, 1991). Each gestural score is assumed to have five elements corresponding to five independently controllable subsystems of speech—glottal, velar, tongue body, tongue tip, and lips. A gestural score specifies the tasks to be performed by each of the subsystems but it does not specify how those tasks should be performed because, depending on the constantly changing configuration of the peripheral speech mechanism during connected speech, the task may be completed in a number of different ways some of which are more efficient than the others (Kent, 1997; Levelt, 1989). The motor commands to the muscles to complete the tasks specified in the speech motor plan are computed and executed by an “articulatory network” (a coordinative motor system) under feedback control (cf., Saltzman & Kelso, 1987). The model of stuttering proposed here, while open to other alternative accounts of speech motor planning and execution (see Fowler (2003) and Kent (1997) for reviews of a range of theories), is compatible with the above account of concatenated speech production.

It is hypothesized here that, in PWS, the delay in retrieving the motor plan is due to a delay in locating the motor plan in memory, which leaves less and, possibly, insufficient amount of time to completely retrieve the different parts of the motor plan. For example, assuming that there are five elements in a syllable motor plan corresponding to the five independently controllable subsystems of speech articulation, the delay in locating the motor plan may result in incomplete retrieval of one or more of these elements. When the articulatory network attempts to execute the underspecified motor plan, it “hangs” leading to repetitions, prolongations or cessation of speech. The exact form of the stutter may depend on what elements are underspecified. An incomplete specification for tongue body/tongue tip while executing a syllable beginning with a bilabial stop might lead to a block (cessation of speech), or to an initial sound repetition, or to a syllable repetition with the “neutral” schwa vowel. On the other hand, if the syllable begins with the bilabial nasal, it might lead to any of the above or to a prolongation of the nasal sound. The repetitions and prolongations probably represent an attempt by the articulatory network to restart itself after a failed attempt.

Johnson and Brown (1935) and Weiner (1984), among others, have reported that over 90% of stutters occur on the first sounds or syllables of words. The delay is most likely to occur while retrieving the beginning portion of the motor plan because if the start point is located without delay, the rest of the plan for the word is likely to be retrieved without delay as well, assuming that the different parts of a motor plan are contiguous or, if they are noncontiguous, the previous part contains an address for the following part. In addition, assuming that priming is pervasive (it appears to be a fundamental organizational principle of the nervous system Tulving & Schacter, 1990), the successful retrieval of the initial portion of the motor plan primes the succeeding portion facilitating its quick retrieval.

5.1. The developing speech–motor system and stuttering

The highly successful and more permanent outcome obtained when treating young children using the Lidcombe program (Onslow, Menzies, et al., 2001; Onslow, Ratner, et al., 2001) as well as other similar stuttering treatment programs (Curlee & Yairi, 1997) contrasts with the generally poor and transient results obtained with adult PWS (Bloodstein, 1995; Onslow, 1996). This suggests that the still plastic speech–motor system of young children may be amenable to restructuring in ways that would partially or completely correct the hypothesized defect in the concatenative utterance motor plan assembly. The restructuring, which may be facilitated by setting up conditions for systematic speech monitoring as in the Lidcombe program, may involve striking a new and favorable balance between the habitual rate of speech and the speed of retrieval of motor plans from memory. The older children and adults who stutter, on the other hand, may need to monitor their speech indefinitely in order to force the speech production system to use speech construction to maintain their fluency because the parameters of concatenative speech motor plan assembly are likely to be less amenable to permanent restructuring in older PWS.

The high rate of success achieved in the treatment of stuttering in young children is, at least in part, due to the high rate of spontaneous (without professional intervention) recovery, which is estimated to be in excess of 80% (Yairi & Ambrose, 1999). Both genetic factors (e.g., girls are more likely to recover than boys and a family history of stuttering diminishes recovery rate) and maturational variables (e.g., recovery is more likely at an younger age) appear to play a role in spontaneous recovery (Curlee & Yairi, 1997). Forster and Webster (2001) have provided some evidence that recovery from stuttering in childhood is related to the maturation of the speech–motor control system, particularly the supplementary motor area (SMA), which is known to play an important role in the execution of skilled motor activities (Bear, Connors, & Paradiso, 1996). Whether unsystematic advice and contingencies, which are almost certainly provided by parents and others in the child's life (Ingham, 1983), play a role in spontaneous recovery is not known at the present time. The favorable genetic factors and environmental variables alluded to above may aid the maturation of the speech–motor system in recovered PWS in ways that would overcome the hypothesized slowness in the retrieval of stored speech–motor programs.

6. Conclusion

Prolonged speech and its variants constitute the most common and arguably the most successful therapy offered for stuttering (Onslow, 1996). Nearly all extant explanations of ameliorative effect of novel speech patterns, of which prolonged speech is just one of many possibilities, rests on the assumption that the novel speech patterns somehow simplify the speech production process (Adams, 1990; Bloodstein, 1995; Perkins, Kent, & Curlee, 1991). However, in spite of intense laboratory research, support for these explanations is scant (Ingham, 1984; Onslow, 1996). In this paper, I have argued that a resource intensive, foreground process called speech construction is the basis for fluent speech in PWS who successfully complete operant learning based stuttering treatment regimens. In addition, the present paper provides a rationale as to why cognitively driven speech construction – speaking while consciously monitoring one's speech to achieve a certain communication goal which, in this case, is speaking without stutters – produces faster and superior results than motorically driven speech construction – speaking while consciously altering certain specific aspects of articulation and prosody. Finally, empirical data appear to suggest that people who stutter are slow to retrieve stored motor plans, which leaves less and, in instances that produce stutters, insufficient time to retrieve the entire motor plan. Very young children who are at risk for chronic stuttering may be able to permanently overcome this hypothesized defect in speech motor plan assembly if placed in a program that systematically encourages them to monitor their speech for fluent utterances and stutters.

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Appendix A. Self-study questions

1. Traditional behavior therapy programs for stuttering require persons who stutter to consciously modify:
   a. Rate
   b. Pitch
   c. Attitudes
   d. All of the above
   e. None of the above
2. The Lidcombe stuttering treatment program:
   a. is intended for children
   b. is intended for adults
   c. is administered by family members

   d. both a and b
   e. both a and c
3. The method of assembling an utterance motor plan by retrieving motor plans stored in memory is designated in this paper as:
   a. speech synthesis
   b. speech concatenation
   c. speech construction
   d. articulatory network
   e. clear speech
4. It is argued in this paper that people who stutter are slow to retrieve motor plans from memory:
   a. True
   b. False
5. In stuttering treatment approaches based on cognitively driven speech construction:
   a. speech pattern changes are not required
   b. speech pattern changes are generated by the client
   c. speech pattern changes are prescribed by the clinician
   d. it is not necessary to monitor one's speech
   e. no attention is paid to naturalness of speech

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